world, chemistry is a truly "philosophical" science, in the sense of philosophy as conceived and defined by the great and pure philosophical minds of Socrates, Plato and Seneca. To them philosophy is to teach men to form their souls; knowledge is to be sought for the good of the mind. Our science preeminently fulfils these requirements. Knowledge and contemplation of chemical phenomena, the very varied manifestations of the science, and the subtle and wonderful forms it assumes can not fail to uplift the soul and broaden and purify the mind.

THE CHEMIST'S EDUCATION

The education and training the industrial chemist should have to make him fit and competent in his career is receiving much attention, both from educators and industrialists. Because of the great share of responsibility that is more and more devolving upon the chemist, the importance of this question is self-evident. But in our zeal to hit the spot we are perhaps shooting a little over the mark. The tendency in our curriculum is to stress the applied and industrial chemical courses. I very much doubt that this path will lead to the desired goal. Let me repeat that the industrial achievements of the chemist have resulted from the inspiration he received from his knowledge of the science. Our great and well-known chemical engineers of to-day have been raised on the undiluted milk of the pure science.

Just as in the nutrition of the body a properly balanced food diet must be maintained to insure health and normal development, so it is with the education of the chemist. He must be given a carefully balanced training in the science of chemistry and its application. And I am of the opinion there is decidedly less danger when the ration is increased in the science than the reverse. The greatest names known to science, and to scientific professions, have not during their college careers specialized in the fields they made famous. Overspecialization in youth narrows the mind and stunts its development. Give the chemist student the tissue-building material, the fundamentals of science, impart to him its spirit; then when he goes out to accomplish his life work he will shape and mold the materials according to the need of time and place and will breathe life into them. As in the words of Lowell:

> New occasions teach new duties;
> Time makes ancient good uncouth;
> They must upward still and onward,
> Who would keep abreast of truth.

GEORGE D. ROSENGARTEN

DOES THE NET ENERGY VALUE OF FOOD DEPEND UPON THE PURPOSE FOR WHICH IT IS USED IN THE BODY?

THROUGHOUT his work on the net energy values of feeds for cattle, Armsby[1] has continually kept in mind the probability that the net energy value of a feed varies with the nature of its disposition in the body, for example, varying when used for fattening or for milk production. This probability of a variable utilization of food energy was based in his mind upon the difference in composition of the products formed, indicating differences in the metabolic reactions concerned in the use of food in the basal metabolism and in its conversion into tissue, fat, milk, etc. In the case of milk production, for instance, certain conversions of nutrients are considered as occurring with no loss of energy as heat, while the conversion of carbohydrates to fat is supposed to involve a definite heat liberation. This conception appears to be equivalent to the assumption that the heating effect of food on the animal is determined to a considerable extent by the chemical reactions to which it is subjected after absorption, since the use to which the food is put could obviously have no effect upon the reactions occurring within the alimentary canal.

This conception of Armsby seems to be quite generally held among those laboratories in this country and Europe that are doing calorimetric work upon farm animals, and a number of experiments recently appearing in the literature[2] have been specifically concerned with the relative utilization of the energy of farm feeds in maintenance, fattening and milk production.

It becomes a matter of importance, therefore, to consider what experimental evidence may be cited in favor of the belief that the stimulating effect of ingested food upon animal metabolism is due to the nature of the metabolic reactions to which it is subjected and whether some other conception may not be more readily defended. The theory appears to assume that certain metabolic reactions liberate energy which can be used in maintaining cellular life and activity before being dissipated as heat, while

[1] Armsby, H. P., "The Nutrition of Farm Animals," New York, 1917, pp. 361, 395, 497–8, 563.

[2] Hanson, N., Kungl. Landtbruksakademiens Handlingar och Tidskrift, 1923; Fries, J. A., Braman, W. W., and Cochrane, D. C., U. S. Dept. Agr. Bul. 1281, 1924; Forbes, E. B., Fries, J. A., Braman, W. W., and Kriss, M., *J. Agr. Res.*, 1926, xxxiii, 483; Møllgaard, H., "New Views regarding the Scientific Feeding of Dairy Cattle," Copenhagen.

other metabolic reactions liberate sensible heat only. The latter type of reactions only would be involved in the specific dynamic effect of food. This conception is essentially identical with that put forward by Rubner[3] twenty-five years ago. However, Rubner's theory resulted more as a revulsion against the older theory of Zuntz that the heating effect of food was due solely to the work of digestion, absorption and excretion, than as a probable interpretation of certain specific experimental data. The logic that Rubner used in defending the theory is not convincing at the present time.

In more recent times, Lusk has accumulated much evidence inconsistent with Rubner's theory. In the case of the specific dynamic action of amino acids, Lusk[4] has shown that the reactions of deamination and urea formation are not involved, since two amino acids, glutamic acid and aspartic acid, exert no specific dynamic action in the body, although evidence of their deamination was obtained. Furthermore, although glycine and alanine exert powerful dynamic effects, the products of their deamination, glycollic and lactic acids, exert only inconsiderable effects upon heat production.[5] Lusk has also found that, under certain conditions, the specific dynamic effect of glycine may be as great as the total gross energy content of the amino acid, a result quite unexplainable on the basis of Rubner's theory.

With regard to the specific dynamic effect of glucose, it has been shown by Anderson and Lusk[6] that the ingestion of 70 gms of glucose by a working dog is without effect upon its heat production, although in the same dog at rest a very marked effect is produced. In both cases, oxidation of glucose occurred, and hence, according to Rubner's theory, the specific dynamic effect should be the same. Baumann and Hunt[7] observed a definite effect of the ingestion of 25 gms of glucose in the normal rabbit, but no effect in the thyroidectomized rabbit, although with both groups of animals oxidation of glucose was occurring as indicated by the respiratory quotient.

The fact that the ingestion of small amounts of foods may produce no effect on heat production is significant in this connection. According to Rubner's theory, the specific dynamic effect of a food material should be proportional to the amount ingested when it is being used for the same purpose. However, Lusk has found that his experimental dogs showed no response to the ingestion of 10 or 20 gms of glucose, although with 50 to 70 gms marked increases in heat production were observed. Similarly, it has been shown that the ingestion of a small breakfast by human subjects does not appreciably affect a subsequent basal metabolism determination.[8]

Among human subjects there are certain pathological conditions, such as certain types of obesity, certain diseases resulting from endocrine deficiencies and certain neuroses, in which the specific dynamic effect of food is either non-existent or distinctly subnormal.[9] To explain this situation on the basis of Rubner's theory would necessitate the assumption that in these disorders the metabolic reactions are markedly abnormal and are all of the type in which liberated energy can be completely utilized in covering the energy requirements of the tissues. The improbability of this assumption requires no elaboration.

Finally, if the specific dynamic action of food were due to the metabolic reactions to which it is subjected, one would expect that it could be calculated from the composition of the food, its digestibility and the average heating effects of the different nutrients of which it is composed. However, Armsby[10] has shown quite conclusively that this can not be done by any rational method in the case of cattle. Similarly, in the case of dogs, the heating effect of a protein can not be predicted from its amino acid constitution.[11]

From these considerations, it appears that Rubner's theory of the specific dynamic effect of food is not in agreement with many of the observed facts of energy metabolism, and hence is no longer tenable. It is interesting to inquire, therefore, if any other theory would lead to the conclusion that the heating effect of food on metabolism will vary depending upon the manner of its utilization.

The theory that Lusk sponsors on the basis of his own extensive investigations is that the specific dynamic effect of food is due to a stimulating effect on cellular oxidations, brought about either by the mere presence of an excess of oxidizable matter in the intercellular fluids (in the case of sugar and fat) or by a stimulus of some other type not so clearly definable (in the case of amino acids). The theory

3 Rubner, M., "Die Gesetze des Energieverbrauchs bei der Erhähnrung," Leipzig and Vienna, 1902, pp. 356–407.

4 Lusk, G., *J. Biol. Chem.*, 1915, xx, 555; Atkinson, H. V., and Lusk, G., *Ibid.*, 1918, xxxvi, 415.

5 Lusk, G., *J. Biol. Chem.*, 1921, xlix, 453.

6 Anderson, R. J., and Lusk, G., *J. Biol. Chem.*, 1917, xxxii, 421.

7 Baumann, E. J., and Hunt, L., *J. Biol. Chem.*, 1925, lxiv, 709.

8 Benedict, C. G., and Benedict, F. G., *Boston Med. and Surg. J.*, 1923, clxxviii, 849.

9 Plaut, R., *Deutsch. Arch. klin. Med.*, 1922, cxxxix, 285; 1923, cxlii, 266. Liebesny, P., *Biochem. Z.*, 1924, cxliv, 308. Wang, C. C., and Strouse, S., *Arch. Intern. Med.*, 1924, xxxiv, 573.

10 *Loc. cit.*, pp. 667–673.

11 Rapport, D., *J. Biol. Chem.*, 1924, lx, 497.

does not lead one to suppose that the ultimate destination of the food in metabolism is a factor in determining its specific dynamic effect, since this effect depends primarily on the concentration of nutrient material within and around the cells. For a given intake of food, any factor that would tend to vary this concentration during absorption would have a corresponding effect upon heat production. This nutrient concentration in the tissues would be depressed by any factor increasing the rate of disposal of the excess food material, such as muscular activity or mammary activity. Hence, on the basis of Lusk's theory, one would expect a smaller heating effect of a given amount of food in a lactating cow than in a dry cow, though no constant difference would be expected for different amounts of milk produced and different amounts of food consumed. If the cow is a high producer, it is evident that in the first few months of lactation, when the animal is in a condition of "physiological underfeeding," the food consumed would presumably exert only a minimal heating effect,[12] and would thus possess a high net energy value. In the later stages of lactation, when the animal may be laying on fat due to overfeeding, the heating effect of the same amount of food may be much greater, if the rate of fat deposition is much less than the rate of milk formation, as it quite probably is. At this time, the net energy value of the food would be less than at first.

On similar reasoning, it would appear that the net energy value of food fed at the maintenance or submaintenance level would be higher than at the higher levels, not because of the different metabolic reactions involved in fattening as compared with maintenance, but because of a probable slower rate of withdrawal of nutrients from the intercellular fluids in the deposition of fat than in the satisfaction of contemporary energy requirements. However, the difference would probably not be a constant one, since the heating effect of a unit of food would presumably vary in each case with the level of feeding. On the same grounds, it would be expected that the net energy value of food would be greater when muscular activity is occurring simultaneous with absorption of food from the intestinal tract, than when the animal is at rest; on the other hand, work performed in the post-absorptive period would be without influence on the utilization of food energy.

[12] Thus, Widmark and Carlens (*Biochem. Z.*, 1925, clvi, 454) observed that the blood sugar content of lactating cows was less than that of dry cows, and that the depression from the normal value was in rough proportion to the amount of milk produced. The lowest values observed were less than half (0.040 per cent.) the average value for dry cows (0.085 per cent.).

It appears, therefore, that Lusk's experimental work affords no grounds for believing that the manner in which food is utilized determines the extent of utilization through its effect on the specific dynamic action of the food. It is true that the net energy value of a food may be expected to be different with animals functioning in a different manner, but it would seem that no characteristic or even approximately constant net energy value can be assigned for a given function, and that no constant relation of net energy values among different functions can be assumed. In particular, it appears unjustifiable to assume that, in an animal utilizing food in a number of different ways, so much metabolizable energy is being used for maintenance, and so much for milk production, since, if mammary activity increases the net energy value of the food by preventing as great a "metabolism of plethora" as would otherwise occur, this increased utilization would apply as much to the food used for maintenance as to that used in the production of milk.[13]

Another possible explanation of the heating effect of food on animal metabolism is that the acid products of digestion may be effective stimuli to cellular activ-

[13] A specific illustration of this point may aid materially in appreciating this argument. In a recent article by Forbes, Fries, Braman and Kriss (2), estimates are made of the utilization of metabolizable energy for milk production, by making certain definite assignments of metabolizable energy for maintenance and body increase, and relating the remainder to the energy content of the milk produced. Thus for Cow 874 (in Tables 5, 6 and 7) it is assumed that the metabolizable energy used for maintenance suffers a loss of 22.3 per cent. as heat, that used for body gain a loss of 38.4 per cent., and hence that used for milk production a loss of 27.8 per cent. The total heat increment for this cow is an experimental observation, but the factoring of it in this manner on the basis of results obtained on the cow when dry is an interpretation that involves theoretical considerations that have neither been justified nor discussed. Hence, the conclusion that the percentage utilization of metabolizable energy for milk production was, for this cow, 72.2 per cent., is an interpretation of the same character. The essential assumption upon which these interpretations are based is that when food is serving a number of purposes in the animal body simultaneously, the utilization of food energy for each purpose is independent of that for the other purposes; in other words, that the heating effect of food used for maintenance is the same whether the animal is producing tissue or milk simultaneously or whether it is only maintaining its *status quo*. While this assumption superficially appears to be a reasonable one, on analysis it is seen to imply that the causes of the heat increment due to the ingestion of food are related directly to the methods of food disposal, *i.e.*, to the metabolic reactions concerned in maintenance, body gain and milk production.

ity. This explanation has been proposed by Benedict,[14] though direct attempts to verify it have not been successful.[15] It is conceivable, however, that acid stimulation may be an important factor with ruminants, in which large amounts of organic acids resulting from extensive bacterial fermentations are absorbed from the intestinal tract. But obviously this theory also can not be construed to favor the view that a definite net energy value for a food is characteristic of each animal function, or that the percentages of utilization of metabolizable energy for different functions bear a constant relation to one another.

Finally, in ruminants at least, the chemical, bacterial, glandular and muscular events occurring in the alimentary canal, or in its accessory organs, during digestion are known to result in a definite and considerable increase in heat production, an increase that may account for a large percentage of the total heat increment following the ingestion of food. But it appears that these events, and the accompanying heat losses, would bear no relation to the events subsequently or simultaneously occurring on the other side of the gastro-intestinal mucosa. They would presumably be related, more or less constantly, to the amount of food consumed, and its physical and chemical make-up, particularly as this bears upon the extent and rapidity of its digestion, but would be quite unrelated to the manner in which the food is utilized after absorption.

It appears, therefore, that the determination of the relative net energy values of feeds for animals in different functional conditions is being approached on the basis of assumptions, not only without experimental justification, but even in contradiction to established experimental findings. The results obtained, in consequence, are being given a significance that they do not seem to possess, in all probability. Hence, a different working hypothesis should be adopted. Since Lusk's experimental work and the theories that he has deduced from it appear to offer the most plausible explanation of the specific dynamic action of food—the only calorigenic effect of food that would conceivably be related to its disposal in metabolism—a working hypothesis based upon these theories would seem to be the safest guide in future investigations of the net energy values of food for farm animals.[16] In a broad way, these theories differentiate three general lines of investigation, involving studies of (1) the heating effect of different amounts of food in animals in the same functional condition, (2) the heating effect of the same amount of food in animals in different functional conditions, and (3) the influence of internal factors, such as heredity and endocrine activity, upon the specific dynamic effect of food. The first study is concerned with the rate of establishment of the metabolism of plethora, the second with the rate of its depression due to withdrawal of food by the tissues and the third with the response of the tissues to a given plethora stimulus; in other words, with the irritability of the tissues.

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RALPH GORDON LUSK

DR. RALPH GORDON LUSK, instructor in geology at Harvard University, died suddenly with heart failure in New York City on July 27, at the age of thirty-one years, just as he was entering upon his career as a geologist. He was born July 14, 1896, at Manchester, Iowa, where his father, the Reverend C. F. Lusk, was at that time pastor of the First Baptist Church. His mother's maiden name was Grace A. Hilbrant. Ralph Lusk was educated in the public schools of Iowa, and in March, 1918, he enlisted in the U. S. Navy and was sent to the Great Lakes Naval Training Station. On April 1 of the same year he was married to Neva Belle Frederick at Lake City, Iowa. At Great Lakes, the heart ailment which finally caused his death was first developed and by September he was discharged for vocational rehabilitation. He entered Denison University that fall and graduated with the class of 1922, after making geology his major subject. The next year was spent as a graduate student at the University of Chicago. At Denison he was elected to membership in Phi Beta Kappa and at Chicago to Sigma Xi. In 1923–24 he was instructor in geology at Denison and in 1924 he entered Harvard University as an Austin Teaching Fellow in Geology. He was appointed instructor in geology in 1926 and in June, 1927, he was awarded the degree of doctor of philosophy at Harvard, having previously received the degree of master of science from Chicago.

[14] Benedict, F. G., Trans. 15th Intern. Congress Hyg. and Demography, Washington, D. C., 1912.

[15] Lusk, G., *J. Biol. Chem.*, 1921, xlix, 453; Taistra, S. A., *ibid.*, 479; Chanutin, A., *ibid.*, 485.

[16] It may, of course, be objected that Lusk's work was done with carnivora and that the conclusions from it can not be assumed to apply to herbivora. However, there is little reason for believing that the energy metabolism of the two types of animals is fundamentally different. In any case, the theories of Rubner as well as those of Lusk were based upon experimental work with carnivora. Until there is definite reason for doubting the applicability of experimental data so obtained to farm animals, they may be considered a safe guide upon which to base working hypotheses.