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HENRY PRENTISS ARMSBY

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BY

FRANCIS G. BENEDICT

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H. P. Armsby

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"Born of good, solid New England stock," an expression characterizing so many of America's foremost citizens, applies to Henry Prentiss Armsby, who, the only child of Lewis and Mary A. (Prentiss) Armsby, was born September 21, 1853, in Northbridge, Massachusetts. The father, a skillful cabinet maker, early moved to Whitinsville and subsequently to Millbury, Massachusetts. After receiving the usual elementary school training in these towns, Henry entered the Worcester County Free Institute of Industrial Science at the age of fifteen years. This Institute later became the Worcester Polytechnic Institute. The records show that Armsby, as a schoolboy, was "absorbed" in chemical experiments. Three years later (1871), in the first class to graduate from this Institute, he received the degree of Bachelor of Science. The following year he remained at the Institute as instructor in chemistry and then realized the objective of many years, graduate work at Yale University under the inspiration of Professor S. W. Johnson. Receipt of the degree of Bachelor of Philosophy at Yale University in 1874 was coincidental with his first scientific publications, "On the Nitrogen of the Soil" and "Experiments on the Decay of Nitrogenous Organic Substances." After a year of teaching science in the high school at Fitchburg, Massachusetts, a long-wished-for sojourn in Germany (Leipzig) followed. Here, under Gustav Kühn, in company with his close friend, E. H. Jenkins of New Haven, a most profitable year full of intense work followed. Jenkins comments on Armsby's method of work as follows:

"He was a thinker. . . . He would sit with his feet to the fire, not drowsing or dreaming, but thinking hard, and then he would go to his desk and write awhile, and then come back to think."

This habit of intense, concentrated thinking characterized the man's entire life. A snap judgment, a hunch, seemed out of his experience.

Although trained as a chemist, Armsby, in the Kühn atmosphere at Leipzig, began to take special interest in problems of physiology and from then on drifted more and more towards physiological work. This inclination culminated in his classic contributions to animal nutrition and calorimetry. Nevertheless he was destined to live a chemist's life for some time, for upon his return from Germany he taught chemistry at Rutgers College, New Brunswick, New Jersey, from 1876 to 1877.

The Agricultural Experiment Station movement began under the stimulation of Johnson and Atwater, and in 1877 Armsby was called to Connecticut to be chemist of the first Agricultural Experiment Station established in the United States. Recognizing the paucity of information in English on cattle feeding, Armsby immediately began a translation of E. v. Wolff's "Landwirtschaftliche Fütterungslehre." The changes and additions that he found necessary to bring this up to date for American conditions resulted in his first book called "Manual of cattle feeding," which was published in 1880. A year before this Yale University had granted him the degree of Doctor of Philosophy. His intense interest in animal feeding led rapidly to the publication of a series of papers on the digestion, the composition, and the utilization of feeds by domestic animals, accompanied by a number of papers on the chemistry of soil, milk, and problems dealing with the furthering of agricultural science. His two years (1881-1883) as Vice-Principal and Professor of Agricultural Chemistry at the Storrs Agricultural School (later the Connecticut Agricultural College) were somewhat in the nature of marking time, but in his appointment as Professor of Agricultural Chemistry and Associate Director and Chemist of the Agricultural Experiment Station at the University of Wisconsin in 1883 he received his first great impetus to administrative and research work. Here he remained until, in 1887, he was called to the directorship of the new Agricultural Experiment Station of Pennsylvania State College, where his great life work was to be accomplished.

The fact that his whole life was associated with institutions of agricultural research has to some extent pushed into the background the fact that his interests were far broader than even

the wide limits of the term "Agricultural Research" would imply. Chemist, physiologist, author, critic, administrator, organizer, all combined in a marvelous manner to make every undertaking an instant and permanent success. The administrative work was irksome but faithfully carried out, and it was with joy that in 1907 he was relieved in part of much routine administrative work as Director of the Pennsylvania Agricultural Experiment Station and made Director of the newly organized Institute of Animal Nutrition of Pennsylvania State College. Although his efforts in behalf of agricultural science prior to 1907 were invariably successful, it was with the new Institute that the full powers of this man developed.

Nearly ten years before, Armsby had become convinced that the true basis of animal feeding, a problem at once of deepest physiological importance and of tremendous economic significance, could best be studied by a wholly new line of attack. Food is given to keep animals alive, to provide for normal growth, to facilitate the best powers of reproduction, and, in the case of cattle, to render fit for human consumption in the shape of beef flesh or milk the fodders, forages, and grasses inedible to man. The energetics of these transformations had always intrigued him and, according to his concept, the one logical method of studying them was with an accurately measurable standard, *i. e.*, the calorie. At the Institute of Animal Nutrition, then, he began plans for that unique instrument, the great respiration calorimeter for large domestic animals. This was housed in a special building, together with most perfect accessory apparatus, and technicians were carefully trained to operate it. Naturally these heroic experiments challenged the attention of research workers in animal nutrition throughout the world. So perfect was the design, construction, and operation of this intricate apparatus that immediately Armsby began to unfold new concepts and impress practices in the highly important economic and physiological problems of animal nutrition. Similar problems had been challenging European scientists for many decades, and shortly his apparatus was duplicated by Hagemann at the Experiment Station at Bonn-Poppelsdorf. Hagemann made a number of unsuccessful "betterments" but was never able to

secure satisfactory results with the equipment, clearly due to his inability to follow well-laid rules and constructive design. A second replica was constructed in the admirable laboratory of Tangl at Budapest. Unfortunately, owing to his untimely death, this instrument was never put into successful operation. Hence today the only respiration calorimeter in which at the same time direct and indirect calorimetric measurements can be made on large domestic animals is that constructed by Armsby, which remains as his monument at State College, Pennsylvania.

Not only was his apparatus at the Institute of Animal Nutrition copied by at least two great European centers of research, but his Institute became a Mecca for a host of scientists who came to this country interested both in animal and in human nutrition, and a visit of Rockefeller Fellows or medical groups from other lands, studying human nutrition in this country, was never complete without a trip to the Armsby Institute at Pennsylvania State College.

In 1905 the Carnegie Institution of Washington commissioned Armsby to examine and report on the entire procedures of the Atwater respiration calorimeter for humans at Wesleyan University, Middletown, Connecticut, preliminary to the establishment by the Carnegie Institution of Washington of a Nutrition Laboratory in Boston. No man in America other than Armsby was even considered for this survey. His critical inspection and suggestions were all presented in a report so complete (as an engineer's report on a project) that the Nutrition Laboratory was started with the sound confidence of its success. In 1919 the Carnegie Institution of Washington again availed itself of Armsby's superior critical judgment, when, prior to the initiation of an extensive study of the basal metabolism and the energy transformations in the complex digestive system of large ruminants, Armsby was commissioned to survey critically the joint research project of the Carnegie Institution's Nutrition Laboratory and the Laboratory of Animal Nutrition (under the direction of Professor E. G. Ritzman) at the New Hampshire Agricultural Experiment Station, Durham, N. H. The project involved the then considered hazardous procedure of submitting ruminants to one or two weeks of fasting (with

water), to observe what the ruminant does with its body reserves, at how low a level of vital activity it can live, and whether upon re-feeding its original metabolic level will be resumed. As a result there was instituted simultaneously at the New Hampshire Agricultural Experiment Station and at Armsby's Institute most profitable researches on the effect of food withdrawal upon the ruminant. From this date onward there was a constant interchange of ideas between the New Hampshire Laboratory, the Nutrition Laboratory in Boston, and the Armsby Institute, all working on closely related problems. This was a striking example of cooperation, with the younger men ever seeking aid from the master. Almost the last letter penned by Armsby dealt with the numerous problems and discussions of the three laboratories. No name appears more frequently in the joint publications of the Nutrition Laboratory and the New Hampshire Agricultural Experiment Station than that of Armsby.

In view of his unique mastery of agricultural chemistry, animal husbandry, and animal nutrition, it is no wonder that his writings were and are today looked upon as authoritative. Through his writings and through his personal visits to Europe, Armsby became well known in all the centers of agricultural research, especially those dealing with animal nutrition in Europe, and no American in agricultural science was more frequently mentioned in discussions than Armsby. His second book, published in 1903, on "The Principles of Animal Nutrition" was in a sense a startling innovation for a man in an agricultural experiment station to write, for it took animal nutrition completely out of the rule-of-thumb barn manual, laid before animal husbandmen the basic principles upon which such feeding must ultimately be considered, and charted many of the guiding courses for his subsequent researches in calorimetry. Fourteen years later his book entitled "The Nutrition of Farm Animals" appeared. This book incorporates most successfully deep scientific insight into the innumerable problems in animal nutrition and a great deal of practical knowledge, which makes it an admirable basis for much agricultural nutritional teaching and likewise the basis for much research. All those interested

in animal nutrition have found a wealth of material in this most carefully prepared, comprehensive work. Concurrent with his important advice on the nutrition of man and animals at the time of the World War, there appeared his book on "The Conservation of Food Energy," which made a distinctly favorable impression. This was almost simultaneous with his appointment as a member of the Interallied Scientific Food Commission, upon which he remained until the end of the war. A posthumous book, the details of which had been carefully worked out prior to his death, was left for completion in the capable hands of the junior author, Professor C. Robert Moulton, and appeared in 1925 under the title "The Animal as a Converter of Matter and Energy. A Study of the Role of Live Stock in Food Production."

Armsby was married to Lucy Atwood Harding of Millbury, Massachusetts, on October 15, 1878.

The honors conferred on Armsby, both at home and abroad, were modestly received but invariably increased his sense of responsibility and obligation. The most outstanding of these honors were:

Doctor of Laws, University of Wisconsin, 1904
Elected member of the Royal Academy of Agriculture of Sweden, 1912
Doctor of Science, Yale University, 1920
Elected member of National Academy of Sciences, 1920
Doctor of Science, Worcester Polytechnic Institute, 1921

Armsby developed during that period when agricultural chemistry, as W. H. Jordan wittily remarked, was so looked down upon that the wife of the professor of organic chemistry occupied a distinctly higher social level than the wife of the professor of agricultural chemistry or, as it was often irreverently called, "cow chemistry." One often wondered if Armsby sensed keenly this lack of appreciation of the importance of agricultural chemistry and by his personality did all he could to overcome this injustice. When one met this gentleman his graceful, modest bearing, his courteous manner, his meticulous dress, instantly dispelled all erroneous notions of the standard of deportment and appearance of the agricultural chemist. A

striking feature of Armsby's personality was his invariably well-groomed appearance. He was a most modest man and spoke at formal or social gatherings with a delicacy of expression, a dry wit, and a charming manner that were the envy of his colleagues. Although having too few hobbies and relaxations, he enjoyed especially bridge whist, to which he applied his mathematical mind and prodigious memory to such purpose that it was commonly said that after the second hand was played he knew the location of all the remaining cards. Because of his naturally frail constitution he felt the responsibility for exercise and was the first golfer on his campus, driving the ball before him in his trips each day to and from his laboratory. His "one man golf club" remained an institution for years. A man considered by most as reserved, although by no means unapproachable, Armsby was, to those fortunate enough to be accepted as intimates, a rare personality. Full of courtesy, dignity, and charm, he became in the intimate circle an endearing personality, rich in dry humor and anecdote. At the only annual dinner (1921) of the Academy that he could attend, those who were at table with him will not forget his clever and delightful anecdotes. The writer was the only one of his "Fach" in the group, and it was interesting to note how he held the attention of those eight others, who represented different branches of science.

His appearance of reserve was undoubtedly due to the fact that he was completely absorbed in his work. There was too little of interest outside the laboratory, and although he took his civic duties seriously, always being available for university committees, an active church worker, and a senior warden in the Episcopal Church, nevertheless his first thought, after his family, was his laboratory and his science. As Director of an Agricultural Experiment Station, he owed certain duties to his constituency which he did not neglect, and the earnest of this is shown in his innumerable papers and the agricultural reports dealing with practical problems of the farmer. On the other hand, his contributions to abstract science are represented by his scholarly book on "The Principles of Animal Nutrition," his development of the unique respiration calorimeter, and the long

series of fundamentally important researches carried out with this instrument.

With almost pitiless energy he drove his research unendingly, and a familiar picture was he, returning to his home from the laboratory, often with a batch of protocols and a large slide rule under his arm. Although he had perfect confidence in the technical operation of his intricate respiration calorimeter by his highly trained associates, he personally supervised all the innumerable calculations. This of itself was an almost superhuman task, and those of us who knew him intimately often have felt that this pressure was his ultimate undoing. Shuttling between the rather inaccessible State College in Center County, Pennsylvania, and the bureaus in Washington at too frequent intervals undoubtedly was more than his frail constitution could stand, but with that spirit of service that characterized him in all his life, he was unwilling to slack any of the work. Perhaps Armsby's greatest fault was that the word "no" did not exist in his vocabulary. To refuse a request of his colleagues or fellow scientists in other institutions, or to refuse the call of service to the Government was to him unthinkable, and as a result he, with his extraordinary capacity for diplomacy, clear thinking, and wide vision, and above all his successful accomplishments, was called upon too much.

Of the innumerable expressions of appreciation of colleagues, associates, and friends, which followed his death on October 19, 1921, but two will be cited here. Professor W. H. Jordan wrote as follows:

"Armsby was a learned man in nutritional science, one of the leaders in this country, perhaps *the* leader in the nutrition of farm animals. When in Berlin in 1913 I asked Dr. N. Zuntz if the United States had any research workers in animal nutrition of equal standing with the best men in Europe. Zuntz answered immediately, 'Armsby.' "

Professor C. Robert Moulton, his collaborator in his last book, wrote as follows:

"Professor Armsby impressed me as an aristocratic gentleman and a member of the intellectual nobility. He was courteous and dignified, yet he showed a true interest in our welfare. The

operation of his laboratory required a well integrated staff with duties assigned and rehearsed, yet one did not feel that he was a cog in a machine, but an individual that was vital to the smooth working of the project. In so far as was possible he allowed his men a freedom and initiative. They were encouraged to give new ideas and suggestions concerning the work of the Institute. He was generous in his dealings with the members of the staff."

Owing to lack of space, the writer refrains from personal statements, much as he would like to make them, for Henry Prentiss Armsby will always remain as one of the rarest figures in his life.

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BIBLIOGRAPHY OF HENRY PRENTISS ARMSBY

1874-1925

On the nitrogen of the soil. Proc. Am. Assoc. Adv. Sci., 1874, **23**, 80.

Experiments on the decay of nitrogenous organic substances. Am. Jour. Sci., 1874, III, **8**, 337.

Value of cottonseed meal and malt sprouts as feed for milch cows. Rpt. Wis. Expt. Station, 1874, 78.

Ueber die Einwirkung der Schwefelsäure auf phosphorsauren Kalk. Jour. Pract. Chem., 1876, **13**, 333.

On the absorption of bases by the soil. Am. Jour. Sci., 1877, III, **14**, 25.

Ueber das Absorptionsvermögen des Bodens für Basen. (Identical with previous paper.) Landw. Vers. Stat., 1877, **21**, 397.

Relations of the soil to water. Rpt. Conn. Expt. Station, 1877, 81; 1878, 83.

The sources of muscular power. Pop. Sci. Monthly, 1878, **12**, 729.

On the determination of albuminoids in hay and coarse fodders. Am. Chem. Jour., 1880, **2**, 81; Rpt. Conn. Expt. Station, 1879, 104.

Manual of cattle feeding. John Wiley & Sons, New York, 1880.

Recent progress in agricultural science. Am. Chem. Jour., 1880-81, **2**, 339, 426; 1881, **3**, 145; 1882-83, **4**, 146, 218.

Observations on the feeding of milch cows as practiced in Connecticut. Rpt. Conn. Expt. Station, 1881, 90.

The Bunsen lamp. Pop. Sci. Monthly, 1882, **20**, 378.

Farmers' Annual Handbook (with E. H. Jenkins). D. Appleton & Co., New York, 1882-3.

Agricultural Experiment Station. Pop. Sci. Monthly, 1883, **23**, 596.

Loss of nitrogen from arable soils. Science, 1884, **3**, 17.

Special manures for particular crops. Science, 1884, **4**, 76.

Field experiments in agriculture. Pop. Sci. Monthly, 1885, **26**, 831.

Comparative value of old and new process bran. Rpt. Wis. Expt. Station, 1885, 86.

Value of new process oil meal compared with corn meal for milk production. Rpt. Wis. Expt. Station, 1885, 97.

The Cooley system of creaming milk. Rpt. Wis. Expt. Station, 1885, 118; Proc. Soc. Promotion Agric. Sci., 1884, 49.

Ueber Aufrahmung mittelst des Cooleyschen Verfahrens. Forschungen a. d. Gebiete der Vieh-haltung, Heft 17, 1. (Identical with previous paper.)

Relation of fat of milk to butter yield. Rpt. Wis. Expt. Station, 1885, 122.

Digestion experiments. Am. Jour. Sci., 1885, **29**, 355.

Apparatus for Kjeldahl's method of nitrogen determination (with F. G. Short). Am. Chem. Jour., 1886, **8**, 323.

Nitrification. Pop. Sci. Monthly, 1886, **29**, 831.

Feeding value of roller bran. Rpt. Wis. Expt. Station, 1886, 113.

Influence of the nutritive ratio on milk production. Rpt. Wis. Expt. Station, 1886, 147.

Analyses of milk of different breeds of cows. Rpt. Wis. Expt. Station, 1886, 159.

Tests of dairy cows at Wisconsin State Fair. Wis. Expt. Station, Bull. 10, 1886.

Oleomargarine. Science, 1886, **7**, 471.

On the digestibility of maize stover (with Wm. Frear). Agric. Sci., 1888, **2**, 149; Rpt. Penna. Expt. Station, 1887, 144.

Comparative value of different forms of phosphoric acid. Rpt. Penna. Expt. Station, 1887, 69; 1888, 124.

Feeding standards and composition of feeding stuffs. Rpt. Penna. Expt. Station, 1888, 47; 1889, 42; 1890, 19; 1893, 13.

The nitrogen supply of maize (with Wm. Frear). Proc. Soc. Promotion Agric. Sci., 1889, 33; Rpt. Penna. Expt. Station, 1889, 195.

The soiling system for milch cows (with Wm. Frear, H. J. Patterson, G. L. Holter, and W. H. Caldwell). Agric. Sci., 1889, **3**, 283, 325; Rpt. Penna. Expt. Station, 1888, 54.

Comparison of ensilage and field-curing for maize (with W. H. Caldwell). Agric. Sci., 1890, **4**, 119; Rpt. Penna. Expt. Station, 1889, 113.

The soiling system for milch cows (with W. H. Caldwell and G. L. Holter). Agric. Sci., 1891, **5**, 1, 39; Rpt. Penna. Expt. Station, 1889, 53.

Influence of the nutritive ratio on milk production. Proc. Soc. Promotion Agric. Sci., 1890, 11.

Ensilage of the corn crop (with Wm. Frear and W. H. Caldwell). Rpt. Penna. Expt. Station, 1890, 43.

Influence of variety and rate of seeding on yield of ensilage corn. Rpt. Penna. Expt. Station, 1891, 17.

Influence of variety and rate of seeding on the yield of soiling corn. Rpt. Penna. Expt. Station, 1891, 36.

Sampling corn fodder. Rpt. Penna. Expt. Station, 1891, 32.

Digestion experiments—Recent work abroad. U. S. Dept. Agric., Office Expt. Stations, Misc. Bull. 3, 1891, 132.

Is it desirable to affix a valuation to feeding stuffs? Agric. Sci., 1892, **6**, 118.

Variations in the composition of forage corn. Agric. Sci., 1892, **6**, 160.

Influence of ensilage and field-curing on the digestibility of forage corn. Agric. Sci., 1892, **6**, 349; Rpt. Penna. Expt. Station, 1892, 14.

The food yield of forage corn. Rpt. Penna. Expt. Station, 1892, 22.

Tests of dairy apparatus (with H. J. Waters and W. H. Caldwell). Rpt. Penna. Expt. Station, 1892, 51.

The Koch test for tuberculosis. Rpt. Penna. Expt. Station, 1892, 94.

The aim and methods of investigations in stock feeding. Agric. Sci., 1893, **7**, 481.

Tests of cream separators (with W. H. Caldwell and L. E. Reber). Rpt. Penna. Expt. Station, 1894, 13.

Cottonseed meal for dairy cows (with E. H. Hess). Rpt. Penna. Expt. Station, 1894, 44.

Rational stock feeding. Rpt. Penna. Expt. Station, 1894, 36; 1895, 16.

The computation of rations for farm animals. Rpt. Penna. Expt. Station, 1896, 18; 1897, 17.

Dried brewers' grains. Rpt. Penna. Expt. Station, 1896, 53.

A soil test with fertilizers. Rpt. Penna. Expt. Station, 1896, 123.

The maintenance ration of cattle. Rpt. Penna. Expt. Station, 1897, 65, 159, and Penna. Expt. Station Bull. 42, 1898, 188 pp.

The sugar beet in Pennsylvania. Rpt. Penna. Expt. Station, 1897, 101.

Tests of the sugar beet in Pennsylvania (with E. H. Hess). Rpt. Penna. Expt. Station, 1898-99, 80.

The available energy of timothy hay (with J. August Fries). Preliminary Report. Proc. Soc. Promotion Agric. Sci., 1902; Rpt. Penna. Expt. Station, 1901-2, 284.

The available energy of timothy hay (with J. August Fries). U. S. Dept. Agric., Bureau Animal Industry, Bull. 51, 1903, 77 pp.; Rpt. Penna. Expt. Station, 1902-3, 96.

Die nutzbare Energie des Timothyheues (with J. August Fries). Landw. Jahrbücher, 1904, **33**, 665. (Identical with previous paper.)

The principles of animal nutrition. John Wiley & Sons, New York, 1903.

The isodynamic replacement of nutrients. Science, 1903, **18**, 481.

The respiration calorimeter at the Pennsylvania State College. Expt. Station Rec., 1904, **15**, 1037; Rpt. Penna. Expt. Station, 1903-4, 208.

Heat values and food values. Arch. Pediat., Feb. 1905.

Relative values of feeding stuffs. Penna. Expt. Station, Bull. 71, 1905; revised ed., 1907, 16 pp.

Energy values of red clover hay and maize meal (with J. August Fries). U. S. Dept. Agric., Bureau Animal Industry, Bull. 74, 1905, 64 pp.; Rpt. Penna. Expt. Station, 1904-5, 124.

Energiewerte des roten Kleeheues und des Maisschrots (with J. August Fries). Landw. Jahrbücher, 1905, **34**, 861. (Identical with above.)

Dried distillers' grains vs. cottonseed meal as a source of protein (with A. K. Risser). Penna. Expt. Station, Bull. 73, 1905.

The promotion of agricultural science. Presidential address. Proc. Soc. Promotion Agric. Sci., 1906, 7-20; Science, 1906, **24**, 673.

Investigations in animal nutrition. U. S. Dept. Agric., Bureau Animal Industry, 23d Ann. Rpt., 1906, 263.

Problems of animal nutrition. Expt. Station Record, 1907, **18**, 508-521.

Research as a career. Presidential address. Proc. Soc. Promotion Agric. Sci., 1907, 9-26.

A suggestion for a new unit of energy. Proc. Soc. Promotion Agric. Sci., 1907, 28, 164-7; Science, 1907, **26**, 670-672.

Feed as a source of energy. Penna. Expt. Station, Bull. 84, 1907, 16 pp.

The available energy of red clover hay (with J. August Fries). U. S. Dept. Agric., Bureau Animal Industry, Bull. 101, 1908, 61 pp.; Rpt. Penna. Expt. Station, 1906-7, 94.

Feeding for meat production. U. S. Dept. Agric., Bureau Animal Industry, Bull. 108, 1908, 89 pp.

The computation of rations for farm animals by the use of energy values. U. S. Dept. Agric., Farmers' Bull. 346, 1909.

Principles of stock feeding. Cyclopaedia of American Agriculture. Macmillan Co., New York, 1907-9.

The food supply of the future. Presidential address. Am. Soc. Animal Nutr., Proc. Ann. Meeting, Nov. 1909, pub. Jan. 1910; Science, 1910, **30**, 817-823.

Essentials in the training of the investigator. Proc. Soc. Promotion Agric. Sci., 1910, 113-119.

The respiration calorimeter at the Institute of Animal Nutrition of the Pennsylvania State College. Penna. Expt. Station, Bull. 104, 1910, 16 pp.; II Congrès International d'Hygiène Alimentaire, vol. 1, Sect. 1, p. 45.

The influence of type and of age upon the utilization of feed by cattle (with J. August Fries). U. S. Dept. Agric., Bureau Animal Industry, Bull. 128, 1911, 245 pp.; Penna. Expt. Station, Bull. 105, 1910, 22 pp.

The nutritive value of the non-protein of feeding stuffs. Presidential address. Am. Soc. Animal Nutr., Proc. Ann. Meeting, Nov. 1910, pub. June 1911.

The nutritive value of the non-protein of feeding stuffs. U. S. Dept. Agric., Bureau Animal Industry, Bull. 139, 1911, 49 pp.

The maintenance ration of cattle. Penna. Expt. Station, Bull. 111, 1911, 20 pp.

The conservation of the food supply. Pop. Sci. Monthly, Nov. 1911, 6 pp.

The maintenance rations of farm animals. U. S. Dept. Agric., Bureau Animal Industry, Bull. 143, 1912, 110 pp.

Some unsolved problems. Presidential address. Am. Soc. Animal Nutr., Proc. Ann. Meeting, Nov. 1911, pub. Jan. 1912.

The influence of standing or lying upon the metabolism of cattle (with J. August Fries). Am. Jour. Physiol., 1913, **31**, 245-253.

The same: Eighth International Congress of Applied Chemistry, 1913, **15**, 23-33.

A comparison of the observed and computed heat production of cattle. Jour. Am. Chem. Soc., 1913, **35**, 1794-1800.

Food as body fuel. Penna. Expt. Station, Bull. 126, 1913, 68 pp.

Net energy values of feeding stuffs for cattle (with J. August Fries). Jour. Agric. Research, 1915, **3**, 435-491.

Net energy values for ruminants (with J. August Fries). Penna. Expt. Station, Bull. 142, 1916, 3-14.

Net energy values of American feeding stuffs (with F. S. Putney). Penna. Expt. Station, Bull. 142, 1916, 15-20.
Computation of dairy rations (with F. S. Putney). Penna. Expt. Station, Bull. 143, 1916, 3-24.
Energy values of red clover hay and maize meal (with J. August Fries and W. W. Braman). Jour. Agric. Research, 1916, **7**, 379-387.
The use of energy values in the computation of rations for farm animals. U. S. Dept. Agric., Bureau Animal Industry, Bull. 459, 1916, 31 pp.
The nutrition of farm animals. Macmillan Co., New York, 1917.
Energy values of hominy feed and maize meal for cattle (with J. August Fries). Jour. Agric. Research, 1917, **10**, 599-613.
Influence of the degree of fatness of cattle upon their utilization of feed (with J. August Fries). Jour. Agric. Research, 1917, **11**, 451-472.
Basal katabolism of cattle and other species (with J. August Fries and W. W. Braman). Jour. Agric. Research, 1918, **13**, 43-57; prelim. rpt., Proc. Nat. Acad. Sci., 1918, **4**, 1-4.
The conservation of food energy. W. B. Saunders Co., Philadelphia, July, 1918.
Net energy values of alfalfa hay and of starch (with J. August Fries). Jour. Agric. Research, 1918, **15**, 269-286.
Net energy values and starch values (with J. August Fries). Jour. Agric. Sci., 1919, **9**, 182-187.
The organization of research. Address before Section M, Am. Assoc. Adv. Sci., St. Louis, 1919; Science, 1919, **51**, 33-38.
A national institute of nutrition. Science, 1919, **50**, 242-244.
The modern science of food values. Yale Review, 1920, **9**, 330-345.
The carbon dioxide: heat ratio in cattle (with J. August Fries and W. W. Braman). Proc. Nat. Acad. Sci., 1920, **6**, 263-265.
Cooperative experiments upon the protein requirements for the growth of cattle. First report of the Subcommittee on Protein Metabolism in Animal Feeding. Nat. Research Council, Bull. 12, 1921, 219-288.
Some fundamentals of stable ventilation (with Max Kriss). Jour. Agric. Research, 1921, **21**, 343-368.
The animal as a converter of matter and energy (with C. Robert Moulton). Chemical Catalogue Co., New York, 1925.