NATIONAL ACADEMY OF SCIENCES

CONRAD ARNOLD ELVEHJEM

1901—1962

A Biographical Memoir by

R. H. BURRIS, C. A. BAUMANN,
AND VAN R. POTTER

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May 27, 1901–July 27, 1962

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THE WORK OF CONRAD ELVEHJEM—a major contributor to the golden era of nutritional research—touched most aspects of animal nutrition, advancing, in particular, our understanding of the B vitamins, the phenomenon of amino acid imbalance, and the identification of trace minerals needed in the diet. Elvehjem made the major discovery that nicotinic acid functions as the antipellagra vitamin.

Elvehjem was also a superb administrator, an efficient man who channeled his great energy with seemingly little effort. On the local scene he served the University of Wisconsin as chairman of the Department of Biochemistry, dean of the Graduate School, and, finally, as president of the University. On the national level he helped make policy decisions concerning the level of vitamins and other nutrients required for health. The implementation of his cure for pellagra was international in scope.

EARLY YEARS

Conrad Elvehjem was born in 1901 to Ole Johnson Elvehjem and Christine Lewis Elvehjem on a modest farm near McFarland, Wisconsin. In this primarily Norwegian area (May 17 is still celebrated as Norwegian Independence Day in Stoughton), Elvehjem grew up and attended high school. He would spend his adult life within a few miles of his birth place, for Madison's capitol building is visible from the farm.

The Elvehjem children were expected to do their share of the farm chores, and—while there was little time for nonsense—education was encouraged. In those days Wisconsin farm boys usually did not go to high school and college, but his family made sure he was able to do so. In 1919, Elvehjem enrolled in the University of Wisconsin's College of Agriculture, already recognized for its research in agricultural chemistry, genetics, plant pathology, and bacteriology. Elvehjem majored in agricultural chemistry, a field in which Babcock, Hart, Steenbock, McCollum, and Peterson had all done, or were doing, meritorious work at Madison. He did his undergraduate research under the direction of Harry Steenbock and wrote his senior thesis jointly with W. P. Elmslie on "buckwheat itch," a light-induced disturbance in animals.

As to Elvehjem's early motivation in the choice of his career, in 1957 he answered a thirteen-year-old boy who had questioned him on this subject as follows: "I chose the field of biochemistry because as a youngster I was interested in what made plants grow and develop. I was very intrigued by the rapid growth of the corn plant, and I was interested in knowing what reactions took place within the plant to allow such rapid growth." Of his achievements, he said: "My achievements cover work on many of the B vitamins—including the isolation and identification of nicotinic acid as the antipellagra factor, also work on a number of trace mineral elements showing that they have specific functions in nutrition and metabolism. I also pioneered in work demonstrating the relationship between vitamins and enzymes. Today I am more interested in amino acids in nutrition." It never occurred to him, apparently, to mention his many administrative successes!

In 1923 Elvehjem began graduate work as a teaching assistant under Professor E. B. Hart, his major professor until he received his Ph.D. degree in 1927. In 1924 he published his first paper with Hart and Steenbock on dietary factors influencing calcium metabolism (1924,1). But his graduate work centered mainly on iron deficiency in rats, including a demonstration that copper must accompany iron in the diet to cure this type of anemia.

Hart's encouragement of Elvehjem during his student days is just one example of his remarkable capacity to pick winners. This was before the period when talented students were being attracted to agricultural chemistry in large numbers, yet Hart had staffed his small department with a remarkable group of investigators. He supported them through administrative difficulties, had a building constructed for their teaching and research, and offered them whatever he could given the limited resources available at that time. As long as Hart lived, he and Elvehjem worked together on many joint research projects. Indeed, approximately half of Elvehjem's long list of publications contains Hart's name as well.

On June 30, 1926, Elvehjem married Constance Waltz, a journalism student at the University of Wisconsin and the daughter of a Rockford, Illinois, dentist. This was a happy union, and the two Connies—called Mr. Connie and Mrs. Connie by their friends—complemented each other. He was relatively quiet, while she bubbled with enthusiasm, meeting people easily with charm and grace. She was a source of strength to her husband throughout all stages of his career, and most particularly when he held administrative positions.

From 1927 to 1929, after receiving his Ph.D. degree, Elvehjem held an instructorship in agricultural biochemistry. In 1929, he received a National Research Council Fellowship to study in the biochemistry laboratories at Cambridge University, England.

This was the only substantial period in his career that

Elvehjem spent away from Madison, and he and Mrs. Connie took full advantage of it. As Elvehjem himself described it, they arrived in England, took a guided tour through London that allowed him to spot the laboratories he wanted to visit later, searched for housing in Cambridge, and met Dr. and Mrs. C. G. King—kindred souls with whom they would share many experiences. According to Elvehjem, the Biochemistry Department at Cambridge was a lively spot in 1929 and 1930, and he describes Sir Frederick Hopkins' lively welcome back as the recently announced recipient of the Nobel Prize.

At Cambridge Elvehjem worked under the tutelage of Dr. David Keilin, who was then busy with the cytochromes and the role of iron in cytochrome *c*. Copper and iron in cytochrome oxidase were of particular interest to Elvehjem, whose own work had shown that animals deficient in copper were also deficient in cytochrome oxidase. By the 1930s, a role for copper in cytochrome oxidase was widely accepted.

At Wisconsin Elvehjem had studied nutritional anemia in rats on a diet very low in iron (viz., milk). The addition of relatively large amounts of inorganic iron salts to such milk failed to prevent this type of anemia. Testing crude materials protective against anemia—and later the ash of those most potent for supplementing iron in a milk diet—Elvehjem, Steenbock, Hart, and Waddell found that traces of inorganic copper were necessary for the incorporation of iron into hemoglobin, even though hemoglobin contains no copper. In this way, the idea of catalysis in life-processes was brought forcibly to Elvehjem's attention.

Elvehjem later published two papers on his work at the Biochemical Laboratory in Cambridge with acknowledgments to Hopkins "for his interest and advice" and to Keilin "for many helpful suggestions." The first, "Factors Affecting the Catalytic Action of Copper in the Oxidation of Cysteine" (1930,1), clearly derived from a project suggested by Keilin.

The second, "The Role of Iron and Copper in the Growth and Metabolism of Yeast" (1931,1), contained observations that, though yeast contains no hemoglobin, its respiration requires iron-containing pigments; and that copper increases the levels of cytochrome *a*, presumably cytochrome oxidase. Both studies gave Elvehjem experience with manometric techniques, and he spent a busy year visiting laboratories, doing research on several problems, and aiding in a laboratory course.

RETURN TO WISCONSIN

At Cambridge, Elvehjem—in the forefront of nutrition research—worried less about finding new vitamins than about understanding how these substances functioned in the metabolism of the living cell. He developed a new research strategy—parallel studies on respiratory enzymes and on deficiency-producing diets, especially designed to be assayed for new growth factors and trace elements. This new methodology would further allow him to isolate the new substances and determine their action. He was, therefore, particularly intrigued by the Barcroft respirometer. This instrument permitted accurate measurements of oxidative enzymatic activity with small samples of tissue, enabling researchers to define differences in the responses of normal versus deficient tissue and the responses of deficient tissue to added compounds.

While he was away, Elvehjem maintained a correspondence with Hart, and their exchange of letters concerning salary is interesting. On April 23, 1930, Hart wrote Elvehjem:

"I understood today that the Board of Regents had passed the budget which appoints you as an Assistant Professor at $3,000 for the academic year. You ought to be very happy over this because it was very difficult to get an increment of $600 for you in the present state of Wisconsin finances. You are young, and with summer pay and gradual increments, and an opportunity for research the position you will hold with us ought to be very attractive."

Elvehjem to Hart, May 16, 1930:

"I was glad to have your letter and to learn that there would be a job waiting for me when I return. . . . I can't say that I am exceedingly happy over the salary but we can talk about that later. What I am wondering about now is, if you will buy a Barcroft for me. If we are going to continue to work on the minor inorganic elements it will come in very handy. In fact there are a thousand things to do in regard to the catalytic action of copper before leaving it in favor of other elements."

Hart agreed to let Elvehjem purchase his device, and he brought a set of respirometers back with him on his return to Wisconsin. In Madison it soon became a treasured possession, and each noninterchangeable flask was carefully guarded. The Potter-Elvehjem homogenizer remains still to remind investigators of the days when Elvehjem was actively studying respiratory enzymes. Elvehjem immediately put his Barcroft respirometer to good use studying the respiration of minced tissues from normal and from vitamin-deficient experimental animals. He also continued his joint researches with Professor Hart and a number of students on the mineral requirements—zinc, manganese, and molybdenum—in the rat, chicken, dog, and pig and began a large program on the vitamin B complex, a relatively neglected area at Wisconsin at that time.

In the early 1930s techniques available for nutritional studies left much to be desired. Deficient diets were usually lacking to varying degrees in more than one essential, and curative preparations contained a number of different vitamins. A typically crude (but useful) method of producing deficiencies was to damage a mixed diet with dry or moist heat, destroying vitamins differentially. The sources used for growth factors were yeast, milk, liver, or fractions of liver left over from the commercial preparation of extracts for the treatment of pernicious anemia. "Success" meant restoration of the growth rate—by means of a supplemented diet—that had decreased on a defective diet.

Elvehjem's approach was similar to that of others working on the B vitamins except that his graduate students worked simultaneously on different growth factors or with different species, so that when one achieved a preparation active against his particular deficiency, others could test a similar preparation for those deficiencies that were their own primary concern. This insured quick determination of the effects of a given concentrate on the various deficiencies under study.

NICOTINIC ACID

Elvehjem was particularly skillful in coordinating experiments and cross-checking results, and he was never timid about postulating the existence of new growth factors. One of these, "Factor W," represented what, in addition to the established B vitamins, remained in a liver concentrate. His recognition of nicotinic acid as the antipellagra principle was typical of his thoroughness and his ability to combine information gleaned from various sources, with data produced by his own students, and of his active collaboration with academic and commercial colleagues.

In 1912, exactly twenty-five years before nicotinic acid's true status as a vitamin was established, Casmir Funk—in one of the more curious twists of nutritional history—attempted to cure a vitamin deficiency by feeding it to polyneuritic birds. The results were unexciting. The substance came into its own as an important biochemical, however, in 1936, when Warburg and Christian identified it as one of the components of "coferment" (NADP). Discovery of its presence in cozymase (NAD) followed quickly. About the same time, several investigators reported it to be essential for the growth of certain microorganisms. Elvehjem and Douglas Frost, feeding nicotinic acid to rats deficient in "Factor W," reported a slight growth response, though much less than that obtained with crude liver preparations.

The isolation of nicotinic acid came about primarily through the fractionation of liver extracts. By means of successive solvent extractions, Carl Koehn had converted 400 grams of liver extract to 2.5 grams of a powder active against canine black tongue. Robert Madden achieved further concentrations by means of adsorption on an appropriate charcoal. Elvehjem had for some time been receiving liver extracts for these studies from the Wilson and Abbott Laboratories. Then Dr. Rhodehamal of the Eli Lilly Company, working according to the Koehn and Elvehjem procedure, furnished a concentrate from seventeen kilograms of liver. The next big step was Frank Strong's sublimation of this concentrate in a molecular still. Almost immediately Wayne Woolley obtained crystals from the distillate and, on Karl Link's microapparatus, H. Campbell determined the percentages of C, H, and N.

The response to these crystals in deficient dogs was dramatic, and the correlation between the analytical values and the theory for nicotinamide was close enough to lead Woolley to take a mixed melting point and perform the appropriate characterization reactions—all in a matter of a few days. Synthetic nicotinic acid and amide were then fed to other dogs and found to be highly active.

The research community lost little time in applying these results to human pellagra. Elvehjem's first published notice of his laboratory's findings appeared in September 1937, in a "letter to the editor" of the *Journal of the American Chemical Society*. Van Potter, who shared an office with him at the time, recalls that Elvehjem sent telegrams to a number of clinical investigators interested in pellagra—including Tom Spies. Before the end of 1937, Elvehjem's results with dogs had been confirmed by six independent investigators. By the time his more complete paper on the subject appeared in 1938, it was possible to add the following: "Spies has used nicotinic acid in four cases of classical pellagra and reports (personal communication) that the fiery red color associated with pellagrous dermatitis, stomatitis, and vaginitis improved promptly." The Wisconsin paper (1938,1) not only summarized the known biochemical facts on nicotinic acid, it even expressed concern about possible toxicity in its application![1]

THE B VITAMINS AND AMINO ACIDS

Nicotinic acid, however, was not the only B vitamin to occupy Elvehjem and his research team. As his list of publications shows, his laboratory investigated every B vitamin at one time or another, though occasionally under a different name until its true nature was established. The clarification and disentanglement of the B complex occupied many investigators worldwide for years, during which the Elvehjem group made substantial contributions to our present understanding. But the latter years of his laboratory career were spent on amino acids, an interest that had grown out of the pellagra problem.

Pellagra occurred in areas where people consumed inadequate diets high in corn, and Elvehjem's studies on black tongue in dogs also involved a diet high in corn. The diets used for studies of the B complex in rats and chicks, on the

[1] Because of Elvehjem's generosity in disseminating his laboratory's findings widely, the medical implications of nicotinic acid in the treatment of pellagra became apparent almost immediately. On January 22, 1938, Tom Spies's November 5, 1937, report of his own experiments to the Central Society for Clinical Research was the subject of an editorial in the *Journal of the American Medical Association*. For his dramatically successful use of nicotinic acid to treat pellagra in humans, *Time* magazine named Spies 1938's "Man of the Year."

other hand, were so-called "semisynthetic"—usually based on casein, starch, sugar, etc. Rats fed this diet never developed nicotinic acid deficiency, nor did administration of nicotinic acid improve their growth. But when corn was used to replace forty percent of such a diet, growth was depressed and could be restored by supplements of nicotinic acid or of tryptophan—an amino acid that is relatively lacking in corn.

Further studies in a number of laboratories clarified the mechanism by which tryptophan is converted to niacin in the body. Working with A. E. Harper, Elvehjem carried out experiments on requirements for other amino acids that presaged an extensive investigation of amino acid imbalance—an investigation that ceased, however, when he became president of the University.

The coenzyme connection to nicotinic acid (NAD and NADP) was important in motivating Elvehjem and Thorfin Hogness, of The University of Chicago, to organize a "Symposium on Respiratory Enzymes" in Madison on September 11–13, 1941, and one on "The Biological Action of the Vitamins," held at The University of Chicago on September 15–19. David H. Smith noted at the vitamin symposium that Elvehjem's observations on the relation of nicotinic acid to canine black tongue (published in the September issue of the *Journal of the American Chemical Society* [1937,4]) were verified promptly and extended to human pellagra by a number of investigators.

Subsequent to the spectacular conquest of pellagra, Elvehjem was invited to Cornell University Medical School to be interviewed for the chairmanship of the Department of Biochemistry—the only position outside of the University of Wisconsin he ever considered. A modest and humble man, Elvehjem had simple tastes and more than a touch of austerity. Potter recalls his dismay on entering their shared office one Saturday shortly after the Cornell trip to find Elvehjem on his knees scrubbing the frayed maroon linoleum—last renewed during Stephen Moulton Babcock's earlier tenancy. Bob Burris, Connie's successor as department chairman, recalls only two occasions of being "chewed out" by him—once when he acquired a new office desk to replace Connie's old one, and once when he approved shifting the time of departmental seminar from 8 A.M. on Saturdays.

The attack on Pearl Harbor in December 1941, followed on the heels of Elvehjem and Hogness's joint symposia in September. As a member of the National Research Council's Food and Nutrition Board, Connie strongly recommended fortifying bread with vitamins on a national scale. Writing to Potter on August 17, 1983, Jean St. Clair, the archivist for the National Research Council, recalled the high regard Elvehjem enjoyed among his colleagues throughout the nation:

"[In] March, 1958 . . . Dr. Elvehjem, Chairman of the Board, had sent word that he could not attend the Friday meeting but that he hoped to attend the dinner and the Saturday morning session. The appointment of Dr. Elvehjem to the presidency of the University of Wisconsin, effective July 1, had been announced at the Friday meeting, as had his decision that, under that circumstance, he would be unable to continue as chairman of the Board.

"The speaker for the dinner was George McGovern, Congressman from South Dakota, [who] had decided, via his membership on the House Committee on Education and Labor, to develop a guide to inform the American people on what to eat to be healthy. . . . The Board's plan was to listen to what he had to say, and then tactfully offer the Congressman its assistance.

"In Dr. Elvehjem's absence, Dr. Grace Goldsmith, vice chairman of the Board, had just introduced McGovern, who had delivered a sentence or two of his speech, when Dr. Elvehjem entered the room. Applause broke out and McGovern said, 'Well, I can't compete with that,' and sat down. A standing ovation followed for 'Connie' Elvehjem, not so much for his new assignment at Wisconsin as for himself as a person. It was a remarkable show of affection and respect.

"Dr. Elvehjem succeeded in restoring quiet. He reintroduced

McGovern who, after his speech, had to leave for another appointment. It was just as well, because it turned out to be the wrong night for an outsider. I don't think the planners of the dinner meeting had anticipated what would happen if Dr. Elvehjem were to appear in the middle of the program, and it was evident that Elvehjem was surprised as well.

"At the close of the dinner session, Dr. Elvehjem was presented with a signed scroll which read: 'On the occasion of his movement into a new orbit, members and friends of the Food and Nutrition Board join in expressing to Conrad A. Elvehjem their appreciation of his scientific leadership, his sustained wisdom, his common sense, and his good humor as a member of the Board from its beginning, and as its chairman from 1955 to 1958.'"

In the years just prior to the discovery of the antipellagra vitamin and for many years thereafter, Elvehjem and Professor Perry Wilson conducted an enzyme seminar with their most interested students and colleagues. This bore fruit in the form of a manual on respiratory enzymes in which sixteen local Wisconsin students and faculty described the state of the field in the period just prior to the date of publication, 1939—a book that remains interesting for its historical introduction by Elvehjem.

In 1945 he attended a national "Conference on Intracellular Enzymes of Normal and Malignant Tissues" at Hershey, Pennsylvania. There he and Van Potter, his former student, discussed the fact that opportunities for postdoctoral study in Europe that had proved so important for Wisconsin biochemists in the past (Hart, Steenbock, Peterson, Link, Elvehjem, Johnson, Baumann, and Strong) would no longer be available to them in the immediate postwar years. The two hit on the idea of a postdoctoral training facility, and—with support from Dean W. S. Middleton of the Medical School, the Wisconsin Alumni Research Foundation, and from the Rockefeller Foundation—the Enzyme Institute became a reality.

Elvehjem traveled to St. Louis in an attempt to recruit Carl

F. Cori for the Institute, but Cori's timely (or untimely) receipt of the Nobel Prize made him impossible to move. Instead, David Green, who had a brilliant record at Cambridge and Columbia universities, was persuaded to become the new Enzyme Institute's first team leader.

Following its original plan, the Institute had several established investigators leading their own group of postdoctoral fellows. The second team leader recruited was Professor Henry Lardy, who moved from the Biochemistry Department to the Enzyme Institute, retaining his privilege of training Ph.D. candidates. Green and Lardy were subsequently named codirectors of the Institute, which was guided by an Enzyme Committee with the dean of the Graduate School (at that time, Elvehjem) as chairman *ex officio*.

PUBLIC SERVICE

Elvehjem's successful researches early in his career brought him many invitations to lecture and to join committees and learned associations.

He was a member of the Food and Nutrition Board from its inception until 1961. The Board, as a measure to improve the national food supply during World War II, developed guidelines for the fortification of foods with vitamins and minerals. It subsequently provided estimates of human nutritional requirements—the so-called "recommended dietary allowances"—that are now regarded as national standards.

Elvehjem was also an active member of the American Medical Association's Council on Food and Nutrition (1941–1958) and served on advisory committees of the Nutrition Foundation and the National Science Foundation. In 1960 he was consultant to the President's Science Advisory Committee and president of the American Institute of Nutrition.

Elvehjem also received a number of honorary degrees. After his death, the American Institute of Nutrition created the Conrad Elvehjem Award to honor those of its members who were remarkable for their distinguished public service. The Wisconsin Alumni Research Foundation provided funds for an Elvehjem Professorship in the Life Sciences, first held by Gobind Khorana who, four years later, received the Nobel Prize.

UNIVERSITY ADMINISTRATION

A scientist at heart, Elvehjem early demonstrated his talents as an administrator managing a large research staff. He grasped concepts with remarkable speed, marshalled evidence pertinent to the problem, and reached logical conclusions without delay. As one rather slow-spoken faculty member remarked, "Connie answers your problem before you have completed stating your question." This is not to say that his conclusions were snap judgments—they were consistently sound and were respected considering his remarkable record for being right. He was also scrupulously honest in his dealings. Intrigue was foreign to him; he trusted his colleagues and they trusted him. On the assumption that he was dealing with reasonable people who were seeking solutions, he willingly used his remarkable perceptiveness and breadth of understanding to help formulate and implement those solutions.

Initially Elvehjem had done research with Harry Steenbock but then shifted to E. B. Hart's group. When Hart stepped down in 1944, after thirty-eight years as chairman of the Department of Biochemistry, Elvehjem was clearly the staff's choice to succeed him. As chairman, Elvehjem followed the pattern set by Hart and did not allow the job to overwhelm him. He treated trivia as trivia. He examined and solved substantive problems with minimal wasted effort. He delegated tasks, and people were pleased to aid so decisive a man whom they admired. Although some were jealous of his uncanny ability to get things done, Connie had few enemies.

Elvehjem's scientific standing and administrative talents were widely recognized locally, and when the position of graduate dean came open, he was asked to fill it. When he accepted the challenge of the deanship, it was probably assumed that he would then relinquish the chairmanship of the Biochemistry Department. But biochemistry was home to Connie and the base for his research, and he carried both jobs. He still appeared daily at the Department well before 8:00 A.M. to make the rounds of the rooms and quiz his students on their latest observations. The mornings sufficed for administering the Biochemistry Department, maintaining a productive research program, and writing technical papers.

The afternoons were spent at the Graduate School office on the central campus. Elvehjem kept operations under control, and one heard no complaints that he was neglecting either biochemistry or the graduate deanship. This was the more remarkable in that Wisconsin's graduate biochemistry program was then the largest in the country and the leading grantor of Ph.D. degrees.

Administration at Wisconsin's Graduate School had long been dominated by people from the sciences, and other sectors of the University felt some trepidation when yet another scientist was selected as its head. Certainly there was nothing in Connie Elvehjem's background to suggest empathy with the arts and humanities. But as graduate dean, he made it his policy to channel flexible supporting funds to areas outside the hard sciences while continuing to support basic science with funds that could not be shifted. This policy reflected his inherent fairness and his clear perception that a university without breadth and balance could not be a great university. For some years, for example, the Graduate Dean and his Research Committee had administered a substantial block-grant from the Wisconsin Alumni Research Foundation. Under Elvehjem, more of this grant went to the Department of History than to Biochemistry—the department that had generated the patents from which ninety-four percent of the Foundation's funds (amplified by skillful investment) had come.

Elvehjem's concern for maintaining and enhancing his great university came through clearly during his tenure as president from 1958 to 1962. He encouraged the establishment of an Institute for Research in the Humanities and found funds for other efforts in the humanities and social sciences. He supported efforts to create a worthy art gallery, and though it came to fruition only after his death, it was named the Elvehjem Museum of Art.

Elvehjem's tenure as president was only four years, but it was a period of substantial change during which the University of Wisconsin-Milwaukee grew rapidly and gained new stature. Without dominating this growth, he helped guide it. Though the physical plant was expanded during his tenure, Elvehjem clearly felt that a great institution is built primarily on people. He encouraged the recruitment of promising scholars in a variety of fields.

President Elvehjem was stricken with a heart attack at his desk on the morning of July 27, 1962, at the age of sixty-one and died within the hour. Although he left tasks unfinished, he also left a great legacy of accomplishment and affection. The faculty memorial resolution on the death of Conrad Arnold Elvehjem catches the character of the man:

"Such basic traditions of the University as academic freedom, enthusiasm for the pursuit of truth, concern for the individual student, and service of the whole state were not only fostered but exemplified by him. . . . He could make allowances for weaknesses he did not share. . . . He even tried to understand the untidy desk but never quite succeeded. . . . Few men changed more than Elvehjem; yet few remained as constant. In his directness and honesty, in his unswerving devotion to high religious and moral standards, in his regard for the rights of others, in his complete dedication to learning and the University of Wisconsin as a home of learning, the undergraduate who became the president was the same man. Both humility and self-confidence were natural to him. He had an iron will which he used to control himself rather than others, a will which turned his natural impatience into an asset and drove his splendid brain from one accomplishment to another.

"For one of the constants of his character was the ability to grow. He could value what he did not himself savor. In the breadth of his sympathies, in the understanding of the foibles of others and of himself, in the appreciation of those of less talent, he grew at each stage of his career. What had been the tolerance of the specialist was at the close of his life ripening into genuine catholicity of interest."

AWARDS

1939 Mead Johnson Award, American Institute of Nutrition
1942 Grocery Manufacturers of America Award
1943 Willard Gibbs Award, American Chemical Society
1948 Nicholas Appert Medal, Institute of Food Technologists
1950 Osborne-Mendel Award, American Institute of Nutrition
1952 Lasker Award in Medical Research, American Public Health Association
1956 Charles Spencer Award, American Chemical Society
1957 American Institute of Baking Award

SELECTED BIBLIOGRAPHY

In addition to the original research papers listed below, Professor Elvehjem published eighty-five commentaries and reviews under his sole authorship.

1924

With E. B. Hart and H. Steenbock. Dietary factors influencing calcium assimilation. V. The effect of light upon calcium and phosphorus equilibrium in mature lactating animals. J. Biol. Chem., 62:117.

1925

With E. B. Hart, H. Steenbock, and J. Waddell. Iron in nutrition. I. Nutritional anemia on whole milk diets and the utilization of inorganic iron in hemoglobin building. J. Biol. Chem., 65:67.

With H. Steenbock, E. B. Hart, and S. W. F. Kletzien. Dietary factors influencing calcium assimilation. VI. The antirachitic properties of hays as related to climatic conditions with some observations on the effect of irradiation with ultra-violet light. J. Biol. Chem., 66:425.

1926

With E. B. Hart. Iron in nutrition. II. Quantitative methods for the determination of iron in biological materials. J. Biol. Chem., 67:43.

1927

With R. C. Herrin and E. B. Hart. Iron in nutrition. III. The effect of diet on the iron content of milk. J. Biol. Chem., 71:255.

With W. H. Peterson. The iron content of animal tissues. J. Biol. Chem., 74:433.

With E. B. Hart, J. Waddell, and R. C. Herrin. Iron in nutrition. IV. Nutritional anemia on whole milk diets and its correction with the ash of certain plant and animal tissues or with soluble iron salts. J. Biol. Chem., 72:299.

1928

With W. H. Peterson. The iron content of plant and animal foods. J. Biol. Chem., 78:215.

With J. Waddell, H. Steenbock, and E. B. Hart. Iron in nutrition. V. The availability of the rat for studies in anemia. J. Biol. Chem., 77:769.

With J. Waddell, H. Steenbock, and E. B. Hart. Iron in nutrition. VI. Iron salts and iron-containing ash extracts in the correction of anemia. J. Biol. Chem., 77:777.

With E. B. Hart, H. Steenbock, and J. Waddell. Iron in nutrition. VII. Copper as a supplement to iron for hemoglobin building in the rat. J. Biol. Chem., 77:797.

1929

With C. W. Lindow. The determination of copper in biological materials. J. Biol. Chem., 81:435.

With E. B. Hart. The copper content of feedingstuffs. J. Biol. Chem., 82:473.

With H. Steenbock and E. B. Hart. The effect of diet on the copper content of milk. J. Biol. Chem., 83:27.

With H. Steenbock and E. B. Hart. Is copper a constituent of the hemoglobin molecule? The distribution of copper in blood. J. Biol. Chem., 83:21.

With E. B. Hart. The relation of iron and copper to hemoglobin synthesis in the chick. J. Biol. Chem., 84:131.

With J. Waddell, H. Steenbock, and E. B. Hart. Iron in nutrition. IX. Further proof that the anemia produced on diets of whole milk and iron is due to a deficiency of copper. J. Biol. Chem., 83:251.

1930

Factors affecting the catalytic action of copper in the oxidation of cysteine. Biochem. J., 24:415.

With E. B. Hart, A. R. Kemmerer, and J. G. Halpin. Does the practical chick ration need iron and copper additions to insure normal hemoglobin building? Poult. Sci., 9:92.

With E. B. Hart, H. Steenbock, G. Bohstedt, and J. M. Fargo. A study of the anemia of young pigs and its prevention. J. Nutr., 2:277.

1931

The role of iron and copper in the growth and metabolism of yeast. J. Biol. Chem., 90:111.

The so-called autoxidation of cysteine. Science, 74:567.
With A. R. Kemmerer and E. B. Hart. Studies on the relation of manganese to the nutrition of the mouse. J. Biol. Chem., 92:623.

1932

The relative value of inorganic and organic iron in hemoglobin formation. J. Am. Med. Assoc., 98:1047–50.
With V. F. Neu. Studies in vitamin A avitaminosis in the chick. J. Biol. Chem., 97:71.
With F. J. Stare. The phosphorus partition in the blood of rachitic and non-rachitic calves. J. Biol. Chem., 97:511.
With W. C. Sherman. The action of copper in iron metabolism. J. Biol. Chem., 98:309.
With O. L. Kline, J. A. Keenan, and E. B. Hart. The use of the chick in vitamin B_1 and B_2 studies. J. Biol. Chem., 99:295.

1933

With F. J. Stare. Cobalt in animal nutrition. J. Biol. Chem., 99:473.
With F. J. Stare. Studies on the respiration of animal tissues. Am. J. Physiol., 105:655.
With M. O. Schultze. The relation of iron and copper to the reticulocyte response in anemic rats. J. Biol. Chem., 102:357.
With J. A. Keenan, O. L. Kline, E. B. Hart, and J. G. Halpin. New nutritional factors required by the chick. J. Biol. Chem., 103:671.

1934

With W. R. Todd and E. B. Hart. Zinc in the nutrition of the rat. Am. J. Physiol., 107:146.
With E. B. Hart and W. C. Sherman. The limitations of cereal-milk diets for hemoglobin formation. J. Pediatr., 4:65.
With O. L. Kline, J. A. Keenan, and E. B. Hart. Studies on the growth factor in liver. J. Biol. Chem., 107:107.
With Eugene Cohen. The relation of iron and copper to the cytochrome and oxidase content of animal tissues. J. Biol. Chem., 107:97.
With M. O. Schultze. The mechanism of the blood changes during the treatment of secondary and pernicious anemia. J. Lab. Clin. Med., 20:13.

1935

With C. J. Koehn, Jr. Non-identity of vitamin B_2 and flavines. Nature, 134:1007.

With F. E. Stirn and E. B. Hart. The indispensability of zinc in the nutrition of the rat. J. Biol. Chem., 109:347.

With A. Siemers and D. R. Mendenhall. Effect of iron and copper therapy on hemoglobin content of the blood in infants. Am. J. Dis. Child., 50:28.

With L. E. Clifhorn and V. W. Meloche. The absorption of carbon monoxide with reduced hematin and pyridine hemochromogen. J. Biol. Chem., 111:399.

1936

With C. J. Koehn, Jr. Studies on vitamin G(B_2) and its relation to canine black tongue. J. Nutr., 2:67.

With V. R. Potter. The effect of selenium on cellular metabolism. The rate of oxygen uptake by living yeast in the presence of sodium selenite. Biochem. J., 30:189.

With W. C. Sherman. In vitro studies on lactic acid metabolism in tissues from polyneuritic chicks. Biochem. J., 30:785.

With V. R. Potter. A modified method for the study of tissue oxidations. J. Biol. Chem., 114:495.

With W. C. Sherman. In vitro action of crystalline vitamin B_1 on pyruvic acid metabolism in tissues from polyneuritic chicks. Am. J. Physiol., 117:142.

With M. O. Schultze and E. B. Hart. Studies on the copper content of the blood in nutritional anemia. J. Biol. Chem., 116:107.

With A. Arnold, O. L. Kline, and E. B. Hart. Further studies on the growth factor required by chicks. The essential nature of arginine. J. Biol. Chem., 116:699.

1937

With V. R. Potter. The effect of inhibitors on succinoxidase. J. Biol. Chem., 117:341.

With C. J. Koehn, Jr. Further studies on the concentration of the antipellagra factor. J. Biol. Chem., 118:693.

With E. B. Hart and G. O. Kohler. Does liver supply factors in addition to iron and copper for hemoglobin regeneration in nutritional anemia? J. Exp. Med., 66:145.

With R. J. Madden, F. M. Strong, and D. W. Woolley. Relation of nicotinic acid and nicotinic acid amide to canine black tongue. J. Am. Chem. Soc., 59:1767.

1938

With R. J. Madden, F. M. Strong, and D. W. Woolley. The isolation and identification of the anti-black tongue factor. J. Biol. Chem., 123:137.

With M. A. Lipschitz and V. R. Potter. The relation of vitamin B_1 to cocarboxylase. Biochem. J., 32:474.

With P. L. Pavcek and W. H. Peterson. Factors affecting the vitamin B_1 content of yeast. Ind. Eng. Chem., 30:802.

With D. W. Woolley, F. M. Strong, and R. J. Madden. Anti-black tongue activity of various pyridine derivatives. J. Biol. Chem., 124:715.

With F. M. Strong and R. J. Madden. The ineffectiveness of β-aminopyridine in black tongue. J. Am. Chem. Soc., 60:2564.

With D. W. Woolley, H. A. Waisman, and O. Mickelsen. Some observations on the chick antidermatitis factor. J. Biol. Chem., 125:715.

With V. R. Potter and E. B. Hart. Anemia studies with dogs. J. Biol. Chem., 126:155.

1939

With J. J. Oleson, H. R. Bird, and E. B. Hart. Additional nutritional factors required by the rat. J. Biol. Chem., 127:23

The vitamin B complex in practical nutrition. J. Am. Diet. Assoc., 15:6.

With A. E. Axelrod. Effect of nicotinic acid deficiency on the cozymase content of tissues. Nature, 143:281.

With D. W. Woolley and H. A. Waisman. Nature and partial synthesis of the chick antidermatitis factor. J. Am. Chem. Soc., 61:977.

With A. Arnold. Influence of the composition of the diet on the thiamin requirement of dogs. Am. J. Physiol., 126:289.

With D. W. Woolley and H. A. Waisman. Studies on the structure of the chick antidermatitis factor. J. Biol. Chem., 129:673.

With A. E. Axelrod and R. J. Madden. The effect of a nicotinic acid deficiency upon the coenzyme I content of animal tissues. J. Biol. Chem., 131:85.

With J. M. McKibbin, R. J. Madden, and S. Black. The importance of vitamin B_6 and factor W in the nutrition of dogs. Am. J. Physiol., 128:102.

With H. D. Anderson and J. E. Gonce, Jr. Vitamin E deficiency in dogs. Proc. Soc. Exp. Biol. Med., 42:750.

1940

With D. V. Frost, V. R. Potter, and E. B. Hart. Iron and copper versus liver in treatment of hemorrhagic anemia in dogs on milk diets. J. Nutr., 19:207.

With M. A. Lipton. Mechanism of the enzymatic phosphorylation of thiamin. Nature, 145:226.

With E. J. Schantz and E. B. Hart. The comparative nutritive value of butter fat and certain vegetable oils. J. Dairy Sci., 23:181.

With A. E. Axelrod and E. S. Gordon. The relationship of the dietary intake of nicotinic acid to the coenzyme I content of blood. Am. J. Med. Sci., 199:697.

With D. M. Hegsted, J. J. Oleson, and E. B. Hart. The essential nature of a new growth factor and vitamin B_6 for chicks. Poult. Sci., 19:167.

With H. A. Sober and M. A. Lipton. The relation of thiamine to citric acid metabolism. J. Biol. Chem., 134:605.

With E. Hove and E. B. Hart. The relation of zinc to carbonic anhydrase. J. Biol. Chem., 136:425.

With M. I. Wegner, A. N. Booth, and E. B. Hart. Rumen synthesis of the vitamin B complex. Proc. Soc. Exp. Biol. Med., 45:769.

1941

With L. W. Wachtal, E. Hove, and E. B. Hart. Blood uric acid and liver uricase of zinc-deficient rats on various diets. J. Biol. Chem., 138:361.

With D. M. Hegsted, R. C. Mills, and E. B. Hart. Choline in the nutrition of chicks. J. Biol. Chem., 138:459.

With T. W. Conger. The biological estimation of pyridoxine (vitamin B_6). J. Biol. Chem., 138:555.

With H. A. Waisman. Chemical estimation of nicotinic acid and vitamin B_6. Ind. Eng. Chem., 13:221.

With M. I. Wegner, A. N. Booth, and E. B. Hart. Rumen synthesis of the vitamin B complex on natural rations. Proc. Soc. Exp. Biol. Med., 47:90.

With S. Black and J. M. McKibbin. Use of sulfaguanidine in nutrition experiments. Proc. Soc. Exp. Biol. Med., 47:308.

With E. Nielsen. Cure of spectacle eye condition in rats with biotin concentrates. Proc. Soc. Exp. Biol. Med., 48:349.

1942

With L. M. Henderson, J. M. McIntire, and H. A. Waisman. Pantothenic acid in the nutrition of the rat. J. Nutr., 23:47.

With A. E. Axelrod and V. R. Potter. The succinoxidase system in riboflavin-deficient rats. J. Biol. Chem., 142:85.

With D. M. Hegsted, R. C. Mills, G. M. Briggs, and E. B. Hart. Biotin in chick nutrition. J. Nutr., 23:175.

With L. J. Teply and F. M. Strong. Nicotinic acid, pantothenic acid and pyridoxine in wheat and wheat products. J. Nutr., 24:167.

With S. Black, R. S. Overman, and K. P. Link. The effect of sulfaguanidine on rat growth and plasma prothrombin. J. Biol. Chem., 145:137.

With D. Orsini and H. A. Waisman. Effect of vitamin deficiencies on basal metabolism and respiratory quotient in rats. Proc. Soc. Exp. Biol. Med., 51:99.

With J. D. Teresi and E. B. Hart. Molybdenum in the nutrition of the rat. Am. J. Physiol., 137:504.

1943

With G. M. Briggs, Jr., T. D. Luckey, R. C. Mills, and E. B. Hart. Effect of p-aminobenzoic acid when added to purified chick diets deficient in unknown vitamins. Proc. Soc. Exp. Biol. Med., 52:7.

With O. K. Gant, B. Ransone, and E. McCoy. Intestinal flora of rats on purified diets containing sulfonamides. Proc. Soc. Exp. Biol. Med., 52:276.

With J. B. Field and C. Juday. A study of the blood constituents of carp and trout. J. Biol. Chem., 148:261.

With H. A. Waisman, A. F. Rasmussen, Jr., and P. F. Clark. Studies on the nutritional requirements of the rhesus monkey. J. Nutr., 26:205.

With L. W. Wachtel and E. B. Hart. Studies on the physiology of manganese in the rat. Am. J. Physiol., 140:72.

1944

With L. J. Teply. Use of germicidal quaternary ammonium salt in nutritional studies. Proc. Soc. Exp. Biol. Med., 55:59.

With H. C. Lichstein, H. A. Waisman, and P. F. Clark. Influence of pantothenic acid deficiency on resistance of mice to experimental poliomyelitis. Proc. Soc. Exp. Biol. and Med., 56:3.

With B. S. Schweigert, J. M. McIntire, and F. M. Strong. The direct determination of valine and leucine in fresh animal tissues. J. Biol. Chem., 155:183.

With J. H. Shaw, B. S. Schweigert, J. M. McIntire, and P. H. Phillips. Dental caries in the cotton rat. II. Methods of study and preliminary nutritional experiments. J. Nutr., 28:333.

With S. R. Ames. Inhibition of the succinoxidase system by cysteine and cystine. Arch. of Biochem., 5:191.

With W. A. Krehl and F. M. Strong. The biological activity of a precursor of nicotinic acid in cereal products. J. Biol. Chem., 156:13.

1945

With H. A. Waisman and K. B. McCall. Acute and chronic biotin deficiencies in the monkey (*Macaca mulatta*). J. Nutr., 29:1.

With L. J. Teply. The titrimetric determination of "Lactobacillus Casei factor" and "Folic acid." J. Biol. Chem., 157:303.

With W. A. Krehl and L. J. Teply. Corn as an etiological factor in the production of a nicotinic acid deficiency in the rat. Science, 101:283.

With James H. Shaw, B. S. Schweigert, and Paul H. Phillips. Dental caries in the cotton rat. II. Production and description of the carious lesions. J. Dent. Res., 23:417.

With B. S. Schweigert and I. E. Tatman. The leucine, valine, and isoleucine content of meats. Arch. Biochem., 6:177.

With W. A. Krehl, L. J. Teply, and P. S. Sarma. Growth-retarding effect of corn in nicotinic-acid-low rations and its counteraction by tryptophane. Science, 101:489.

With B. S. Schweigert, J. M. McIntire, and L. M. Henderson. Intestinal synthesis of B vitamins by the rat. Arch. Biochem., 6:403.

With B. Schweigert, J. H. Shaw, and P. H. Phillips. Dental caries in the cotton rat. III. Effect of different dietary carbohydrates on the incidence and extent of dental caries. J. Nutr., 29:405.

With J. H. Shaw, B. S. Schweigert, and P. H. Phillips. Dental caries in the cotton rat. IV. Inhibitory effect of fluorine additions to the ration. Proc. Soc. Exp. Biol. Med., 59:89.

With H. C. Lichstein, H. A. Waisman, K. B. McCall, and P. F. Clark. Influence of pyridoxine, inositol, and biotin on susceptibility of Swiss mice to experimental poliomyelitis. Proc. Soc. Exp. Biol. Med., 60:279.

1946

With W. A. Krehl, P. S. Sarma, and L. J. Teply. Factors affecting the dietary niacin and tryptophane requirement of the growing rat. J. Nutr., 31:85.

With W. H. Ruegamer and E. B. Hart. Potassium deficiency in the dog. Proc. Soc. Exp. Biol. Med., 61:234.

With A. Evenson, Elizabeth McCoy, and B. R. Geyer. The cecal flora of white rats on a purified diet and its modification by succinylsulfathiazole. J. Bacteriol., 51:513.

With A. E. Schaefer and C. K. Whitehair. Purified rations and the importance of folic acid in mink nutrition. Proc. Soc. Exp. Biol. Med., 62:169.

With B. A. McLaren and E. F. Herman. Nutrition of rainbow trout; studies with purified rations. Arch. Biochem., 10:433.

With S. R. Ames. Enzymatic oxidation of glutathione II. Studies on the addition of several cofactors. Arch. Biochem., 10:443.

With P. S. Sarma and E. E. Snell. The vitamin B_6 group. VIII. Biological assay of pyridoxal, pyridoxamine, and pyridoxine. J. Biol. Chem., 165:55.

With S. P. Ames and A. J. Ziegenhagen. Studies on the inhibition of enzyme systems involving cytochrome c. J. Biol. Chem., 165:81.

With S. R. Ames. Determination of aspartic-glutamic transaminase in tissue homogenates. J. Biol. Chem., 166:81.

With W. A. Krehl, L. M. Henderson, and J. de la Huerga. Relation of amino acid imbalance to niacin-tryptophane deficiency in growing rats. J. Biol. Chem., 166:531.

1947

With L. J. Teply and W. A. Krehl. The intestinal synthesis of niacin and folic acid in the rat. Am. J. Physiol., 148:91.

With S. R. Ames and P. S. Sarma. Transaminase and pyridoxine deficiency. J. Biol. Chem., 167:135.

With T. D. Luckey, P. R. Moore, and E. B. Hart. Growth of chicks on purified and synthetic diets containing amino acids. Proc. Soc. Exp. Biol. Med., 64:423.

With B. A. McLaren and E. F. Herman. Nutrition of trout: Studies with practical diets. Proc. Soc. Exp. Biol. Med., 65:97.

With A. E. Schaefer and C. K. Whitehair. The importance of riboflavin, pantothenic acid, niacin and pyridoxine in the nutrition of foxes. J. Nutr., 34:131.

With H. A. Lardy and R. L. Potter. The role of biotin in bicarbonate utilization by bacteria. J. Biol. Chem., 169:451.

With G. W. Newell, T. C. Erickson, W. E. Gilson, and S. N. Gershoff. Role of "agenized" flour in the production of running fits. J. Am. Med. Assoc., 135:760.

1948

With A. E. Schaefer, S. B. Tove, and C. K. Whitehair. The requirement of unidentified factors for mink. J. Nutr., 35:157.

With V. H. Barki, H. Nath, and E. B. Hart. Production of essential fatty acid deficiency symptoms in the mature rat. Proc. Soc. Exp. Biol. Med., 66:474.

With E. J. Wakeman, J. K. Smith, W. B. Sarles, and P. H. Phillips. A method for quantitative determinations of microorganisms in carious and noncarious teeth of the cotton rat. J. Dent. Res., 27:41.

With E. M. Sporn and W. R. Ruegamer. Studies with monkeys fed army combat rations. J. Nutr., 35:559.

With O. E. Olson, E. E. C. Fager, and R. H. Burris. The use of a hog kidney conjugase in the assay of plant materials for folic acid. Arch. Biochem., 18:261.

With L. V. Hankes, L. M. Henderson, and W. L. Brickson. Effect of amino acids on the growth of rats on niacin-tryptophan-deficient rations. J. Biol. Chem., 174:873.

1949

With A. Sreenivasan and A. E. Harper. The use of conjugase preparations in the microbiological assay of folic acid. J. Biol. Chem., 177:117.

With C. A. Nichol, L. S. Dietrich, and W. W. Cravens. Activity of vitamin B_{12} in the growth of chicks. Proc. Soc. Exp. Biol. Med., 70:40.

With K. H. Maddy. Studies on growth of mice fed rations containing free amino acids. J. Biol. Chem., 177:577.

With C. A. Nichol and A. E. Harper. Effect of folic acid, liver extract, and vitamin B_{12} on hemoglobin regeneration in chicks. Proc. Soc. Exp. Biol. Med., 71:34.

With G. B. Ramasarma and L. M. Henderson. Purified amino acids as a source of nitrogen for the growing rat. J. Nutr., 38:177.

With V. H. Barki, R. A. Collins, and E. B. Hart. Relation of fat deficiency symptoms to the polyunsaturated fatty acid content of the tissues of the mature rat. Proc. Soc. Exp. Biol. Med., 71:694.

With V. H. Barki, P. Feigelson, R. A. Collins, and E. B. Hart. Factors influencing galactose utilization. J. Biol. Chem., 181:565.

1950

With H. T. Thompson, P. E. Schurr, and L. M. Henderson. The influence of fasting and nitrogen deprivation on the concentration of free amino acids in rat tissues. J. Biol. Chem., 182:47.

With P. Roine. Significance of the intestinal flora in nutrition of the guinea pig. Proc. Soc. Exp. Biol. Med., 73:308.

With J. N. Williams, Jr., and P. Feigelson. A study of xanthine metabolism in the rat. J. Biol. Chem., 185:887.

With A. E. Denton and J. N. Williams, Jr. The influence of methionine deficiency on amino acid metabolism in the rat. J. Biol. Chem., 186:377.

With L. S. Dietrich and W. J. Monson. Effect of sulfasuxidine on the interrelation of folic acid, vitamin B_{12} and vitamin C. Proc. Soc. Exp. Biol. Med., 75:130.

With L. V. Hankes and R. L. Lyman. Effect of niacin precursors on growth of rats fed tryptophan-low rations. J. Biol. Chem., 187:547.

1951

With J. N. Williams, Jr., P. Feigelson, and S. S. Shahinian. Interrelationships of vitamin B_6, niacin, and tryptophan in pyridine nucleotide formation. Proc. Soc. Exp. Biol. Med., 76:441.

With P. Feigelson and J. N. Williams, Jr. Inhibition of diphosphopyridine nucleotide-requiring enzymes by *nicotinamide*. J. Biol. Chem., 189:361.

With R. J. Sirny and L. T. Cheng. An arginine-proline interdependence in *Leuconostoc mesenteroides* P-60. J. Biol. Chem., 190:547.

With J. N. Williams, Jr., and G. Litwack. Studies on rat liver choline oxidase: an assay method. J. Biol. Chem., 192:73.

With S. N. Gershoff. Studies of the biological effects of methionine sulfoximine. J. Biol. Chem., 192:569.

With R. L. Lyman. Further studies on amino acid imbalance produced by gelatin in rats on niacin–tryptophan-low ration. J. Nutr., 45:101.

1952

With A. R. Taborda, L. C. Taborda, and J. N. Williams, Jr. A study of the ribonuclease activity of snake venoms. J. Biol. Chem., 194:227.

With D. V. Tappan, U. J. Lewis, and U. D. Register. Niacin deficiency in the rhesus monkey. J. Nutr., 46:75.

With M. Constant and P. H. Phillips. Dental caries in the cotton rat. XIII. The effect of whole grain and processed cereals on dental caries production. J. Nutr., 46:271.

With J. P. Kring, K. Ebisuzaki, and J. N. Williams, Jr. The influence of vitamin B_6 on the formation of liver pyridine nucleotides. J. Biol. Chem., 195:591.

With S. S. Shahinian, K. Ebisuzaki, J. P. Kring, and J. N. Williams, Jr. The action of threonine in inducing an amino acid imbalance. Proc. Soc. Exp. Biol. Med., 80:146.

With L. S. Dietrich and W. J. Monson. Utilization of pteroylglutamic acid conjugates in the in vitro synthesis of *L. citrovorum* activity. J. Am. Chem. Soc., 74:3705.

With W. L. Davies, W. L. Pond, S. C. Smith, A. F. Rasmussen, Jr., and P. F. Clark. The effect of certain amino acid deficiencies on Lansing poliomyelitis in mice. J. Bacteriol., 64:571.

1953

With H. Nino-Herrera, M. Schreiber, and R. A. Collins. Dermatosis in weanling rats fed lactose diets. II. Histological studies. J. Nutr., 49:99.

With A. E. Denton. Enzymatic liberation of amino acids from different proteins. J. Nutr., 49:221.

With G. Litwack and J. N. Williams, Jr. The roles of essential and nonessential amino acids in maintaining liver xanthine oxidase. J. Biol. Chem., 201:261.

With S. C. Smith, A. F. Rasmussen, Jr., and P. F. Clark. Influence of hyper- and hypothyroidism on susceptibility of mice to infection with Lansing poliomyelitis virus. Proc. Soc. Exp. Biol. Med., 82:269.

With J. N. Williams, Jr., A. Sreenivasan, and S. C. Sung. Relationship of the deposition of folic and folinic acids to choline oxidase of isolated mitochondria. J. Biol. Chem., 202:233.

With J. N. Williams, Jr., W. J. Monson, A. Sreenivasan, L. S. Dietrich, and A. E. Harper. Effects of a vitamin B_{12} deficiency on liver enzymes in the rat. J. Biol. Chem., 202:151.

With A. E. Harper, W. J. Monson, and D. A. Benton. The influence of protein and certain amino acids, particularly threonine, on the deposition of fat in the liver of the rat. J. Nutr., 50:383.

1954

With A. E. Denton. Amino acid concentration in the portal vein after ingestion of amino acid. J. Biol. Chem., 206:455.

With W. L. Loeschke. Prevention of urinary calculi formation in mink by alteration of urinary pH. Proc. Soc. Exp. Biol. Med., 85:42.

With W. J. Monson, A. E. Harper, and M. E. Winje. A mechanism of the vitamin-sparing effect of antibiotics. J. Nutr., 52:627.

With A. E. Harper, D. A. Benton, and M. E. Winje. Leucine-isoleucine antagonism in the rat. Arch. Biochem. Biophys., 51:523.

With M. E. Winje, A. E. Harper, D. A. Benton, and R. E. Boldt. Effect of dietary amino acid balance on fat deposition in the livers of rats fed low protein diets. J. Nutr., 54:155.

1955

With L.-E. Ericson and J. N. Williams, Jr. Studies on partially purified betaine-homocysteine transmethylase of liver. J. Biol. Chem., 212:537.

With D. A. Benton and A. E. Harper. Effect of isoleucine supplementation on the growth of rats fed zein or corn diets. Arch. Biochem. Biophys., 57:13.

With Selma Hayman, S. S. Shahinian, and J. N. Williams, Jr. Effect of 3-acetylpyridine on pyridine nucleotide formation from tryptophan and niacin. J. Biol. Chem., 217:225.

With P. D. Deshpande, A. E. Harper, and Felipe Quiros-Perez. Further observations on the improvement of polished rice with protein and amino acid supplements. J. Nutr., 57:415.

With H. R. Heinicke and A. E. Harper. Protein and amino acid requirements of the guinea pig. I. Effect of carbohydrate, protein level and amino acid supplementation. J. Nutr., 57:483.

1956

With D. A. Benton, A. E. Harper, and H. E. Spivey. Leucine, isoleucine, and valine relationships in the rat. Arch. Biochem. Biophys., 60:147.

With D. A. Benton and A. E. Harper. The effect of different dietary fats on liver fat deposition. J. Biol. Chem., 218:693.

With L. E. Ericson, A. E. Harper, and J. N. Williams, Jr. Effect of diet on the betaine-homocysteine transmethylase activity of rat liver. J. Biol. Chem., 219:59.

With A. E. Harper, L. E. Ericson, and R. E. Boldt. Effect of thyroid-active substances on the betaine-homocysteine transmethylase activity of rat liver. Am. J. Physiol., 184:457.

With R. F. Wiseman, W. B. Sarles, D. A. Benton, and A. E. Harper. Effects of dietary antibiotics upon numbers and kinds of intestinal bacteria used in chicks. J. Bacteriol., 72:723.

1957

With P. D. Deshpande, A. E. Harper, and Macie Collins. Biological availability of isoleucine. Arch. Biochem. Biophys., 67:341.

With P. D. Deshpande and A. E. Harper. Nutritional improvement of white flour with protein and amino acid supplements. J. Nutr., 62:503.

With J. D. Gupta. Biological availability of tryptophan. J. Nutr., 62:313.

With F. N. Hepburn and E. W. Lewis, Jr. The amino acid content of wheat, flour, and bread. Cereal Chem., 34:312.

1958

With M. M. Chaloupka, J. N. Williams, Jr., and May S. Reynolds. Relative roles of niacin and tryptophan in maintaining blood pyridine nucleotides, nitrogen balance and growth in adult rats. J. Nutr., 63:361.

With P. D. Deshpande and A. E. Harper. Amino acid imbalance and nitrogen retention. J. Biol. Chem., 230:335.

With J. D. Gupta, A. M. Dakroury, and A. E. Harper. Biological availability of lysine. J. Nutr., 64:259.

With Narindar Nath and A. E. Harper. Dietary protein and serum cholesterol. Arch. Biochem. Biophys., 77:234.

With A. Yoshida and A. E. Harper. Effect of dietary level of fat and type of carbohydrate on growth and food intake. J. Nutr., 66:217.

1959

With Narindar Nath, Ruta Wiener, and A. E. Harper. Diet and cholesteremia. I. Development of a diet for the study of nutritional factors affecting cholesteremia in the rat. J. Nutr., 67:289.

With A. J. Bosch and A. E. Harper. Factors affecting liver pyridine nucleotide concentration in hyperthyroid rats. Soc. Exp. Biol. Med., 100:774.

With W. L. Loeschke. The importance of arginine and methionine for the growth and fur development of mink fed purified diets. J. Nutr., 69:147.

With W. L. Loeschke. Riboflavin in the nutrition of the chinchilla. J. Nutr., 69:214.