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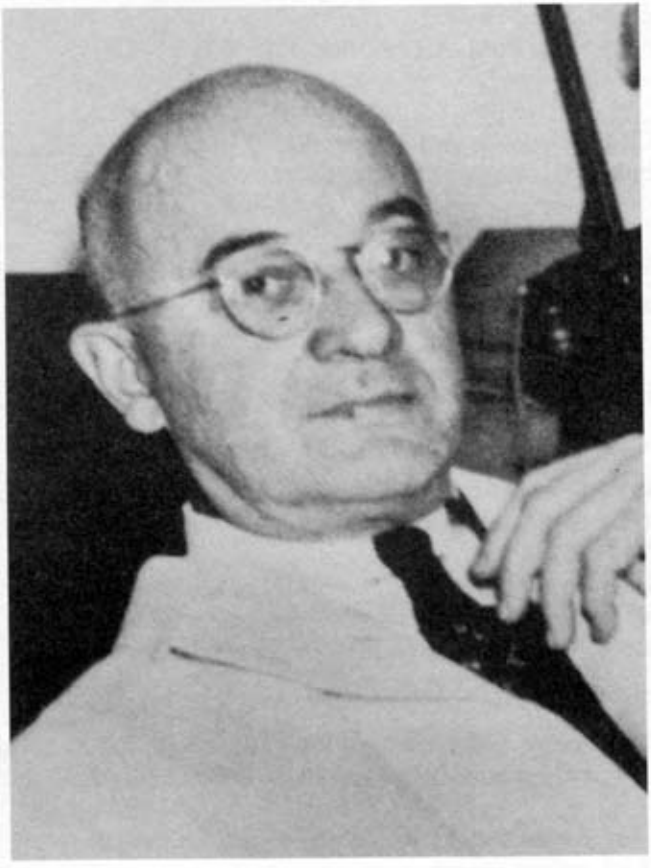
WILLIAM CHRISTOPHER STADIE

1886—1959

A Biographical Memoir by

ISAAC STARR

Biographical Memoir



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Wm C Stadtfeld

WILLIAM CHRISTOPHER STADIE

June 15, 1886–September 12, 1959

BY ISAAC STARR

FEW INVESTIGATORS have been so consistently productive as William Stadie. His life work can be most easily presented by dividing it into three parts. In the first, his attention was focused on the cyanosis so conspicuous in patients with influenza; he was the father of oxygen therapy. In the second—responding to the needs of World War II—he was chiefly concerned with oxygen toxicity. In the third, Stadie made major contributions to our knowledge of the abnormalities of carbohydrate metabolism and diabetes.

For many years, Bill Stadie and I had adjacent laboratories on the eighth floor of the Maloney Building of the University Hospital and we usually lunched together. He was one of my oldest medical friends.

Bill had an unusually difficult time completing his medical education. Believed to have pulmonary tuberculosis as an adolescent, he was taken out of school and sent to work on a farm for a year. When this episode was evaluated later by experts in the diagnosis of tuberculosis, using both his old and more recent chest X-rays, all agreed that Stadie had never, in all probability, had TB at all. But the episode cost him a year of his working life. In addition, he had to earn money by teaching school for several years before he was able to finish college at New York University, from which he took his degree in 1907.

Stadie liked to boast, with a twinkle in his eye, that he had put himself through medical school at the College of Physicians and Surgeons (which granted him the M.D. degree in 1916) by writing a textbook of pathology. If listeners expressed suprise at so major an accomplishment by so young a man, they soon learned that Bill had helped finance his education while a medical school undergraduate by typing the manuscript of McCallum's well-known pathology text.

After a stint in the Army Medical Corps during World War I, Stadie's successful internship at the Presbyterian Hospital won him a research job at the Hospital of the Rockefeller Institute, where a group was being organized to study the newer treatments of syphillis. But before this study could get off the ground, the great influenza epidemic paralyzed the country.

In many influenza cases, cyanosis of bronchial pneumonia was a conspicuous symptom. After learning the new techniques of blood-gas analysis from Van Slyke (who had just originated them), he worked to perfect techniques of arterial puncture—experimenting first with animals, then on himself and other volunteers, and finally on his patients—proving to the satisfaction of everyone that arterial puncture, long thought by clinicians to be a dangerous procedure, was harmless in skilled hands. Many give Stadie the credit for the first arterial puncture on a patient, but I often heard him deny, with characteristic modesty, that he had been first, insisting rather that Hurter, a German researcher, had preceded him.

Having introduced the arterial puncture in clinical medicine, Stadie was able to make pioneering studies of lung function in his patients by comparing the oxygen content of the air inhaled with that of arterial blood. This technique allowed him to demonstrate that the cyanosis was due to arterial anoxemia of a dangerous severity. Studies on the effectiveness of various methods of treating cyanosis followed,

and Stadie soon found that anoxemia could be overcome by breathing air enriched with oxygen. He then supervised the construction of a small, gas-tight room in the Rockefeller Hospital with controls for oxygen, carbon dioxide, moisture, and air temperature that permitted bed patients to breathe the desired concentrations over long periods without the discomfort of masks and nose-pieces. The principles of Stadie's chamber formed the basis for the oxygen chambers and tents that have since become routine hospital equipment.

After four productive years with the Rockefeller Hospital, Bill Stadie moved to Yale, where Francis Blake was putting new life into the Department of Medicine. He served on Yale's medical faculty from 1921 to 1924, then came to the University of Pennsylvania. He was appointed John Herr Musser Professor of Research Medicine in 1941. In 1944 he served with the Office of Scientific Research and Development of the United States Public Health Service. Though he had retired from teaching in 1956, Stadie continued as the Musser Professor Emeritus and was actively engaged in research at the time of his death, at the age of seventy-three, in 1959.

After his groundbreaking discoveries in oxygen therapy and his introduction of the arterial puncture into clinical medicine, Stadie moved on to investigate oxygen toxicity—a concern of the military during World War II. He extended his researches to the combination of oxygen and carbon monoxide with hemoglobin and assisted in clarifying the roles of the carbamino compounds and of carbonic anhydrase in accelerating the shifts of carbon dioxide to and from the blood. Stadie contributed refinements of methods for blood-gas analyses, determinations of hemoglobin, methomoglobin, fixed-base cations in blood, and an electron-tube potentiometer for blood pH measurements.

During his researches he discovered a discrepancy in the data then available on the supposedly well-understood pro-

cess of oxygen and CO_2 exchange in blood. According to his findings, much more CO_2 emerged from the blood during its passage through the lungs than the views of physical chemistry of blood then current could account for. To interpret this unexpected finding, new techniques were needed: those of enzyme chemistry to measure enzyme activity and those of radioactivity to locate the enzymes in tissues and identify the sources of their metabolic byproducts. Stadie not only mastered these new techniques, he added considerably to our knowledge of abnormalities in carbohydrate metabolism—work for which he was particularly suited by his unusual facility with mathematics.

He was the first to label insulin with radioactive tracers and to demonstrate that a high-affinity binding of the hormone to its target tissue was required for its biological effects. More than two decades later, quantitative studies of insulin-binding have fully confirmed Stadie's observation.

He further demonstrated that the hyperketonemia of animals with acute experimental diabetes results primarily from hepatic overproduction of ketone bodies rather than from a defect in their utilization. Stadie adduced an important part of the evidence on which presently accepted views regarding diabetes are based: that the liver splits fats almost quantitatively into acetoacetic and hydroxybutyric acid, which are circulated to the other tissues for combustion; that the muscles of a diabetic can burn acetoacetic acid at a normal rate; and that excretion of acetoacetic and hydroxybutyric acids occurs in diabetes—when carbohydrate is not available for combustion—because these acids are formed faster than the tissues can burn them.

Any tribute to Bill Stadie as a scientist would be incomplete without a tribute to him as a man. His talents were not limited to research. He ran a happy and successful laboratory—as his many associates, graduate students, and techni-

cians are glad to attest. Those of us made welcome in his home often paused to admire the beautiful mahogany furniture and were surprised to learn that he had made the pieces himself. He played both the cello and the clarinet—if not well, well enough to enjoy it—and great music always delighted him. Outside his house was his carefully tended garden, bordered by a row of beehives.

The quality of the man and his work have been recognized everywhere. He was an editor of the *Journal of Biological Chemistry* for many years and was editor-in-chief of the American Diabetes Association journal, *Diabetes*, for the last three years of his life.

Elected to the National Academy of Sciences in 1945, Stadie received the Alverenga Award of the Philadelphia College of Physicians in 1957, the Phillips Medal of the American College of Physicians in 1941, the Kober Medal of the Association of American Physicians in 1955, and the Banting Medal of the American Diabetes Association in 1956. He acted as a consultant to the National Institutes of Health's Division of Metabolic Diseases. He was a member of the American Philosophical Society, the American Society for Clinical Investigation, the American Society of Biological Chemists, and the Association of American Physicians and received the honorary degree of doctor of science from the University of Pennsylvania in 1959.

He married Amanda Brugger, who was working in the library at Yale while he was on the faculty there. Their daughter was a constant source of delight to them both. The death of his first wife from a brain tumor was so devastating to him that his friends feared he might not recover, but he eventually did, and his second marriage to Catherine Tyler was also a happy one.

Throughout his active years and even after his retirement he never showed signs of the mental rigidity that so often

comes with age. During his later years—despite considerable ill health—his mind remained as fertile for new ideas as in his younger days. He also took an interest in his fellow man and—poor himself in his youth—was greatly concerned with social problems of the poor.

Suffering from mild angina pectoris occasionally for several years, he died of a heart attack. His refined experiments, which so much advanced his fields of interest, will live long after him.

SELECTED BIBLIOGRAPHY

1919

The oxygen of the arterial and venous blood in pneumonia and its relation to cyanosis. J. Exp. Med., 30:215.

1920

With D. D. Van Slyke. Studies of acidosis. XV. Carbon dioxide content and capacity in arterial and venous blood plasma. J. Biol. Chem., 41:191.

A method for the determination of methemoglobin in blood. J. Biol. Chem., 41:237.

With D. D. Van Slyke. The effect of acute yellow atrophy on metabolism and on the composition of the liver. Arch. Int. Med., 25:693.

1921

Studies on blood changes in pneumococcus infections. An experimental study of the formation and fate of methemoglobin in the blood. J. Exp. Med., 33:627.

With D. D. Van Slyke. The determination of the gases of the blood. J. Biol. Chem., 49:1.

A mechanical shaker and other devices for use with the Van Slyke blood gas apparatus. J. Biol. Chem., 49:43.

1922

Construction of an oxygen chamber for the treatment of pneumonia. J. Exp. Med., 35:323.

The treatment of anoxemia in pneumonia in an oxygen chamber. J. Exp. Med., 35:337.

1924

With K. A. Martin. Thermodynamic relations of oxygen- and base-combining properties of blood. J. Biol. Chem., 60:191.

1925

With K. A. Martin. Elimination of carbon monoxide from blood, theoretical and experimental study. J. Clin. Invest., 2:77.

With E. C. Ross. A micro-method for the determination of base in

blood and serum and other biological materials. J. Biol. Chem., 65:735.

With J. H. Austin and H. W. Robinson. The relation between colorimetric reading and true pH of serum or plasma. J. Biol. Chem., 66:505.

With J. M. Austin and H. W. Robinson. The effect of temperature on the acid-base-protein equilibrium and its influence on the CO_2 absorption curve of whole blood, true and separated serum. J. Biol. Chem., 66:901.

1926

With J. H. Austin and H. W. Robinson. The influence of change in temperature on the location of the CO_2 absorption curve of blood and serum. Am. J. Med. Sci., 171:310.

With E. C. Ross. Studies on the oxygen-, acid-, and base-combining properties of blood. II. A rapid method for the preparation of crystalline isoelectric hemoglobin by the electrodialysis of red blood cells. J. Biol. Chem., 68:229, and Am. J. Med. Sci., 171:620.

1927

With E. C. Ross. The first dissociation constant of carbonic acid in red blood cells. Am. J. Med. Sci., 173:154.

With E. R. Hawes. The extension of the Debye-Hückel theory to hemoglobin solutions. Am. J. Med. Sci., 173:896.

1928

With E. R. Hawes. Studies on the oxygen-, acid-, and base-combining properties of blood. III. The validity of hydrogen ion activity determinations by the hydrogen electrode in systems containing carbonic acid, carbonates, hemoglobin, carbon monoxide hemoglobin, and methemoglobin. J. Biol. Chem., 77:241, 1928.

With E. R. Hawes. Studies on the oxygen-, acid-, and base-combining properties of blood. IV. The apparent first dissociation constant, pK_1', of carbonic acid and the activity coefficient of the bicarbonate ion in solutions of hemoglobin, methemoglobin, cyanhemoglobin, and nitric oxide hemoglobin at varying ionic strengths. J. Biol. Chem., 77:265.

Studies on the oxygen-, acid-, and base-combining properties of blood. V. Extension of the Debye-Hückel theory of ionic interaction to hemoglobin, bicarbonate-sodium chloride systems. J. Biol. Chem., 77:303.

With F. W. Sunderman. A new method for the determination of the freezing point of solutions. Am. J. Med. Sci., 175:152.

With E. R. Hawes. The activity coefficients of the carbonate and bicarbonate ions. Am. J. Med. Sci., 175:578.

With E. R. Hawes. The role of the liquid junction potential in the electrometric determination of single ion activity coefficients. J. Biol. Chem., 78:29.

1929

An electron tube potentiometer for the determination of pH with the glass electrode. J. Biol. Chem., 83:477.

With E. R. Hawes. The glass electrode. Am. J. Med. Sci., 177:306.

With F. W. Sunderman. The osmotic activity coefficients of ions in hemoglobin solutions. Am. J. Phys., 90:526.

1930

With H. O'Brien. Comparison of the hydrogen and the glass electrode in the determination of the pH of serum. Am. J. Med. Sci., 180:142.

1931

With H. O'Brien. Über die Zustandsformen des Kohlendioxyds im Blut. Z. Biochem., 237:290.

With H. O'Brien and E. P. Laug. Determination of the pH of serum at 38° with the glass electrode and an improved electron tube potentiometer. J. Biol. Chem., 91:243.

With F. W. Sunderman. A method for the determination of the freezing point depression of aqueous solutions particularly those containing protein. J. Biol. Chem., 91:217.

With F. W. Sunderman. The osmotic coefficient of sodium in sodium hemoglobinate and of sodium chloride in hemoglobin solution. J. Biol. Chem., 91:227.

With H. O'Brien. Does any CO_2 in the blood exist as carbohemoglobin? J. Biol. Chem., 92:27, and Am. J. Med. Sci., 181:742.

1932

With F. W. Sunderman, H. O'Brien, and P. Williams. Further studies on the occurrence of carbohemoglobin in the blood. J. Biol. Chem., 97:97.

1933

With H. O'Brien. The kinetics of carbon dioxide reactions in buffer systems and blood. J. Biol. Chem., 100:88.

With H. O'Brien. The catalysis of the hydration of carbon dioxide and dehydration of carbonic acid by an enzyme isolated from red blood cells. J. Biol. Chem., 103:521.

With H. O'Brien. The kinetics of CO_2 reactions in buffer systems. Am. J. Med. Sci., 185:599.

With S. L. Wright, Jr. An inexpensive pyrometer for temperatures up to 1000°C. Science, 77:172.

1934

Blood gases. Introduction. Cyclopedia Med., 6:577.

1935

The role of the carbamino compounds in the transport of CO_2 by the blood. Science, 81:207.

1936

With H. O'Brien. The carbamate equilibrium. I. The equilibrium of amino acids, carbon dioxide, and carbamates in aqueous solutions, with a note on the Ferguson-Roughton carbamate method. J. Biol. Chem., 112:723.

1937

With H. O'Brien. Carbamate equilibrium. II. The equilibrium of oxyhemoglobin and reduced hemoglobin. J. Biol. Chem., 117:439.

1938

With N. R. Joseph. The simultaneous determination of total base and chloride on the same sample of serum by electrodialysis. J. Biol. Chem., 127:795.

1939

With M. Jones. The choline esterase content of the muscle of myasthenia gravis and of the serum of four other groups of clinical conditions. Q. J. Exp. Physiol., 29:63.

With F. D. W. Lukens and J. A. Zapp, Jr. The action of insulin upon urea formation and carbohydrate synthesis by liver slices of normal and diabetic animals. J. Biol. Chem., 98:128.

With F. D. W. Lukens and J. A. Zapp, Jr. Ketone formation and utilization in normal and diabetic animals. Am. J. Med. Sci., 198:145.

Blood gases (VIII). Cyclopedia Med., 2:608.

With F. D. W. Lukens and J. A. Zapp, Jr. The action of insulin upon protein and carbohydrate metabolism of surviving liver slices of normal and diabetic animals. Am. J. Med. Sci., 197:139.

1940

With W. C. Lukens, F. D. W. Francis, and J. A. Zapp, Jr. The effect of insulin upon urea formation, carbohydrate synthesis, and respiration of liver of normal and diabetic animals. J. Biol. Chem., 132:393.

With J. A. Zapp, Jr., and F. D. W. Lukens. The effect of insulin upon oxidations of isolated minced muscle tissue. J. Biol. Chem., 132:411.

With J. A. Zapp, Jr., and F. D. W. Lukens. The effect of insulin upon the ketone metabolism of normal and diabetic cats. J. Biol. Chem., 132:423.

Fat metabolism in diabetes mellitus. J. Clin. Invest., 19:843.

With J. A. Zapp, Jr., and F. D. W. Lukens. Fat metabolism in diabetes mellitus. Science, 92:458.

With J. A. Zapp, Jr., and F. D. W. Lukens. Experimental studies on ketone metabolism in the diabetic animal. Trans. Assoc. Am. Physicians, 55:247.

The chemical action of insulin upon the intermediary metabolism of isolated surviving tissue of normal and pathological animals. Yearb. Am. Philos. Soc., 254.

1941

With J. A. Zapp, Jr., and F. D. W. Lukens. Intermediary metabolism in diabetes mellitus. The nonformation of acetic acid and the

ratio of ketone body increase to fatty acid decrease in livers of diabetic animals. J. Biol. Chem., 137:75.

With J. A. Zapp, Jr., and F. D. W. Lukens. Intermediary metabolism in diabetes mellitus. On the synthesis of carbohydrate from fat in the liver and from acetoacetate in the kidney. J. Biol. Chem., 137:63.

1941

Fat metabolism in diabetes mellitus. Ann. Int. Med., 15:783.

Book review of *The Glass Electrode*, by Malcolm Dole. Science, 94:393.

1942

Intermediary metabolism in diabetes mellitus. Harvey Lect. 37:129.

1943

With J. A. Zapp, Jr. The aerobic carbohydrate and lactic acid metabolism of muscle preparations in vitro. J. Biol. Chem., 148:669.

With J. A. Zapp, Jr. The equilibrium relations of d-amino acid oxidase, flavin adenine dinucleotide and amino acids from kinetic data. J. Biol. Chem., 150:165.

With B. C. Riggs. A photoelectric method for the determination of peptic activity in gastric juice. J. Biol. Chem., 150:463.

Intermediary metabolism in diabetes mellitus. Bull. N.Y. Acad. Med., 778.

1944

With B. C. Riggs and N. Haugaard. Oxygen poisoning. Am. J. Med. Sci., 207:84.

The relation of insulin to phosphate metabolism. Yale J. Biol. Med., 16:539.

With B. C. Riggs. An apparatus for the determination of the gaseous metabolism of surviving tissues in vitro at high pressures of oxygen. J. Biol. Chem., 154:669.

With B. C. Riggs. Microtome for the preparation of tissue slices for metabolic studies of surviving tissues in vitro. J. Biol. Chem., 154:687.

Memoir of William Osler Abbott. Trans. Coll. Physicians Philadelphia, 12.

1945

The intermediary metabolism of fatty acids. Physiol. Rev., 25:395.

With B. C. Riggs and N. Haugaard. Oxygen poisoning. III. The effect of high oxygen pressures upon the metabolism of brain. J. Biol. Chem., 160:191–208.

With B. C. Riggs and N. Haugaard. Oxygen poisoning. IV. The effect of high oxygen pressure upon the metabolism of liver, kidney, lung, and muscle tissue. J. Biol. Chem., 160:209–16.

With N. Haugaard. Oxygen poisoning. V. The effect of high oxygen pressure upon enzymes: succinic dehydrogenase and cytochrome oxidase. J. Biol. Chem., 161:153–74.

With B. C. Riggs and N. Haugaard. Oxygen poisoning. VI. The effect of high oxygen pressure upon enzymes: pepsin, catalase, choline, esterase, and carbonic anhydrase. J. Biol. Chem., 161:175–80.

With N. Haugaard. Oxygen poisoning. VII. The effect of high oxygen pressure upon enzymes: uricase, xanthine oxidase, and d-amino acid oxidase. J. Biol. Chem., 161:181–88.

With B. C. Riggs and N. Haugaard. Oxygen poisoning. VIII. The effect of high oxygen pressure on enzymes: the system synthesizing acetyl choline. J. Biol. Chem., 161:189–96.

1946

With N. Haugaard. Oxygen poisoning. X. The effect of oxygen at eight atmospheres upon the oxygen consumption of the intact mouse. J. Biol. Chem., 164:257.

Fat metabolism. Annu. Rev. Biochem., 15:219.

1947

With M. Perlmutter. The tyrosinase inhibiting action of serum from normal and cancerous patients. Am. J. Med. Sci., 213:655.

With J. D. Zapp, Jr. The effect of insulin upon the synthesis of glycogen by rat diaphragm in vitro. J. Biol. Chem., 170:55.

With J. B. Marsh. The effect of cytochrome C upon the metabolism of rat tissues. J. Clin. Invest., 26:899.

With N. Haugaard and M. Perlmutter. The synthesis of glycogen by rat heart slices. J. Biol. Chem., 171:419.

1948

The reducing properties of serum from subjects with malignant disease. Science, 108:211.

With N. Haugaard and M. Perlmutter. The effect of insulin upon pyruvate utilization by pigeon muscle. J. Biol. Chem., 172:567.

1949

With N. Haugaard. The hexokinase reaction in tissue extracts from normal and diabetic rats. J. Biol. Chem., 177:311.

With N. Haugaard, J. B. Marsh, and A. G. Hills. The chemical combination of insulin with muscle (diaphragm) of normal rats. Am. J. Med. Sci., 218:265.

With N. Haugaard, J. B. Marsh, and A. G. Hills. Hormonal influences on the chemical combination of insulin with rat muscle (diaphragm). Am. J. Med. Sci., 218:275.

1950

The chemical combination of insulin with muscle and its hormonal regulation. Proc. Am. Philos. Soc., 94:171.

With N. Haugaard and A. G. Hills. The effect of insulin and adrenal cortical extract on the hexokinase reaction in extracts of muscle from depancreatized cats. J. Biol. Chem., 184:617.

With N. Haugaard, J. B. Marsh, and A. G. Hills. The chemical combination of insulin with muscle and its hormonal regulation. Assoc. Am. Physicians, 63:196.

1951

With N. Haugaard and J. B. Marsh. Combination of epinephrine and 2,4-dinitrophenol with muscle of the normal rat. J. Biol. Chem., 188:173.

With N. Haugaard and J. B. Marsh. Combination of insulin with muscle of the hypophysectomized rat. J. Biol. Chem., 188:167.

With N. Haugaard and J. B. Marsh. Factors influencing the combination of insulin with muscle from normal rats. J. Biol. Chem., 189:53.

With N. Haugaard and J. B. Marsh. Phosphate metabolism of the isolated rat diaphragm. J. Biol. Chem., 189:59.

The combination of insulin with tissue. Ann. N.Y. Acad. Sci., 54:531.

1952

With A. G. Hills. The effect of combined insulin upon the metabolism of the lactating mammary gland of the rat. J. Biol. Chem., 194:25.

With N. Haugaard and J. B. Marsh. The effect of growth hormone and cortisone on the action of bound insulin. J. Biol. Chem., 198:785.

With N. Haugaard and M. Vaughan. Studies of insulin binding with isotopically labeled insulin. J. Biol. Chem., 199:729.

With E. S. Haugaard. Relation between glycogen content and synthesis of fatty acids by rat liver. J. Biol. Chem., 199:741.

With N. Haugaard and M. Vaughan. The action of isotopic insulin bound to tissues. Trans. Assoc. Am. Physicians, 65:230.

James Harold Austin. Trans. Assoc. Am. Physicians, 65:7.

1953

With E. S. Haugaard. The effect of hyperglycemic-glycogenolytic factor and epinephrine on fatty acid synthesis. J. Biol. Chem., 200:753.

With N. Haugaard and M. Vaughan. The quantitative relation between insulin and its biological activity. J. Biol. Chem., 200:745.

1954

Current concepts of the action of insulin. Physiol. Rev., 34:52.

With N. Haugaard, M. Vaughan, and E. S. Haugaard. Studies of radioactive injected labeled insulin. J. Biol. Chem., 208:549.

With N. Haugaard and E. S. Haugaard. Combination of insulin with cells. J. Biol. Chem., 211:289.

1955

The problem of the action of insulin. Am. J. Med. Sci., 229:233.

Current views on the mechanisms of insulin action. Am. J. Med., 19:257.

Acceptance of the Kober Medal for 1955. Trans. Assoc. Am. Physicians, 68:29.

1956

Recent advances in insulin research. Diabetes, 5:263.

1957

Newer concepts of the action of insulin. Am. J. Clin. Nutr., 5:393.

The "permeability" hypothesis of the action of insulin. (Editorial.) Diabetes, 6:446.

With J. W. Vester. Studies of oxidative phosphorylation by hepatic mitochondria from the diabetic cat. J. Biol. Chem., 227:669.

With W. N. Shaw. Coexistence of insulin-responsive and insulin-nonresponsive glycolytic systems in rat diaphragm. J. Biol. Chem., 227:115.

1958

Aspects of carbohydrate and phosphate metabolism in diabetes. Bull. N.Y. Acad. Med., 34:5.

Current views on insulin action. Trans. Stud. Coll. Physicians Philadelphia, 25:133.

Is the metabolism of peripheral tissues affected by the arylsulfonylureas? (Editorial.) Diabetes, 7:61.

Henry Rawle Geyelin. Diabetes, 6:291.

Ketogenesis. Diabetes, 7:173.

1959

With A. I. Winegrad, W. N. Shaw, F. D. W. Lukens, and A. E. Renold. Effects of growth hormone in vitro on the metabolism of glucose in rat adipose tissue. J. Biol. Chem., 234:1922.

With W. N. Shaw. Two identical Embden-Meyerhof enzyme systems in normal rat diaphragms differing in cytological location and response to insulin. J. Biol. Chem., 234:2491.

With A. I. Winegrad, W. N. Shaw, and F. D. W. Lukens. Effects of prolactin in vitro on fatty acid synthesis in rat adipose tissue. J. Biol. Chem., 234:3111.

1960

With A. I. Winegrad, W. N. Shaw, and F. D. W. Lukens. Lipogenesis in adipose tissue. J. Clin. Nutr., 8:51.