It was of interest to determine whether the biochemical changes produced by training and fatigue were dependent only upon the degree of training and extent of work or whether other factors were of significance. Previous experiments had suggested the importance of nutritional factors. Experiments were therefore undertaken to elucidate the influence of diet on the metabolic changes produced by training. We started by studying the effects of a vitamin C-free diet. Experiments carried out at the Institute of Biochemistry showed[9] that fatiguing work raised the lactic acid content of the muscle of normal guinea pigs by an average of 28 per cent., and that of scorbutic guinea pigs on a vitamin C-free diet by 48 per cent. That is, work of similar intensity resulted in greater changes in the lactic acid metabolism in scorbutic guinea pigs than in normal. Concurrently, it was shown that muscle work in trained guinea pigs on a normal diet did not result in an accumulation of lactic acid, but in scorbutic guinea pigs which were trained, similar work always resulted in a considerable accumulation of lactic acid. In scorbutic animals, training does not result in an improvement of the synthetic processes of muscle. These observations supplemented the results of experiments in which the effects of a vitamin C-free diet on the reductive capacity of trained and fatigued muscle was studied.[6] Experiments showed that the lack of vitamin C resulted in a more rapid onset of fatigue and that training under such adverse nutritional conditions had less effect on the ultimate work capacity of such a muscle.

Similar results were obtained on pigeons fed on a thiamin-free diet. Preliminary training did not produce the favorable effects on oxidation reduction processes as resulted in the case of birds fed on a high thiamin diet.[10] Similarly, in pigeons on a thiamin-free diet muscle work resulted in a considerable accumulation of lactic acid, both in trained and untrained animals. Pigeons on the normal diet, but previously trained, when subjected to similar conditions of work did not show an accumulation of lactic acid in muscle. It is to be concluded, therefore, that deficiencies of ascorbic acid and thiamin affect the biochemical processes of muscle produced by training or by fatigue.

Diets were next investigated which were not vitamin free but which were acid or alkaline—normal in all respects except for the predominance of inorganic anions in some and in organic cations in others. On the basis of our experiments with phenol under fatiguing work and with various diets, we found[13] that work on an acid diet interrupted to a lesser degree the oxidation of phenol than synthesis of its detoxication product, but it interrupted these processes to a greater degree when on an alkaline diet. While the general applicability of these findings to all oxidation processes is not to be inferred, they none the less provide a foundation for the concept that the synthetic and oxidative-reductive processes in muscle, as altered by fatiguing work, may be further varied by the alkaline- or acid-forming nature of the diet. Similar results were obtained in studies of the metabolic processes of muscle tissue. The experiments of Guly show[23] that training does not have the same effect on the reduction capacity of rabbit muscle on both alkaline and acid diets. Training to a greater degree improved the oxidation-synthetic processes of rabbit muscle on an acid-forming diet than on an alkaline-forming diet. In the same way, fatiguing work inhibits glycolysis to a great extent, alters the permeability of cell membranes and upsets the water balance of rabbits on an alkaline diet more than in the case of those maintained on a diet of acid-forming substances.[24] All our experiments[10] thus show that the dietary ingredients in respect to quantity of vitamins and preponderance of inorganic anions or cations have a great influence on muscle metabolism, *viz.*, on changes in carbohydrate metabolism, in oxidative and synthetic processes brought about by training and fatigue in muscle and on the work capacity of muscle. These observations bring forth for further elucidation an important theoretical and practical problem—whether by varying the diet it is possible to make the muscle more receptive for training, for more rapidly increasing its work capacity or for delaying the onset of fatigue.

OBITUARY

GEORGE DAVID BIRKHOFF

MIDDAY on Sunday, November 12, 1944, George Birkhoff and his wife were preparing to go over to their son Garrett's. He was ready a quarter to half hour before time to leave and took the occasion to lie down. It was not that he felt badly, but incident to a minor illness in the preceding spring he had been advised to take it a bit easier now he was sixty and in particular to lie down a little while in the middle of the day whenever possible—as so many good doctors advise so many older patients—and being the conscientious person he was, wishing to do the right thing by his doctor, his family, his university and his science, he took that particular opportunity, as he had taken others, to follow the advice. A little later when his wife went to get him to go, he was dead.

[23] N. F. Guly, *Ukrainian Biochem. Jour.*, 9: 2, 1936.
[24] *Ibid.*, 11: 3, 1938.

Thus passed America's leading mathematician, who had been recognized here and abroad more widely than any other mathematician America has yet produced.

We had seen him around as usual during the autumn. It was only a few days since he had been in my office to correct proof on an article in the Proceedings of the National Academy of Sciences and had left with the remark that he had another which he expected would be ready in a few weeks. He could be seen at the meeting of the Faculty of Arts and Sciences the previous Tuesday sitting at the back of the room, thoughtful and smiling. He had attended a meeting of a scientific dining club on Friday and had participated interestedly in the discussions. And on Sunday a coronary thrombosis snuffed out his life. His light will long shine on.

Of especial interest to readers of SCIENCE must be Birkhoff's services to the American Association for the Advancement of Science. He was elected president in 1937—the first mathematician to be so honored since E. H. Moore, under whom he took his doctorate. I would refer to the sympathetic appreciation of the new president written by H. S. White.[1] Reference should also be made to his presidential address, "Intuition, Reason and Faith in Science" printed in SCIENCE, December 30, 1938 (Vol. 88, pp. 601–609). Birkhoff remained on the executive committee of the association from 1938 to 1942. In 1938 he was one of a committee of three, the other two being F. R. and H. G. Moulton, in attendance at the meeting of the British Association for the Advancement of Science charged with discussing with that association the possibility of establishing closer relations with the American Association than had existed in the past. He had been vice-president for the section on mathematics and astronomy in 1918, and in 1926 had received the $1,000 prize for a distinguished paper presented at the meeting of that year, his paper being entitled "Mathematical Criticism of Some Physical Theories." A useful, if little known service of Birkhoff to the association during recent years was his frequent and carefully considered advice to the editor of SCIENCE in respect to appropriate reviewers of books on the branches of science with which he was familiar.

In one of the last papers Poincaré wrote he mentioned a theorem which he believed to be true but which he had been unable to prove. It was this: If an incompressible fluid is moving in two dimensions in the ring-shaped area between two concentric circles and if its motion is clockwise (though not necessarily uniform) along one of the circles bounding the ring but counterclockwise along the other, then there must be at each instant at least one point of the fluid which is at rest. Birkhoff proved that theorem, and received a great deal of recognition therefor, albeit some of his previous papers may have been even greater accomplishments.

Nearly twenty years later in 1937 Birkhoff stated and proved his Ergodic Theorem. As simple an explanation of this result as I know is that he himself gave in the *American Mathematical Monthly,* vol. 49, pp. 222–226, 1942, under the title: "What is the Ergodic Theorem?" The ergodic hypothesis had long been used by leading workers in the kinetic theory of gases and in statistical mechanics. The statement of the hypothesis, like that of many others in applied mathematics, though sufficiently clear for the purposes in hand, had not been given the precision necessary for a mathematically strict proof. It was a great achievement to find a proper precise formulation for and to give a proof of the ergodic theorem, which Wiener and Wintner have characterized as "the only result of real generality established for the solutions of dynamical equations." The applications of the theorem are numerous.

In 1935 Professor Birkhoff was appointed acting dean of the Faculty of Arts and Sciences of Harvard University for the ensuing academic year and a year later he was given a three-year appointment as dean.[2] When he was in college this deanship was held by some distinguished professor and was largely an honorary and advisory position involving little administrative detail. During the presidency of Mr. Lowell, first under Clifford Moore and then under Kenneth Murdock, the office had become a really important part of the central administration of the university, comparable to the academic vice-presidency or the provostship of other universities. When I heard of Birkhoff's appointment I remarked to him that I thought it was too bad for him to sacrifice the better part of his time and strength to this executive position. He replied that he understood that the

[1] *The Scientific Monthly,* February, 1937, vol. 44, pp. 191–3. In this article White says that Birkhoff had quite recently been advanced to the rank of research professor. I can not find any such item in the official record of the university. The reference may have been to his becoming Perkins professor of mathematics in 1933 on the retirement of Osgood, who held that chair in succession to Benjamin Peirce, James Peirce and Byerly. The title generally goes to the leading active professor of mathematics but does not imply a research professorship.

[2] In the *Harvard University Gazette,* vol. 40, No. 42, pp. 171–2, there is printed the Minute on the life of George David Birkhoff prepared by R. B. Merriman, P. W. Bridgman, J. H. VanVleck and J. L. Coolidge (chairman) and placed upon the records of the Faculty of Arts and Sciences at the meeting of April 17, 1945. In this minute is stated: "From 1937 to 1939 he assumed the arduous and important task of serving as Dean of the Faculty of Arts and Sciences." The dates I give are taken from the official records of the university.

new president was planning to make changes in administration which would reduce the office back to its earlier status, that it would take only a few hours a week and that he felt it his duty to make this relatively small sacrifice to aid his new president with many of whose ideas and ambitions he was himself in whole-hearted agreement. For four years he labored and undoubtedly sacrificed much more in time and strength than he had expected. The office was not returned to its earlier status; Birkhoff was succeeded by a practically full-time dean and two, perhaps half-time, assistant deans. In matters social it seems often to eventuate that the effort to displace a system in one direction results in the system executing a displacement in the contrary direction.[3]

When George Birkhoff was starting out as a mathematician the first strong group of pure mathematicians which we have had in this country was supplanting, and even trying to suppress, the applied mathematicians who had dominated American mathematics. No doubt it was high time that modern pure mathematics was given more attention in the United States. When Birkhoff came to Harvard from Princeton in 1912 he came as an analyst. I remember some of the sharp discussions and violent differences of opinion among the Harvard mathematical professors at the time. All rated him very high in analysis; some wanted him in Harvard for that reason alone, others thought Harvard already strong enough in that field and felt that it would be better to strengthen Harvard in some other branch of pure or applied mathematics. It is indeed a matter of inevitable disagreement whether a university department should be sharply specialized in some one main line of activity or be spread generally over several important lines.

As a matter of fact it would be hard to say whether in his thirty-two Harvard years, 1912–1944, Birkhoff was more the analyst or the applied mathematician; he returned to the great tradition. Of his four books —"Relativity and Modern Physics" (1923), "The Origin, Nature and Influence of Relativity" (1925), "Dynamical Systems" (1928), "Aesthetic Measure" (1933)—three certainly and perhaps all four would be classified as applied mathematics. Meanwhile he continued to publish contributions to pure mathematics in the leading mathematical journals of the world. At the time of his death he had in press in France a monograph on auto-equivalent functions and was publishing here upon his theory of gravitation.[4]

If I were to emphasize any personal trait of the Birkhoff I knew for forty years, it would be his keen esthetic sense. It was that which led him to write on esthetic measure, but it showed equally in his mathematics and in his daily life. He was an artist, a simple, generous, zestful artist. Everybody seemed to like him and those who conferred honors upon him seemed to take as great pleasure in giving as he in receiving. I shall not list his many honorary degrees and prizes but must mention that he was personally known and welcome not only in his own country but in Europe, in Asia and in Latin America.

EDWIN B. WILSON

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[3] For an inanimate system regulated by thermodynamics or statistical mechanics—and the ergodic theorem—we have the principle of LeChatelier that every system in stable equilibrium experiences from the variation of any single one of the factors which maintain the equilibrium a transformation in a direction such as, if it occurred by itself, would bring about a variation of the factor in the opposite direction, *i.e.*, a variation of one of the factors which have to do with a stable or neutral equilibrium can not have as ultimate effect a change of which the direction is opposite to the infinitesimal change with which the disturbance starts. Indeed, some have maintained that this principle is really the definition of stable equilibrium and in essence goes back to Hippocrates. If we displace a body from a position of unstable equilibrium, it is considered as a definition of the instability that the body will persist of itself in moving further in that direction. The phenomenon which so often appears to take place in a social system in that the reaction reverses the displacement one has attempted to impose upon it would therefore seem, at least superficially, to be something different in kind from the phenomenon of deviations from equilibrium (stable, neutral or unstable) in inanimate systems. Possibly when the dynamics of biological and social change shall have advanced to an adequate state of development some future Birkhoff will find and prove some super-ergodic theorem that will be a basic bit of mathematics in the statistical mechanics of such systems.

RECENT DEATHS

DR. HENRY B. WARD, professor of zoology, emeritus, of the University of Illinois, died on November 30 at the age of eighty years.

DR. HANS FREDERIK BLICHFELDT, professor emeritus of mathematics of Stanford University, died on November 16 at the age of sixty-nine years.

JACOB DAVID TAMARKIN, professor of mathematics, who was on leave of absence from Brown University, died on November 18. He was fifty-seven years old.

DR. CHARLES A. VAN VELZER, emeritus professor of mathematics of Carthage College, from 1881 to

[4] See, Proc. Nat. Acad. Sci., Washington, vol. 30, Oct. 1944, pp. 324–334. Birkhoff replaced the curved space-time of Einstein by a flat space-time, using 4-vectors in place of tensors. If we regard physical theory as a convention adopted as a convenience in correlating the main facts of observation in some domain of science, we must admit that a change in any widely accepted theory may well be at first an inconvenience even though it prove in the long run to be a convenience because of its greater simplicity or because of its greater coverage of the facts. Thus only the future can determine the place that may be assigned to this latest, and unhappily last, of Birkhoff's contributions to science, but there are some of his pupils and friends who rate it very highly and will be active in pursuing its implications.