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(*b*. Madras, India, 11 November 1904; *d*. Princeton, New Jersey, 8 May 1960)

mathematics.

Whitehead is perhaps best remembered for his idea of developing the theory of homotopy equivalence by the strictly combinatorial method of allowed transformations. He built up an important school of topology at Oxford.

Whitehead was the son of the Right Reverend Henry Whitehead, from 1899 to 1922 bishop of Madras, and of Isobel Duncan of Calne, Wiltshire. She had been one of the first undergraduates to study mathematics at Lady Margaret Hall, Oxford. Bishop Whitehead was the brother of the mathematician Alfred North Whitehead.

Sent to England before he was two, Whitehead saw little of his parents until his father's retirement to England in 1922. He was educated at Eton and Balliol College, Oxford. His Balliol tutor was J. W. Nicholson, who had studied under A. N. Whitehead. Whitehead boxed for the university, was a good cricketer, and an even better poker player. After graduating in mathematics he joined a firm of stockbrokers, but in 1928 he returned to Oxford to do further mathematical work. There he met Oswald Veblen, on leave from Princeton University, and it was arranged that Whitehead should visit Princeton on a Commonwealth fellowship. He was there from 1929 to 1932, when, having taken a Ph. D., he returned to Oxford and a fellowship at Balliol. In 1934 Whitehead married Barbara Shiela Carew Smyth, a concert pianist. They had two sons.

From 1941 to 1945 Whitehead worked at the Admiralty and Foreign Office. He was elected a fellow of the Royal Society in 1944, and Waynflete professor of pure mathematics and fellow of Magdalen College, Oxford, in 1947. He was president of the London Mathematical Society from 1953 to 1955. He died of a heart attack during a visit to Princeton.

On Whitehead's first visit to Princeton he took up the studies that were to occupy the remainder of his life. There he collaborated with S. Lefschetz on a proof that all analytic manifolds can be triangulated (*Mathematical Works*, II. no. 15 [1933]; see bibliography for details of the edition). He offered a proof (*ibid*., no. 16 [1934]; corrected in no. 18 [1935]) of the Poincaré hypothesis that a simply connected 3-manifold, compact and without boundary, is a topological 3-sphere. Although Whitehead soon found his proof to have been erroneous, work on it committed him to topology. One memorable early discovery was of a counterexample for open 3-manifolds (*ibid*., no. 20. [1935]). Before turning to topology, Whitehead had made an important study of the geometry of paths. A monograph on the foundations of differential geometry, written with Veblen, contains the first precise definition, through axioms, of a differential manifold (*Mathematical Works*, **I** , no.7 [1932]). This definition was much more precise than the concept of a global differential manifold offered, for example, by Robert König (1919) and E. Cartan (1928). In another work written with Veblen (*ibid*., no. 6 [1931]) the independence of the axioms is proved.

Under the influence of Marston Morse, Whitehead studied differential geometry in the large, and his paper "On the Covering of a Complete Space by the Geodesics Through a Point" (*Mathematical Works*, **I** , no. 17 [1935]) marks a turning point in this subject. Assuming an analytic manifold with a Finsler metric, he discussed the relationship between different concepts of completeness in the manifold. He also made a detailed investigation of the properties of the locus of characteristic points of a given point. Other notable work in differential geometry includes his new and elegant proof of a theorem first stated by E. E. Levi and of an important analogue (*ibid*., no. 22 [1936], and no. 36 [1941]).

After 1941 Whitehead was mainly concerned with topology. He had never lost his early interest in the subject, and J. W. Milnor describes his "Simplicial Spaces, Nuclei and M-Groups" (*Mathematical Works*, **II** , no. 28 [1939]) as the paper that will probably be remembered as his most significant work. Milnor discusses this and related work at length (*Mathematical Works*, **I** , xxv-xxxiii). The 1939 paper was a brilliant extension of the strictly combinatorial type of topoloty developed by J. W. Alexander and M. H. A. Newman between 1925 and 1932. (Whitehead had met Newman on his first visit to Princeton.) The contents of the paper were characterized by Whitehead's idea of using the strictly combinatorial method of allowed transformations to solve problems in the theory of homotopy equivalence.

Whitehead's interests gradually shifted toward algebaraic topology as a result of his search for invariants to characterize the homotopy type of complexes, and for methods of computing their homotopy groups. Newman explains how Whitehead's discovery of certain mistakes he had made in a paper written in 1941 persuaded him to avoid a free "geometrical" style of composition. Whitehead therefore undertook a complete restatement of his earlier work on homotopy, in a way expertly outlined by Newman. In the last three years of Whitehead's life there was a revival of geometrical topology, which led him to offer, jointly with A. Shapiro, a proof of Dehn's lemma much simpler than the one given in 1957 by C. D. Papakyriakopoulos (*Mathematical Works*, **IV** , no. 84 [1958]). Here, and in his elaboration of methods laid down by B. Mazur (1958) and Morton Brown (1960), there is ample evidence that Whitehead died at the height of his mathematical powers.

BIBLIOGRAPHY

I. Original Works. Ninety papers, some of them lengthy memoris, are collected in *Mathematical Works of J. H. C. Whitehead*, **I. M.** James, ed., 4 vols. (Oxford, 1962). References in text are to this collection, the numbers corresponding to the list of Whitehead's publications in **I** , ix-xiii, and the original year of publication being added in brackets. The papers are classified as follows: vol. **I** , differential geometry; vol. **II** , complexes and manifolds; vol. **III** , homotopy theory; vol. **IV** , algebraic and classical topology. Whitehead collaborated with Oswald Veblen on *The Foundations of Differential Geometry* (Cambridge, 1932), included in *Mathematical Works*, **I** . His Oxford lectures on Riemannian geometry and linear algebras, which were separately duplicated and circulated by the Mathematical Institute. Oxford, in 1959, are not included in the collected edition.

II. Secondary Literature. Vol. **I** of the *Mathematical Works* is prefaced by a biographical note by M. H. A. Newman and Barbara Whitehead, and by a mathematical appreciation by John W. Milnor. Two other valuable surveys of Whitehead's work are M. H. A. Newman's obituary notice in *Biographical Memoris of Fellows of the Royal Society*, **7** (1961), 349–363: and P. J. Hilton, "Memorial Tribute to J. H. C. Whitehead," in *L'enseignement mathématique*, 2nd ser., **7** (1961), 107–124.

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