TISSERAND

of the Faraday Society, **33** (1937), 524–531, originally sent for publication to a biochemical journal but refused as being "too physical"; "Electrophoresis of Serumglobulin II. Electrophoretic Analysis of Normal and Immune Sera," in *Biochemical Journal*, **31** (1937), 1464–1477; "A New Method of Adsorption Analysis and Some of Its Applications," in *Advances in Colloid Science*, **1** (1942), 81–98; "Adsorption Analysis by Interferometric Observation," in *Arkiv för kemi, mineralogi och geologi*, **15B**, no. 18 (1942), 1–6, written with S. Claesson; "Displacement Development in Adsorption Analysis," *ibid.*, **16A**, no. 18 (1943), 1–11; "Electrophoresis and Adsorption Analysis as Aids in Investigations of Large Molecular Weight Substances and Their Breakdown Products," in *Les Prix Nobel en 1948*, 102–121, in *Nobel Lectures in Chemistry 1942–1962* (Amsterdam, 1964), 195–215; "Chromatography of Proteins on Calcium-Phosphate Columns," in *Arkiv för kemi*, **7** (1954), 443–449; "Separation and Fractionation of Macromolecules and Particles," in *Science*, **141** (1963), 13–20, written with J. Porath and P. Å. Albertsson; and the autobiographical essay "Reflections From Both Sides of the Counter," in *Annual Review of Biochemistry*, **37** (1968), 1–24.

II. Secondary Literature. Tiselius' collaborator S. Hjertén published a biography of his former teacher, "Arne Tiselius 1902–1971," in *Journal of Chromatography*, **65** (1972), 345–348; a bibliography of Tiselius' papers is in R. A. Kekwick and K. O. Pedersen, "Arne Tiselius 1902–1971," in *Biographical Memoirs of Fellows of the Royal Society*, **20** (1974), 401–428. An earlier publication dealing with Tiselius' scientific life is K. O. Pedersen, "Arne Tiselius," in *Acta chemica scandinavica*, **2** (1948), 620–624. The important new approach to the chromatography of proteins is given in E. A. Peterson and H. A. Sober, "Chromatography of Proteins. I. Cellulose Ion-Exchange Adsorbents," in *Journal of the American Chemical Society*, **78** (1956), 751–755. In honor of Tiselius' sixtieth birthday a number of his friends published "Perspectives in the Biochemistry of Large Molecules," which is *Archives of Biochemistry and Biophysics*, supp. **1** (1962).

Kai O. Pedersen

TISSERAND, FRANÇOIS FÉLIX (*b.* Nuits-St.-Georges, Côte-d'Or, France, 15 January 1845; *d.* Paris, France, 20 October 1896), *celestial mechanics, astronomy.*

Tisserand was the younger son in a poor Burgundian family. His father, a cooper, died when Tisserand was very young; and his mother brought up the two children. Tisserand was a brilliant student at schools in Beaune and Dijon and later at the École Normale Supérieure, which he entered at age eighteen. Immediately after his graduation as *agrégé des sciences* in 1866, Le Verrier offered him the post of *astronome-adjoint* at the Paris observatory.

Le Verrier questioned the value of the lunar theory developed by Delaunay, his personal enemy. He entrusted the examination of the theory to Tisserand, who presented Delaunay's results concisely and demonstrated them in a new way, on the basis of Jacobi's principles of analytical mechanics. Tisserand also generalized the results to such an extent that Poincaré wrote: "[Tisserand] has grasped their true significance better, perhaps, than the author" (*Bulletin astronomique*, **13** [1896], 431).

This work constituted Tisserand's doctoral dissertation, which he defended in 1868. He then devoted some time to astronomy, participating in the mission sent to Malacca to observe the solar eclipse of 1868. At the Paris observatory he worked in the Service Méridien, the Service Géodésique, and the Service des Équatoriaux.

In 1873 Tisserand was named director of the Toulouse observatory and professor of astronomy at that city's university. During the next five years, besides reequipping the observatory, he did research on the theoretical and practical determination of the orbits of the asteroids and satellites, and on the perturbations in their orbits. He also contributed to potential theory. Having quickly established a reputation, he was elected a corresponding member of the Académie des Sciences in 1874, although he had not published a major work since his dissertation.

Tisserand was hired by the Paris Faculty of Sciences in 1878 to teach rational mechanics and, from 1883, celestial mechanics. Henceforth he devoted his research primarily to the latter subject, which he examined thoroughly, regularly publishing five or six notes or papers on it every year. In 1885 Tisserand obtained an important result on the three-body problem. Newcomb and, previously, Delaunay (for the case of the moon) had shown that the solutions can be expressed with the aid of purely trigonometric expansions; Tisserand gave a general method that, by means of a contact transformation, allows one actually to compute the expansions. In 1889 he established the relationship known as "Tisserand's criterion," which is applied to the two orbits described by an asteroid or comet before and after it passes close to a planet. The relationship is a function of the orbital elements that is not affected by the perturbation experienced

by the body. This criterion is widely used to establish the identity, or lack of identity, of two objects observed at different times and following distinct orbits.

Tisserand's greatest work is his *Traité de mécanique céleste*, the publication of which, begun in 1889, was completed a few months before his death. The four volumes represent an up-to-date version of Laplace's *Mécanique céleste*. In them Tisserand sets forth the general theory of perturbations and the works of Le Verrier on the theory of the planets, and discusses the theories of the moon, the theory of the satellites, the computation of the perturbations of the asteroids, potential theory, and the theory of the shapes of the celestial bodies and of their rotational movements. In addition, he reviews the most significant recent studies on these subjects, up through those of Poincaré. Laplace integrated the works of his predecessors into his text and therefore often was credited with results that were not his own. Tisserand, on the other hand, presents each author's memoir, simplifies its exposition, and integrates into it the fruit of his own research, without always making clear what part of the work is his. Thirty papers are incorporated into the *Traité* in this fashion. Since the authors of modern works on celestial mechanics often derive more of their information from this treatise than from the original papers, Tisserand's contributions are now diffused without being credited to him. A very modest person, Tisserand no doubt would have approved of this situation.

Tisserand was appointed director of the Paris observatory in 1892. In this capacity he pursued the project begun by Admiral Ernest Mouchez of producing the *Catalogue photographique de la carte du ciel*, and in 1896 he presided over the Congrès International de la Carte du Ciel. He succeeded Le Verrier as member of the Académie des Sciences in 1878 and was elected a member of the Bureau des Longitudes in 1879.

Tisserand suffered a fatal stroke in 1896, and was survived by three daughters. He had married while at Toulouse and, having become a widower soon after the birth of his first daughter, remarried in 1885. His collaborators, all of whom were also his friends, described Tisserand as honest, kind, and very solicitous toward young astronomers. His lectures were said to be exceptionally clear. This gift for clarity also is evident in his writings, which are all the easier to read by virtue of the economy and elegance of their demonstrations.

BIBLIOGRAPHY

I. ORIGINAL WORKS. Tisserand's writings include "Extension d'après les principes de Jacobi de la méthode suivie par Delaunay dans sa théorie du mouvement de la lune," in *Journal de mathématiques pures et appliquées*, **13** (1868), 255–303; *Sur la théorie des perturbations planétaires* (Toulouse, 1875), repr. in *Annales scientifiques de l'École normale supérieure*, **7** (1878), 261–274; *Déplacement séculaire du plan de l'orbite du 8ème satellite de Saturne; mouvement des apsides des satellites de Saturne, masse de l'anneau de Saturne* (Toulouse, 1877), repr. in *Annales de l'Observatoire astronomique de Toulouse*, **1** (1880), A1–A71; "Développement de la fonction perturbatrice dans le cas d'une forte inclinaison; perturbation de Pallas par Jupiter," in *Annales de l'Observatoire de Paris*, **15** (1880), C1–C52; "Parallaxe du soleil," *ibid.*, **16** (1882), D1–D48; "Mouvement séculaire des plans des orbites de trois planètes," *ibid.*, E1–E57; "Sur le problème des trois corps," *ibid.*, **18** (1885), G1–G19; *Traité de mécanique céleste*, 4 vols. (Paris, 1889–1896; I and II repr. 1960); and *Leçons sur la détermination des orbites*, J. Perchot, ed. (Paris, 1899).

Tisserand published seventy notes in the *Comptes rendus . . . de l'Académie des sciences* (**70–122** [1870–1896]), most of which were incorporated into the articles and books cited above. In *Bulletin astronomique*, **1–13** (1884–1896), which he founded and edited, he published twenty-eight short articles, the most important of which are "Théorie de la capture des comètes . . .," **6** (1889), 241–257, 289–292, which contains Tisserand's criterion; "État actuel de la théorie de la lune," **8** (1891), 481–503; "Perturbations . . . dans un milieu résistant," **10** (1893), 504–517; "Déplacement séculaire de l'équateur d'une planète et du plan de l'orbite de son satellite," **11** (1894), 337–343; and "Libération des petites planètes," **12** (1895), 488–507.

In the field of teaching and scientific popularization, Tisserand published *Recueil d'exercices sur le calcul infinitésimal* (Paris, 1876; 2nd ed., enl., 1896) and *Leçons de cosmographie* (Paris, 1895), written with H. Andoyer. The latter work contains a chapter on the history of astronomy that consists mainly of the text of three articles that Tisserand had published in *Annuaire du Bureau des longitudes*: "Perturbations et découverte de Neptune" (1885), 805–845; "Mesure des masses en astronomie" (1889), 671–723; and "Accélération séculaire de la lune" (1892), B1–B32. Tisserand wrote four other historical or popular articles for the *Annuaire du Bureau des longitudes*: "Quelques observatoires français du 18ème siècle" (1881), 736–765; "Planètes intramercurielles" (1882), 729–772 (the subject is treated in more detail here than in the *Traité de mécanique céleste*, IV, 524–528); "Petites planètes" (1891), B1–B20; and "Mouvement propre du système solaire" (1897), A1–A32.

II. SECONDARY LITERATURE. See the following, listed chronologically: "Discours prononcés aux obsèques de F. Tisserand," in *Bulletin astronomique*, **13** (1896), 417–439; O. Callandreau, "François Félix Tisserand," in *Monthly Notices of the Royal Astronomical Society*, **57** (1897), 231–233; L. Bassot, H. Poincaré, and M. Loewy, "Discours prononcés à l'inauguration de la statue de F. Tisserand à Nuits-St.-Georges . . .," in *Annuaire du Bureau des longitudes* (1900), E1–E19 (see also *Bulletin astronomique*, **16** [1899], 401); J. Bertrand, "Notice historique sur la vie et les travaux de F. Tisserand," in *Mémoires de l'Académie des sciences de l'Institut de France*, **47** (1904), 269–282; and A. Danjon and A. Léauté, "Inauguration du nouveau monument de F. Tisserand," in *Institut de France, Académie des sciences, notices et discours*, **4** (1962), 559–571.

The *Traité de mécanique céleste* was the subject of many reviews, the most detailed of which is R. Radau, in *Bulletin astronomique*, **6** (1889), 15–26; **7** (1890), 419–424; **11** (1894), 102–110; and **13** (1896), 300–306.

JACQUES R. LÉVY

TITCHMARSH, EDWARD CHARLES (*b.* Newbury, England, 1 June 1899; *d.* Oxford, England, 18 January 1963), *mathematics.*

Titchmarsh was the son of Edward Harper and Caroline Titchmarsh. In 1925 he married Kathleen Blomfield; they had three children. Titchmarsh received his mathematical training at Oxford; and, like most of his contemporaries, he did not take a doctorate. After teaching at University College, London (1923–1929) and the University of Liverpool (1929–1931), he became Savilian professor of geometry at Oxford. He held this position for the rest of his life.

All of Titchmarsh's extensive research was in various branches of analysis; and in spite of his professorial title, he even lectured exclusively on analysis. He made many significant contributions to Fourier series and integrals; to integral equations (in collaboration with G. H. Hardy); to entire functions of a complex variable; to the Riemann zeta-function; and to eigenfunctions of second-order differential equations, a subject to which he devoted the last twenty-five years of his life.

Titchmarsh wrote a Cambridge tract on the zeta-function (1930), and later expanded it into a much larger book (1951) containing practically everything that was known on the subject. His survey of Fourier integrals (1937) is a definitive account of the classical parts of the theory. His work on eigenfunctions appeared in two parts in 1946 and 1958. His text *The Theory of Functions* (1932) was his best-known book; a generation of mathematicians learned the theory of analytic functions and Lebesgue integration from it, and also learned (by observation) how to write mathematics. He also wrote *Mathematics for the General Reader* (1948).

Titchmarsh made many original contributions to analysis, but his influence was at least as great through his systematization of existing knowledge and his improvements of proofs of known results. He saw physics as a source of interesting mathematical problems; but his interest was exclusively in the mathematics, without any regard for its real applicability. The approach, so often sterile, was successful in his case, for it led him into his study of eigenfunctions, in which the importance of his results was less appreciated in Great Britain than in other countries, especially the Soviet Union.

BIBLIOGRAPHY

Titchmarsh's works are *The Zeta-Function of Riemann* (London, 1930); *The Theory of Functions* (Oxford, 1932); *Introduction to the Theory of Fourier Integrals* (Oxford, 1937); *Eigenfunction Expansions Associated With Second-Order Differential Equations*, pt. 1 (Oxford, 1946), pt. 2 (Oxford, 1958); *Mathematics for the General Reader* (London, 1948); and *The Theory of the Riemann Zeta-Function* (Oxford, 1951).

On Titchmarsh and his work, see the obituary by M. L. Cartwright, in *Journal of the London Mathematical Society*, **39** (1964), 544–565.

R. P. BOAS, JR.

TITIUS (TIETZ), JOHANN DANIEL (*b.* Konitz, Germany [now Chojnice, Poland], 2 January 1729; *d.* Wittenberg, Germany, 16 December 1796), *astronomy, physics, biology.*

Titius was the son of Barbara Dorothea Hanow, the daughter of a Lutheran minister, and Jacob Tietz, a draper and Konitz city councillor. His father died when he was young, and Titius was sent to Danzig to be brought up by his maternal uncle, the natural historian Michael Christoph Hanow, who encouraged his interest in natural science. Titius finished his studies at the Danzig grammar school, then, in 1748, entered the University of Leipzig, from which he received the master's degree four years later with a dissertation on Euler's theory of moonlight. In 1755 he became a private lecturer in the Leipzig Faculty of Philosophy; in