Maurice Anthony Biot

1905–1985

By Raymond D. Mindlin

Maurice Anthony Biot died on September 12, 1985, while he and his wife Nady were reading at home in Brussels, Belgium. By the time of his death, he had built a distinguished career of research, teaching, and consulting that spanned a broad range of science and technology centered in classical mechanics. His work extended from the most highly theoretical and mathematical problems through experimental studies to practical applications and patented inventions. He was active in his field until the day of his death.

My old friend Tony Biot was born in Antwerp, Belgium, on May 25, 1905. His early college training was at the University of Louvain in Belgium, from which he received a bachelor's degree in Thomistic philosophy in 1927. Then, in rapid succession (at only one-year intervals), he collected mining and electrical engineering degrees and a doctorate in the sciences—with enough time to spare to complete the curriculum at the Louvain Institute of Economic Sciences.

Within another year, after emigrating to the United States, he earned a doctorate in aeronautical sciences from the California Institute of Technology. It was also at Caltech that he began his long, fruitful association with Theodore von Karman.

After leaving Caltech, Biot held teaching positions at Harvard University's Graduate School of Engineering (1934–

1935), the University of Louvain (1936–1937), Columbia University (1937–1946, interrupted by his two-year enlistment in the U.S. Navy beginning in 1940), and Brown University (1946–1952). Subsequently, he became a consultant, working mainly with the Cornell Aeronautical Laboratory, Shell Development Company, and the Mobil Research and Development Company.

I first met Tony Biot more than fifty years ago during a summer session at the University of Michigan, where he had stopped on his way from Caltech to Harvard. In those days, young engineering teachers of his age from all over the United States converged on the Ann Arbor campus each summer, where they were taught the theory and applications of solid mechanics by Stephen Timoshenko and, occasionally, by H. M. Westergaard and R. V. Southwell. In the fall, these young men (there were no women in attendance at that time) went back home to spread the solid mechanics "gospel"—new to this country—among their own students. Tony Biot was well beyond this stage, however; by 1934, he had already published some two dozen research papers in this area.

In the 1930s, while most of us were concerned about simple steady-state vibrations, Tony had already published some of his pioneering works on the response of structures to transient disturbances. While we were struggling with the elements of the theory of elasticity, he had already begun to publish his nonlinear, second-order theory accounting for the effects of initial stress and large rotation. When we were first being introduced to the mysteries of photoelasticity, he was already an old hand, having published papers on experimental techniques and applications to thermal and shrinkage stresses by means of mathematical analogies.

In addition, Tony's first few papers on soil mechanics (involving foundation pressures and consolidation) had appeared by this time, as had his works on fluid flows and electromagnetic wave propagation. By 1935 he had been awarded a number of patents ranging from a steering linkage for automobiles to the now well-known scheme of aircraft navigation based on the establishment of fixed-interference patterns of radio waves.

From the early 1930s until the time of his death, Biot continued to make notable advances in the fields he had entered at the beginning of his career. His early interest in fluids and aeronautics led to his later work in transonic and supersonic aerodynamics, the three-dimensional theory of airfoil flutter, and the introduction of matrix methods and generalized coordinates in aeroelasticity. He applied his ideas of mechanical transients to the design of earthquake-resistant buildings, to aircraft landing gear, and to the sound emitted from stringed musical instruments.

His initial papers on soil consolidation blossomed into his general mathematical theory of porous media with applications to geophysical prospecting and well logging. His ingenious solutions of problems involving the reflection of electromagnetic and acoustic waves from rough surfaces are outgrowths of his early interest in radio waves.

Tony Biot's initial work on thermal stresses developed into a major advance in irreversible thermodynamics. His conceptions of generalized free energy and entropy displacement vectors made it possible to establish variational principles on which he based his new methods for the solution of problems in heat conduction, diffusion, thermoelasticity, thermoviscoelasticity, and chemical reactions. He published an extensive review of this work in *Advances in Applied Mechanics*, (vol. 24, pp. 1–91 [New York: Academic Press, 1984]). In addition, his longtime interest in the nonlinear effects of initial stress and the inelastic behavior of solids culminated in his mathematical theory of the folding of stratified rock, complete with its amazingly detailed physical verification, both in the laboratory and on the geological time scale.

Tony Biot's accomplishments did not go unrecognized. He was awarded the Timoshenko Medal of the American Society of Mechanical Engineers in 1962 and the Theodore von Karman Medal of the American Society of Civil Engineers in 1967. He was elected to the Royal Academy of Sciences of

Belgium in 1966 and to the U.S. National Academy of Engineering in 1967. In 1983 he became the seventh recipient of the Acoustical Society of America's honorary fellowship. In celebration of his seventy-fifth birthday, the Indian Institute of Technology dedicated the fourteenth volume of its *Journal of Mathematical and Physical Sciences* to him, listing his reports, patents, and research publications as well as his three books: *Mathematical Methods of Engineering*, coauthored by Theodore von Karman (New York: McGraw-Hill, 1940); *Mechanics of Incremental Deformation* (New York: John Wiley & Sons, 1965); and *Variational Principles in Heat Transfer* (New York: Oxford University Press, 1970).

Biot possessed a strong consciousness of the physical world that surrounded him. His keen insight enabled him to recognize the essential features of a physical phenomenon and to build them into a mathematical model without blindly including nonessentials. In addition, he had at his fingertips the tools of mathematical analysis and analytical methods of approximation, which he used skillfully to extract from the model predictions of the hitherto unpredictable.

The philosophy underlying Tony Biot's work and success is revealed in his acceptance speech on the occasion of the award of the Timoshenko Medal. This speech is published in *Applied Mechanics Reviews*, (vol. 16, no. 2, February 1963, pp. 89–90):

> Let us hope for a revival of humanism and a spirit of synthesis in science. Let us also put new emphasis on engineering as a professional craft, requiring high skill, natural talent, deserving social recognition, and distinctly different from the scientific professions as such. New stirrings are appearing in this direction. I am inclined to believe that engineers and engineering schools will play an important part in restoring the unity and central viewpoint in the natural sciences. This is because modern engineering by its very nature must be synthetic.