"Mileva [Marić Einstein] and her sons Eduard and Hans Albert in 1914, when she left Albert Einstein and returned to Zurich" from Berlin, in effect ending their life together. [From *The Private Lives of Albert Einstein*]

"Albert Einstein and his second wife, Elsa, on board the *SS Rotterdam* in 1921, the year they paid their first visit to the United States." [From *The Private Lives of Albert Einstein*; AIP Emilio Segrè Visual Archives]

One of the more heated controversies in this regard surrounds the role, if any, of Einstein's first wife, Mileva, in his early work, especially in the formulation of the theory of special relativity. The authors claim the middle ground by concluding that Mileva did not contribute directly to Einstein's breakthroughs but did provide the encouragement and the intellectual and emotional support that Einstein needed to complete his work. His success eventually led to the collapse of their marriage, however, for in finding intellectual support elsewhere he no longer needed her, especially as general relativity began to consume his entire being. For emotional support, Einstein turned from the now increasingly jealous Mileva to his motherly first cousin Elsa, whose presence in Berlin beckoned him to that city and who eventually became his second wife. With his wrenching separation and divorce from Mileva, something seemed to have died within Einstein, for, if the authors are right, his emotional reactions to those closest to him became increasingly cruel and unfeeling. Yet Albert and Mileva remained somehow "knotted together" until the end of her sad and lonely life in 1948. Indeed, for everyone close to Einstein, including Einstein himself, life took a tragic turn, perhaps even more so because of Einstein's emotional limitations. These are themes and insights that bear closer study and, if maintained, will prove essential for any comprehensive appreciation of Einstein as both scientist and human being.

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Respiratory Physiology

Oxygen Transport in Biological Systems. Modelling of Pathways from Environment to Cell. S. EGGINTON and H. F. ROSS, Eds. Cambridge University Press, New York, 1993. xii, 298 pp., illus. $110 or £55. Society for Experimental Biology Seminar Series, 51. From a symposium, Birmingham, U.K., April 1991.

Multicellular organisms are possible only because of transport systems that have developed to carry oxygen from the environment to individual cells and subcellular particles. A complete system transfers oxygen between the environment and a transport fluid, which is convected to an internal exchanger by which the oxygen is delivered to the cell. Models have contributed greatly to our understanding of oxygen delivery. *Oxygen Transport in Biological Systems* reviews the most recent advances in modeling oxygen transport in the animal kingdom as well as in plants.

The first chapter (Shelton) discusses total respiratory exchange as an engineering system in a broad variety of animals, with emphasis on the different types of exchangers—counter, parallel, and cross-flow—for steady-state and non–steady-state conditions. The second chapter (Alexander and Young) explores the dynamic interaction between lung ventilation and major bodily movement by way of a simple, ingenious model of mass, spring, and dashpot. The authors are able to prove that the piston-like action of the viscera probably contributes little to ventilation in the galloping horse, although it contributes significantly in the wallaby.

In the 1980s Weibel and Taylor stimulated interest in comparing structure and function in the respiratory system by using stereoscopic morphologic techniques to determine structure and proposing that nature provided no more structure than necessary for functional demands. An excellent review (Perry) of comparisons of the effective transfer function in lungs and gills for oxygen calculated by morphometry methods and measured by physiological methods is more discouraging than I consider justified, given the general agreement of the two methods' results and the many limitations of the experimental measurements from both approaches. The limitations on exchange provided by the red cells themselves are not addressed here.

In fetal mammals the placenta (rather than the lung) becomes the external exchange organ, but with additional layers on the maternal side. A morphometric study of human placentas from births at high and low altitudes is reported by Mayhew. The diffusion distances were found to decrease remarkably with gestational age and with altitude, indicating adaptations of the exchanger to oxygen need. Hemoglobin, the most studied protein, is the star of oxygen transport. Our knowledge of its structure, models of its function, and recent contributions from molecular biology are reviewed succinctly by Bellelli and di Prisco.

Fractals and L sets are irregular geometric structures or sets produced by recursive (repeated) rules. An example is a bifurcating vascular network in which the length of each daughter branch is a constant (trivial if not different) fraction of the length of the mother branch. Fractals resemble natural objects—in the present context, trees and vascular beds—rather than regular geometric shapes. This tool provides a mathematical statement of vascular heterogeneity that can be manipulated in computer descriptions of oxygen transport in tissues. Van Beck provides a clear introduction to the subject and discusses as an example the flow distribution in fractal self-similar networks of increasing complexity. Fractals could prove to vitalize the field much as did the advent of the computer. The recursive rules that govern them may even be analogous to the unknown laws that govern the growth of tissue vascular beds.

Models are most fruitful when their predictions can be verified by measurements, but they remain useful even when experimental tools are limited. This is true of the simplified model developed by Krogh and the mathematician Erlang in 1918 of the final step in oxygen transport in muscle, the progression from the capillary through the cell. This model consisted of a single capillary surrounded by homogeneously metabolizing muscle fibers whose axes were parallel to that of the capillary. The basic form of this model is still used today. One of its major defects is that it does not capture the fact that in real tissue there are many capillaries, not all of which are parallel to

the muscle fiber, with a varying ratio of capillary blood supply to oxygen consumption; in other words, there is marked heterogeneity. Three contributions deal with modifications and improvements to the basic single-capillary Krogh-Erlang model for oxygen movement from blood into the cells, but only in muscle and using only one dimension of measurement: the distance between capillary and muscle fiber. Eggleton and Ross describe improved morphometrics, particularly the use of capillary domains—two-dimensional polygons limiting the cross-sectional area of muscle fibers supplied by each capillary. The actual domains are obtained by microscopy and show a smooth statistical distribution of domain size. Hoofd takes an analytic approach to updating the Krogh-Erlang model, listing 15 simplifying assumptions and investigating the effect of some of them, such as that there are multiple capillaries rather than a single one, that oxygen flux is facilitated by hemoglobin in erythrocytes and myoglobin in muscle cells, and that there is heterogeneity in distribution. Groebe reviews the numerical data available for use in models and uses a variant of the Krogh-Erlang model to demonstrate that several of the simplifying assumptions can safely be ignored.

Oxygen transport in plants, a topic that should fascinate those interested in oxygen delivery to mammalian tissues, is discussed by Beckett and Armstrong. In marsh plants oxygen is carried through a gas-filled cortex (aerenchyma) to cells deep in an anaerobic environment in which the loss of carbon dioxide radially combined with the local consumption of oxygen produces a negative pressure in the aerenchyma and convective flow from the air above. It would be interesting to compare oxygen and carbon dioxide transport in plants with transport in the gas-filled tracheoles of insects. The models of plant ventilation put forth in this chapter are especially useful because they can be tested experimentally.

I recommend this book to anyone interested in the most recent developments in morphometry and modeling of gas transport systems.

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Vignettes: Quasi-Knowledge

I wonder whether the phrase "ontogeny recapitulates phylogeny" would so persistently have fascinated biologists, or so long have survived among the debris of half-forgotten science that we all retain from high school, if it were not rather euphonious. Would something like "development repeats evolutionary history" have worn so well?

—*Keith Stewart Thomson*, in *The Common but Less Frequent Loon and Other Essays* (Yale University Press)

If you made a list of all the things you know for certain under four headings: (1) those things that you know from direct experience, (2) those that logically follow from self-evident truths, (3) those that you believe because you were told, (4) those you "just know" because of an intuitive gut-level feeling, which one of the headings would have the longest list?

—*Mihaly Csikszentmihalyi*, in *The Evolving Self: A Psychology for the Third Millennium* (HarperCollins)

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