Richard Darwin Keynes

1919–2010

Richard Keynes died peacefully at home, ending a long and successful career as a university academic, in the international promotion of science, and as a cell physiologist. He was born in 1919, the eldest son of the surgeon and bibliographer Sir Geoffrey Keynes and of Margaret Darwin. He was educated at Oundle School and won a Scholarship to read physical sciences at Trinity College, Cambridge. He added physiology to his first year subjects thus beginning the central interest of his eventual scientific career. He interrupted his university studies to work on sonar at HM Anti-submarine Experimental Establishment and centimetric radar at the Admiralty Signals Establishment during the Second World War, before returning to Cambridge in 1945 to read Part II Physiology and begin a research career in physiology. He become research fellow at Trinity College, teaching fellow at Peterhouse and University Lecturer in Physiology between 1948 and 1960. He then joined the Agricultural Research Council Institute of Animal Physiology at Babraham, becoming its Director in 1965, contributing much to the development of its high international reputation. This would probably not have been achieved with a less energetic individual whom the Agricultural Research Council might sometimes have preferred. He finally returned to Cambridge in 1973 as Professor of Physiology.

Richard Keynes at his desk in the Physiological Laboratory, Cambridge.

Both this energy and exuberance, and his distinguished lineages, are reflected in his life and achievements within and beyond the physiological field. These included his passion for collecting and natural history, and his attachment to and fascination with South America, where, like Darwin, he did some of his most important work. His physiological contributions represent a broad sweep of interests through a range of strategic areas. They extended well beyond the electrophysiological studies in excitable membranes that eventually formed his principal interest.

Within physiology, Keynes was amongst the first researchers successfully to apply radioactive tracer measurements in studies of ionic movements across membranes of living cells. He began these studies when such techniques were in their infancy, and developed several novel quantitative methods in collaboration with Peter Lewis. They used an ancient cyclotron in the Cavendish Laboratory to bombard appropriate targets with neutrons, and improvised methods to purify the resulting isotopes. This led to one of the most important contributions to biology: the direct demonstration relating nerve impulses in squid giant axon to sodium ion influx (Fig. 1) and potassium ion efflux across the nerve membrane. This directly supported the analysis of the nerve impulse by Alan Hodgkin and Andrew Huxley that later led to their Nobel prize. It was during this period that he also began work demonstrating how the underlying ionic concentration gradients for these fluxes were maintained, through an energy-consuming biochemical process, later to be known as the sodium pump (Fig. 2).

Keynes pursued his scientific interests not only through his many administrative and teaching duties but also in the course of his manifold activities in international science and laboratories overseas. Over a three-month period in Rio de Janeiro in 1951, during his first visit to South America, he clarified the mechanisms, in electrophysiological terms, by which the electric eel *Electrophorus* generates the massive shock that stuns or kills its prey, together with Hugo Martins-Ferreira. This confirmed conjectures made by the physicist Alessandro Volta 150 years earlier. A change in ionic permeability causes the membrane of one surface of each muscle cell within the electrical organ to reverse its resting potential whereas the other surface remains unchanged. This leads to effects akin to deposition of a large charge across the plates of a capacitor, in this case leading to development of potential differences of about 1/6 of a volt across each plate. Arrangements of several thousand such plates in series results in the capacity to generate a powerful electric shock.

At Babraham, Keynes combined a heavy administrative load with an active research programme that included measurements of

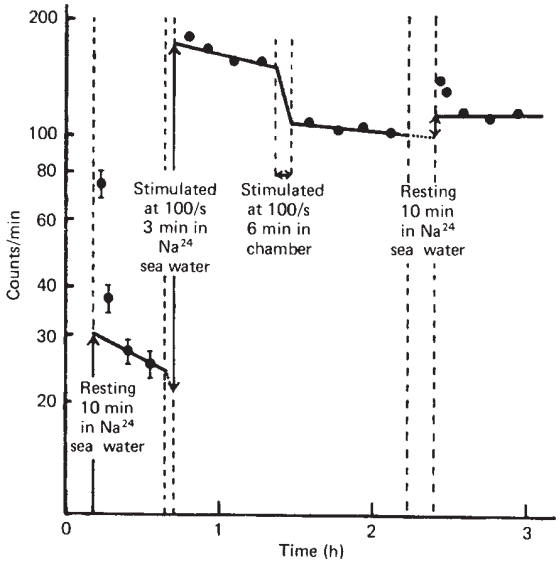

Figure 1. Geiger counter readings following ^{24}Na fluxes in a stimulated *Sepia* axon alternately exposed to ^{24}Na-containing, and inactive sea water. The loss of counts during the first 10 min after exposure to ^{24}Na resulted from washing away of extracellular Na^+, and was ignored. 1 count/min is equivalent to 42.5 x 10^{-12} mol Na (cm axon)$^{-1}$. (From Keynes RD (1951). The ionic movements during nervous activity. *J Physiol* **114**, 119–150.)

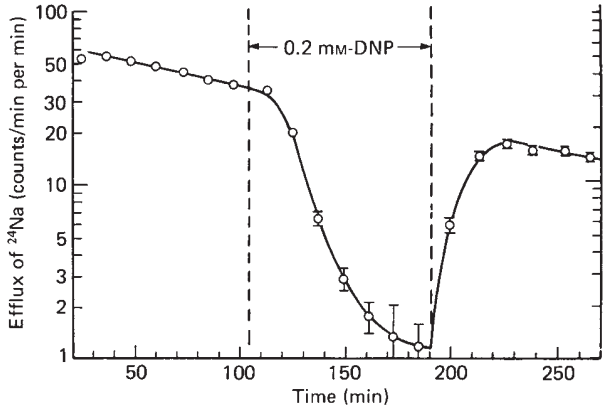

Figure 2. Reversible effect on ^{24}Na efflux produced by the metabolic blocker dinitrophenol in Sepia axon. (From Hodgkin AL & Keynes RD (1955). Active transport of cations in giant axons from *Sepia* and *Loligo*. *J Physiol* **128**, 28–60.)

thermodynamic, and membrane light scattering and birefringence changes during activity in nerve and electric organs. This formed a broad front of interests combined with studies on ion transport across secretory epithelia, that extended to work on ruminal epithelial potassium transport, thermoregulation and metabolism in sheep.

Back at Cambridge, Keynes managed to carry out his administrative and teaching duties as head of department while resuming his early interests in biophysical properties of nerve membranes. These involved laboratory work during vacations at Plymouth where he dissected giant axons from mantles of freshly caught squid (*Loligo)*, for electrophysiological study. This probably represented the one of his many activities in which he was the most absorbed and happy. The work extended concepts bearing on the mechanisms of ion movements across nerve membranes to the molecular level.

Working with Eduardo Rojas, further technical advances were made that permitted direct measurements of the 'gating currents' generated by conformational changes in the sodium channel molecule associated with channel activation, interests he continued to pursue after retirement (Fig. 3).

Keynes complemented his scientific pursuits with keen interests in Darwin's zoological research, particularly those he pursued on the voyage of the *Beagle,* prompted by sketches he discovered by the ship's artist in 1965. This led to publication over the following 35 years of *The Beagle Record* (1979), *Darwin's Beagle Diary* (1988) and his *Zoology Notes from HMS Beagle* (2000). He also supported science for the conservation of Galapagos, in the 1980s and 1990s. He served on the Executive Council of the Charles Darwin Foundation for Galapagos and the Board of the Galapagos Conservation Trust. At the time of

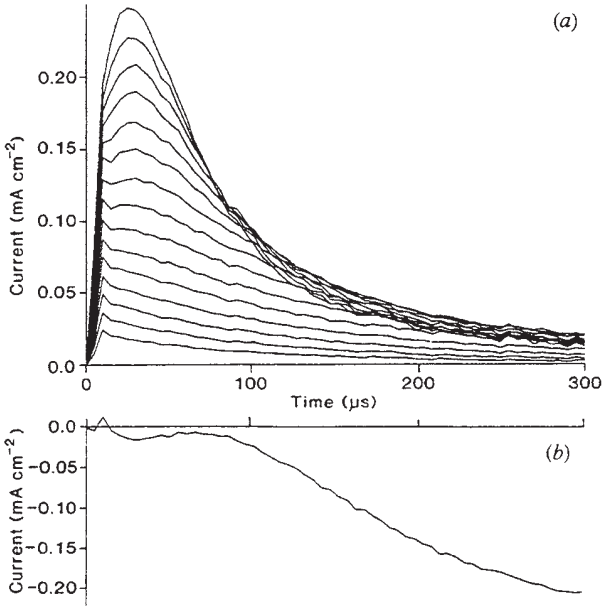

Figure 3. *a*, averaged sodium gating currents in response to pulses from −80 to between −57 and +83 mV from a tetramethylammonium fluoride dialysed squid axon bathed in sodium-free, tetrodotoxin-containing artificial sea water, compared to (*b*) the initial rise of sodium current following a pulse to −23 mV. (From Keynes RD & Elinder F (1998). On the slowly rising phase of the sodium gating current in the squid giant axon. *Proc R Soc Lond B* **265**, 255–262.)

Richard dissecting the giant axon of *Loligo* in the Marine Biological Laboratory, Plymouth.

his death, he had just completed work on the 4th edition of his undergraduate book *Nerve and Muscle* in collaboration with Chris Huang.

Keynes was elected Fellow of the Royal Society in 1959, and was a Vice-President from 1965 to 1968. He was elected a Fellow of Churchill College, Cambridge, in 1961 and was a Fellow of Eton College from 1963 to 1978. His international scientific activities led him to becoming Secretary General (1972) then President (1981–84) of the International Union for Pure and Applied Biophysics. He participated in establishing the ICSU/Unesco International Biosciences Networks in the 1980s, later becoming its Chairman (1982–1993). For all these activities he received the Order of Scientific Merit (Brazil) and Honorary Membership of the Latin American Academy of Sciences amongst many academic honours, and was awarded the CBE in 1984. He became a Member of The Physiological Society in 1948 and an Honorary Member in 1993. He served on the Committee (1961–65) and was an Editor for *The Journal of Physiology (*1954–61).

Keynes married Anne Adrian, daughter of Lord Adrian in 1945. They had four sons (of whom the eldest died in 1974). Many will have fond memories of visiting their home in north Norfolk and enjoying sailing trips in Keynes's sailing dinghy *Electrophorus*.

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I would like to thank Professor Roger Keynes for access to historical material in the preparation of this obituary.