Journal of the History of the Neurosciences

Basic and Clinical Perspectives

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/njhn20

Early Australian neuroscientists and the tyranny of distance

Laurie Geffen & Nick J. Spencer

To cite this article: Laurie Geffen & Nick J. Spencer (2024) Early Australian neuroscientists and the tyranny of distance, Journal of the History of the Neurosciences, 33:1, 57-72, DOI: 10.1080/0964704X.2023.2232824

To link to this article: https://doi.org/10.1080/0964704X.2023.2232824

JOURNAL OF THE HISTORY OF THE NEUROSCIENCES
2024, VOL. 33, NO. 1, 57–72
https://doi.org/10.1080/0964704X.2023.2232824

Early Australian neuroscientists and the tyranny of distance

Laurie Geffen[a] and Nick J. Spencer[b]

[a]School of Medicine, University of Queensland, Brisbane, Australia; [b]Visceral Neurophysiology Laboratory, College of Medicine and Public Health, Flinders Health and Medical Research Institute, Flinders University, Bedford Park, Australia

ABSTRACT
Australian neuroscientists at the turn of the twentieth century and in the succeeding decades faced formidable obstacles to communication and supply due to their geographical isolation from centers of learning in Europe and North America. Consequently, they had to spend significant periods of their lives overseas for training and experience. The careers of six pioneers—Laura Forster, James Wilson, Grafton Elliot Smith, Alfred Campbell, Raymond Dart, and John Eccles—are presented in the form of vignettes that address their lives and most enduring scientific contributions. All six were medically trained and, although they never collaborated directly with one another, they were linked by their neuroanatomical interests and by shared mentors, who included Nobelists Ramon y Cajal and Charles Sherrington. By the 1960s, as the so-called "tyranny of distance" was overcome by advances in communication and transport technology, local collaborative groups of neuroscientists emerged in several Australian university departments that built on the individual achievements of these pioneers. This in turn led to the establishment of the Australasian Neuroscience Society in 1981.

KEYWORDS
Alfred Campbell; Raymond Dart; early Australian neuroscientists; John Eccles; Grafton Elliot Smith; Laura Forster; James Wilson

Introduction

Neuroscientific research commenced in Australia about a decade before the colonies were united as a federation in 1901. In common with other scientific disciplines, early Australian neuroscientists labored under the "tyranny of distance," a term popularized by historian Geoffrey Blainey (Blainey 1966) to encompass the consequences of Australia's geographic isolation. Difficulties in communication with the centres of learning in Europe included accessing current scientific literature, interacting with peers, and obtaining equipment and supplies (Home 1988).

A round trip by sea between Australia and Europe could take months during the nineteenth century and required a degree of personal fortitude. In the 1920s, an airmail connection to Europe was established, and by the 1930s it was possible to fly as a passenger. However, a round trip could take weeks due to multiple refueling stops and scarce connections.

Overseas telephone calls became possible in the 1930s, albeit by crackling shortwave radio. Radio communication was supplanted only in the 1960s, when land and sea telecommunication cables were completed. By the 1980s, advances in digital communications

CONTACT Laurie Geffen l.geffen@uq.edu.au School of Medicine, University of Queensland, 1103/241 Wellington Road, East Brisbane, QLD 4169, Australia

and in transport technology had dissipated many of these difficulties. It is a measure of how keenly Australia's isolation was felt that all the pioneer Australian neuroscientists discussed here found it necessary to either begin or complete their training overseas and to work there for extended periods.

An earlier description of the origins of Australian neuroscience focused on three pioneers: Alfred Campbell, Grafton Elliot Smith, and Stanley Porteus (Macmillan 2009). This article includes Campbell and Grafton Elliot Smith, alongside Laura Forster, James Wilson, Raymond Dart, and John Eccles. The biographical vignettes, presented in order of birth, illustrate the common challenges these six pioneers faced and the ways in which they overcame them.

Laura Forster (1858–1917)

The literature on the life and career of Laura Forster is scant. Wagner (2017) provided the most complete account of Forster's personal life. The most comprehensive evaluation of her scientific work is an account of women neuroscientists who worked in the Spanish Neurological School in Madrid in the early twentieth century (Gine et al. 2019).

Laura Forster (Figure 1) was born in Sydney in 1858, the fifth of six children of the New South Wales (NSW) Premier William Forster and his first wife, Elizabeth Wall. Her mother died when Laura was just four years old and when her father died in 1882, she moved to England with her stepmother, Maud Edwards. When she decided to become a doctor, she faced obstacles to women enrolling in British medical schools. Although the "Enabling Act" of 1875 allowed British universities to grant medical licences to women, most medical schools discriminated with quotas for women well into the 1960s (Jefferson, Bloor, and Maynard 2015). In 1887, she enrolled in the medical school at the University of Bern, which had admitted women since the 1870s (Universität Bern portal: History of women as university students). She graduated with a dissertation on muscle spindles (Forster 1894) and then worked at the Bern Institute of Pathology for several years.

After further training in Scotland, as both a doctor and a nurse, she set up a medical practice in Oxford, where she was appointed medical officer at the Cutler Boulter Dispensary in 1900. In addition to her medical practice, Forster continued her research on muscle spindles in the Physiology Laboratory of Oxford University under the mentorship of Gustav Mann, a founder of physiological histology. In her first journal publication, Forster described the development of muscle spindles in human foetuses during the first four to six months of gestation (Forster 1902).

In 1911, on Mann's suggestion, she visited the Madrid laboratory of Nobel Prize laureate Santiago Ramón y Cajal to learn some neuro-histological techniques. At Cajal's suggestion, Forster replicated in birds his observations on mammalian nerve degeneration and regeneration after spinal trauma (Ramón y Cajal 1914). She observed identical but more rapid responses, comprising degenerative retracted fibers with varicose ball-like endings and regenerative nerve sprouts. She published her elegantly illustrated findings in an obscure Spanish journal (Forster 1911). However, her work would have been forgotten had Cajal and his colleagues had not subsequently cited it in several of their own papers. It is a measure of Cajal's regard for Forster that he included her in his memoir as one of only two women in a list of 28 major collaborators (Ramón y Cajal 1917). A decade later,

Figure 1. Laura Forster in her early 20s. Reproduced from Laura Forster and Manuela Serra at the Cajal school. In Untold Stories: the Women Pioneers of Neuroscience in Europe, WiNEu: European women in Neuroscience, Federation of European Neuroscience Societies, https://wineurope.eu/forster-serra-cajal-school/.

Forster's avian work was replicated in amphibians by Cajal's former collaborators, Rafael Lorente de Nó and Manuela Serra, both of whom acknowledged Forster's work as fundamental to their own (Lorente de Nó 1921; Serra 1921).

In addition to her work on muscle spindle development and on neuronal plasticity in response to trauma, Forster's other neuroscience interest was the relationship of ovarian diseases with mental illness. At the pathology laboratory of the Claybury Asylum, she performed more than 100 autopsies on women who had died in London mental asylums and studied their ovaries. Before she could publish her findings, she abruptly abandoned her scientific career when war broke out in the Balkans in 1912. Volunteering as a nurse because women couldn't serve as physicians at the war front, Forster worked in Greece, Belgium, and France before joining the Russian Army as a surgeon in Petrograd. She went on to serve with the Russian Red Cross in the Caucasus and in Turkey, where she supervised an infectious diseases hospital before transferring to the Galicia front (now in

Ukraine). In 1917, exhausted by her heavy workload and the atrocious conditions, including constant bombardments and exposure to infection, she died of influenza at the age of 58.

Forster's work on the histology of ovaries in mental disorders was communicated posthumously to the Royal Society of Medicine by Frederick Mott and was published a year later (Forster 1918). Mott acknowledged that her work was of fundamental value to his own studies on psychopathology and gonadal function (Mott 1921; Mott and Such 1922).

There is little information on Laura Foster's personal life that could account for her fateful change of careers. Perhaps it was the proximity of the local Russian Orthodox Church to the Cutler Boulter Dispensary in Oxford that established connections that eventually led her to work in Russia. She would also have had many connections from her time at Bern University, where many women students had escaped restrictions elsewhere, particularly in Russia.

Whatever the reasons for her change of career, her achievements both as a neuroscientist and as a clinician reflect her great determination and courage. She has long been recognized in Australia as an icon for female physicians, and she also deserves to be better known as one of the pioneers of Australian neuroscience.

James Wilson (1861–1945)

James Wilson (Figure 2) was born in Scotland in 1861 and graduated in medicine from the University of Edinburgh in 1883. The most extensive accounts of his life and scientific accomplishments are by Hill (1949) and Morison (1997).

After completing his internship, Wilson worked intermittently as a ship's doctor and anatomy demonstrator in the Edinburgh Medical School, where he imbibed its traditional emphasis on comparative anatomy. In 1887, he accepted an appointment as demonstrator in anatomy from Anderson Stuart, the dean of the new medical school at the University of Sydney. For the next 33 years, Wilson devoted himself to developing the anatomy department, while furthering his naturalist interests by studying Australia's unique fauna.

Within a few years, Wilson had published several short papers, (Wilson 1888, 1889a, 1889b). They dealt mainly with the abnormalities of limb muscle innervation he observed in cadavers in the dissecting room, some of which he surmised resembled those he had observed in marsupials.

In 1890, Wilson was appointed professor of anatomy and immediately set about teaching anatomy as a biological science, using the dissection, museum, and laboratory techniques he had acquired in Edinburgh. For the next 30 years, he ran an expanding department with heavy teaching commitments, assisted initially only by a few technicians and student demonstrators.

Wilson had an austere persona and was considered humorless and a dull lecturer. But in research, his enthusiasm was irresistible, and his devotion to his proteges was legendary, "advising, criticizing and, above all, encouraging, all with great vehemence" (Morison 1997). He also feuded constantly with the dean. It was said that Anderson Stuart built the Sydney Medical School, but it was Wilson who furnished it with a research reputation (Morison 1990).

Figure 2. James Thomas Wilson as Challis Chair of Anatomy, University of Sydney. This image is out of copyright. The identifier number of this photo is ref-00003085, obtained from the University of Sydney Archive.

Together with physiologist Charles Martin, Wilson formed an informal group of comparative researchers that included two young postgraduates, Grafton Elliot Smith and James Hill. Collectively, they were known as the Duckmaloi Fraternity, after the river in the Blue Mountains where they obtained many of the specimens they used for the first systematic anatomical studies of Australia's native fauna. All four were subsequently elected Fellows of the Royal Society.

In 1914, Wilson organized the first overseas congress of the British Association for the Advancement of Science held in Sydney. At the congress, he caused a sensation by exhibiting the Talgai skull, then the oldest human fossil discovered in Australia (Allen 2010). The skull had been found in 1886 by a Queensland farm worker and was later purchased by a philanthropist and donated to the University of Sydney. Wilson had previously examined the skull in 1896 as a trustee of the Australian Museum, but he disingenuously neglected to mention this when presenting the Talgai skull 18 years later as a new discovery. At the congress, the skull was interpreted by Wilson and his protégé Elliot Smith as resembling the newly discovered Piltdown fossils. Radiocarbon dating later indicated that the Talgai skull was about 11,000 years old, long after the first humans had reached Australia.

In 1920, Wilson returned to the United Kingdom as professor of anatomy at Cambridge University, where he remained until his death in 1945 (Morison 1990). Alongside his contributions to comparative neuroanatomy, his other enduring influence on Australian neuroscience was his mentorship of several other pioneers, including Elliot Smith and Raymond Dart.

Grafton Elliot Smith (1871–1937)

Grafton Elliot Smith (Figure 3) was born in Grafton in NSW in 1871. His life and work have been extensively documented by Wilson (1938) and Dawson (1938).

Elliot Smith studied medicine at Sydney University, graduating in 1893. He had originally intended to work on the spinothalamic tract in the cat for his M.D. thesis. However, he was persuaded by physiologist Charles Martin to focus instead on Australia's unique fauna, and completed his MD thesis in 1894 on the neuroanatomy of the bandicoot and platypus.

In 1896, Elliot Smith won a scholarship to St John's College in Cambridge, where he published several papers in which he compared monotreme, marsupial, and other mammalian brains. At first, he focused on the cerebral commissures; he subsequently extended his work to other forebrain structures and the cerebellum (Elliot Smith 1902a).

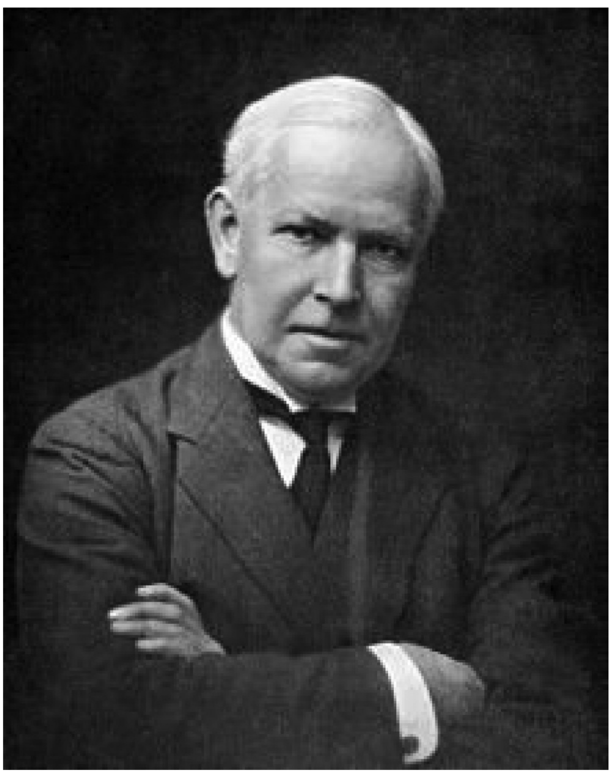

Figure 3. Grafton Elliot Smith as professor of anatomy at University College London. Reproduced from The University of Sydney Archives. This image is out of copyright.

In 1900, he was appointed to the chair of anatomy in the virtually defunct Government School of Medicine in Cairo. During his decade-long tenure, in addition to reviving local medical training he produced a topographic map of the human cerebral cortex, achieved by the remarkable feat of cutting fresh brain sections by hand with a scalpel and examining them unstained using a hand-held magnifying lens (Triarhou 2020).

While in Cairo, Elliot Smith took an interest in the brains and other organs of early Egyptian mummies (Elliot Smith 1902b). His anthropological horizons expanded when he became convinced that ancient Egyptian knowledge and culture had diffused through Northern Africa to Europe and eventually to Asia and North America, where it influenced all other civilizations. In 1907, Elliot Smith was elected to the Royal Society. Two years later he was appointed professor of anatomy at Manchester University, where he revolutionized the teaching of anatomy using clinical methods to demonstrate living anatomy.

Elliot Smith returned to Australia in 1914 to attend the British Association for the Advancement of Science meeting in Sydney, where he discussed the significance of the Talgai skull presented by Wilson. Before the meeting, Elliot Smith was shown an embalmed body found in the nineteenth century in the Torres Strait between New Guinea and the Australian mainland that exhibited evidence of posthumous handling, a practice that Elliot Smith immediately linked to Egyptian mummification. Despite the contrary arguments of other experts on the prehistory of the region, this episode confirmed his belief in the distant diffusion of Egyptian influence (Derricourt 2012).

While in Manchester, Elliot Smith published "Shell Shock and Its Lessons," which contributed to more humane therapies for this condition, now known as posttraumatic stress disorder (Elliot Smith and Pear 1917).

In 1919, Elliot Smith was appointed professor of anatomy at University College London, where he established a respected school of comparative anatomy. He also became famous for his books on social anthropology, including *The Evolution of the Dragon* (Elliot Smith 1919), *The Evolution of Man* (Elliot Smith 1924), and *The Diffusion of Culture* (Elliot Smith 1933). Unlike his contributions to anatomy, Elliot Smith's anthropological theories have since been widely discredited.

More enduring to Elliot Smith's reputation than his excursions into social anthropology was his legacy as a mentor to some 20 protégés, many of whom later occupied chairs of anatomy across the world, including Raymond Dart. According to one protégé he sent to Australia, Elliot Smith had an outgoing and forceful but charming personality, with "the smile of a school boy and the appearance of a benevolent dignitary of the Church . . . . genial in social intercourse but in debating and writing on controversial topics, his gentleness forsook him!" (Jones 1937).

Elliot Smith was knighted three years before his death in 1937.

Alfred Campbell (1868–1937)

Alfred Campbell's life and career have been extensively documented (Eadie 1981, 2003; Foley and Storey 2010; Macmillan 2009, 2016; Triarhou 2020).

Campbell (Figure 4) was born in rural NSW in 1868. At the age of 18, he enrolled in medicine at Edinburgh University. Like his contemporaries, James Wilson and Grafton Elliot Smith, Campbell's career was greatly influenced by his rigorous training in the

Figure 4. A.W. Campbell as a neurologist in Sydney. Reproduced from Foley and Storey (2010).

Anatomy Department of the Edinburgh Medical School. After graduating in 1889, he toured European centers of neurology, beginning in London, where he met Hughlings Jackson at Queen Square. He then went to Vienna as an assistant to Krafft-Ebing and finally to Prague, where he began his studies on so-called *polyneuritis alcoholica*, which he considered primarily a central not peripheral nervous system disorder (Macmillan 2009).

In 1892, Campbell was appointed director of pathology at the Rainhill Mental Hospital, near Liverpool, where he undertook "epoch-making studies of the cortex by the almost incredible task of cutting serial sections of each of 25 brains; (and) staining his sections alternately for cells and fibres!" (Fulton 1938). In this work, he was guided by Charles Sherrington, then professor of physiology at Liverpool University

At Rainhill, Campbell aimed to establish a correlation between physiological function and the histological structure of the cerebral cortex. He designated 17 cortical areas and named them with either topographical or provisional functional terms stating that, "not until the ground is prospected and prepared by the physiologist and clinician can the histologist hope to step in and work with any real measure of success" (Campbell 1905). His cytoarchitectonic maps of the cerebral cortex have largely stood the test of time, and he is regarded as one of the founders of the discipline. His seminal paper "Histological Studies on the Localisation of Cerebral Function" (Campbell 1905) was widely quoted by Lorente de

No' in his chapter, "Architectonics and Structure of the Cerebral Cortex," in Fulton's classic text, *Physiology of the Nervous System* (Fulton 1938).

Macmillan (2009) quotes de No' as writing to Fulton:

> [T]he only really good [illustrations] are those of Campbell, who, let me put it in capital letters, HAS BEEN THE ONLY CYTOARCHITECTONIST WHO HAS DESCRIBED FACTS AND ONLY FACTS. The German architectonists have mixed facts with theories in such a manner that nobody can tell where facts end and theories begin.

It will be recalled that de No' had been similarly generous in his acknowledgment of the work of Laura Forster.

Campbell's other significant achievement at Rainhill was his collaboration with Henry Head to map the surface areas of the body innervated by spinal cord segments. For this purpose, they used the strategy of mapping the distribution of herpes zoster lesions in their patients and then patiently waiting until they could perform autopsies (Head and Campbell 1900).

In 1906, Campbell returned to Sydney, where, having been overlooked for the Foundation Chair of Pathology at Sydney University, he practised as a private neurologist until his retirement. Although he published many clinical papers on the neurological and psychiatric disorders he encountered, he lacked time to conduct more systematic research. Nevertheless, at his own expense he persisted in his quest for evidence of localization of function in the cerebellar cortex, not only in humans but also in native fauna and even a gorilla brain provided by Sherrington (Macmillan 2009). However, he failed to find any topology of cerebellar motor functions and concluded that the cerebellum was "a general receiving station for impressions from muscles, bones, and joints, and from the vestibulum" (Campbell 1913).

At the outbreak of World War I, Campbell served as a medical officer in a Cairo hospital, where he dealt with the casualties of the disastrous Dardanelles campaign, including sufferers of "shell shock." His landmark paper describing the features of the condition and advocating for its humane treatment (Campbell 1916) appeared a year before Elliot Smith and Pear's publication, which had similar laudable objectives. Campbell and Elliot Smith shared several neuroanatomical interests, including cerebral and cerebellar functional topography, but they do not appear to have directly interacted.

Despite his manifold achievements, Campbell remained a private person devoted to his family. After his death in 1937, he was lauded both as a founder of cerebral cytoarchitectonics and as the pioneer of Australian neurology (Porter et al., 1993). He has been commemorated by the Australasian Neuroscience Society in the form of the annual A. W. Campbell Award for the best postdoctoral publication.

Raymond Dart (1892–1998)

Raymond Dart (Figure 5) was born in Brisbane in 1892. There have been several published biographies, the most comprehensive being that by Wheelhouse and Smithford (2001). The son of devout Baptists, he intended to become a medical missionary in China. After completing a degree in biology at the University of Queensland, he enrolled in medicine at Sydney University in 1914. There he fell under the influence of James Wilson, who recruited him to help organize the congress of the British Association for the Advancement

Figure 5. Raymond Dart holding the Taung skull and endocranial cast. Image reproduced from University of Minnesota Duluth.

of Science, where he met Elliot Smith, who was to shape his future career in paleoanthropology. In 1919, Dart joined Elliot Smith at University College London, where he honed his comparative neuroanatomy skills. In 1920–1921, he worked on a Rockerfeller Foundation Fellowship with histologist Robert R. Terry at Washington University in St Louis.

In 1924, Dart was dispatched by Elliot Smith to become professor of anatomy at the University of Witwatersrand in Johannesburg. There he found a department in total disarray after the hasty departure of his predecessor following a marital "scandal." Dart emulated Wilson by establishing an anatomical museum and sent his students out fossil hunting, with serendipitous results. Limestone rubble from a quarry called Taung had been dumped in his driveway at the behest of his students, from which, as Dart related with his characteristic flair for the dramatic, he managed to extract, using his wife's knitting needles as chisels, the frontal skull bones of a juvenile hominid, together with a limestone endocranial cast of its brain: "I stood . . . holding the brain cast as greedily as any miser hugs his gold, my mind racing ahead. Here, I was certain, was one of the most significant finds ever made in the history of anthropology!" (Dart and Craig 1959).

Dart's short publication in *Nature* entitled, "Australopithecus Africanus: The Man-Ape of South Africa," was a sensation (Dart 1925). He described the modest brain size of the Taung fossil, the upright position of its foramen magnum, the vertical face and human-like dentition, all of which he intuited was evidence that humans had evolved in Africa from upright bipedal *Australopithecines* several million years ago. However, this proposition was derided by the anthropological establishment, led by its doyen Sir Arthur Keith, because the prevailing paradigm was that humans had evolved in Europe. This view had been reinforced by the so-called "missing link" between man and ape discovered in 1912 at Piltdown, a quarry in Sussex. The Piltdown skull had a large cranial capacity, a prognathous jaw, and robust dentition, characteristics diametrically opposed to those of the Taung fossil. Together with the discovery of large-brained Neanderthals in Europe, this had led to the conclusion that the critical evolutionary event leading to the emergence of Homo sapiens from its hominid predecessors was the development of a larger brain. Dart's intuition was that it was, instead, the freeing of the hands from locomotion and brachiation that facilitated the use of tools in the smaller brained but upright Australopithecines. It was this development of manipulative adaptations, including an opposable thumb, that he argued became a prime driver of brain development (Dart 1973).

It was the discoveries of adult specimens of Australopithecines by Scottish anthropologist Broom and others that led Sir Arthur Keith, Dart's most eminent critic, to aver, "I am now convinced on the evidence presented by Dr. Robert Broom that Professor Dart was right and I was wrong" (Keith 1947).

Although it is now accepted that the genus Homo evolved from the Australopithecines that roamed the African savannah upright 3 to 4 million years ago, what has proved less acceptable are Dart's subsequent speculations that the Australopithecines had developed an osteodontokeratic tool culture that they used to aid their carnivorous diet and as weapons (Dart 1973).

Many of Dart's subsequent forays into social anthropology and archeology have also been disputed, and it is his earlier contributions to neuroanatomy that have endured (Derricort 2009, 2010). Such was the impact of the Taung skull on prevailing views of human brain evolution that, on the occasion of the centenary of the journal *Nature*, its editors selected Dart's 1925 paper as one of the 21 most influential papers it had published in that period (Garwin and Lincoln 2003).

John Eccles (1903–1997)

John Eccles (Figure 6) was born in Melbourne in 1903 and died in Switzerland in 1997. His biographers have provided extensive commentary on his neuroscientific achievements recorded in his 568 publications (Boreck 1998; Curtis and Andersen 2001).

After qualifying in medicine at Melbourne University in 1925, Eccles won a Rhodes Scholarship to Magdalen College, Oxford. Despite his medical degree, he was required to undertake a bachelor's degree in physiology before being permitted to undertake doctoral studies with Sir Charles Sherrington, who was to win the Nobel Prize in 1932 for his classical work on spinal reflexes.

While working with Sherrington on the cause of the synaptic delay they had observed, Eccles became convinced that synaptic transmission in the central nervous system was not chemical, as had been established in the peripheral nervous system, but electrical in nature. This provoked the famous controversy in which Eccles led the "Sparks" camp, proposing synaptic transmission in the central nervous system was electrical, as opposed by the chemical "Soup" camp led by Henry Dale, who had been awarded the Nobel Prize in 1936 for discovering chemical transmission in the peripheral and autonomic nervous systems (Dale 1954).

In 1937, Eccles returned to Australia as director of the Kanematsu Institute in Sydney, where he was joined by two European refugees, Bernard Katz and Stephen Kuffler.

Figure 6. Sir John Eccles. This file comes from Wellcome Images, a website operated by Wellcome Trust, a global charitable foundation based in the United Kingdom. This image is out of copyright.

Together, they constituted probably the most distinguished medical science team ever to work in Australia. Both Katz and Eccles were to win separate Nobel Prizes; Kuffler was probably only denied one by his early death.

Following a dispute with the board of the Sydney Hospital, who moved to get rid of Eccles's animal facility without notifying him, Eccles moved to New Zealand in 1944 as professor of physiology at the University of Otago. For the next eight years, despite a heavy teaching load, he joined his new colleagues, including Archie McIntyre, who were developing the technique of intracellular recording from vertebrate spinal neurons (Eccles, Brock, and Coombs 1951).

In 1952, Eccles joined the John Curtin School of Medical Research at the Australian National University (ANU), where he remained for the next 14 years. There he and his colleagues demonstrated that hyperpolarizing synaptic potentials accompanied spinal motor neurone inhibition and that central synaptic transmission was consequently probably chemical, as in the periphery. This capitulation led Dale (1954) to comment, "a remarkable conversion indeed. One is reminded almost inevitably of Saul on his way to Damascus when sudden light shone and the scales fell from his eyes!"

During this period—which he later referred to as his "golden" research years, working with collaborators from all over the world—Eccles concentrated on synaptic inhibition in the motor neurones of the spinal cord and later extended these studies to the hippocampus and cerebellum. By using clamped membrane potentials and injection of different ion species, they elucidated the ionic basis of inhibitory synaptic transmission. It was this work that led, in 1963, to Eccles being awarded the Nobel Prize, with Andrew Huxley and Alan Hodgkin, "for their discoveries concerning the ionic mechanisms involved in excitation and inhibition in the peripheral and central portions of the nerve cell membrane" (Eccles 1972).

Eccles was greatly influenced by the philosopher Karl Popper, whom he had met in New Zealand, where Popper had taken refuge before World War II. It was Popper's assertion that refutation was a fundamental process in science that influenced Eccles to refute his own cherished hypothesis about electrical synaptic transmission in the central nervous system (Eccles 1976).

Eccles was said to possess extraordinary powers of motivation and stamina, and an exceptional ability to create productive research teams. After being forced into retirement at age 65 by the ANU, he established laboratories in Chicago and Buffalo, but these were less productive years by Eccles's high standards, probably because he lacked the continual influx of talented young investigators on which he thrived at the ANU.

In 1975 he retired to Switzerland, where he wrote several books and many articles on the relation between brain and mind, including "How the Self Controls Its Brain" (Eccles 1994). In his philosophical writing, Eccles adopted a dualist stance on the separation and interaction of mind and brain, even speculating that supernatural forces might mediate their connection. These views on the mind–brain relationship have not been accepted by most neuroscientists (Sperry 1980).

Discussion

This brief account of the lives and work of six Australian neuroscience pioneers, encompassing both the pre- and post-Federation periods, outlined the difficulties imposed by Australia's geographic isolation. Each overcame these difficulties by working overseas for formative periods in their careers.

All six pioneers were medically trained: Forster in Bern, Wilson and Campbell in Edinburgh, Elliot Smith and Dart in Sydney, and Eccles in Melbourne. Although they never collaborated directly with one another, they were linked by shared mentors and sojourns in common laboratories. Wilson and Campbell spent formative years in the anatomy department of Edinburgh University; Wilson mentored Elliot Smith and Dart in the anatomy department of Sydney University; Elliot Smith mentored Dart at University College London; Campbell and Eccles were both mentored by Sherrington, Campbell in Liverpool and Eccles in Oxford; and Forster and Eccles spent critical periods of their careers in the Physiology Laboratory of Oxford University.

Although these Australian neuroscientists shared both the difficulties of isolation and used common strategies to overcome them, an account of their career affinities would not be complete without reference to one striking difference—namely, between those who confined themselves to their neuroanatomical expertise (Forster, Wilson, and Campbell) and those who, in the later stages of their careers, became preoccupied with incursions into other disciplines: social anthropology and archeology in the case of Elliot Smith and Dart, and philosophy in the case of Eccles. These later speculations subsequently come under widespread criticism from their peers in these latter fields.

Compared with the individual isolation in which the early pioneers (apart from Eccles) mainly worked, the succeeding era of Australian neuroscience from the 1960s to the 1980s was characterized by the emergence in discipline-based university departments of collaborative groups with concentrated areas of expertise in cellular electrophysiology, vision, audition, autonomic and enteric nervous function, cardiovascular control, sensorimotor function, and neuropsychology. By the 1980s, there was a sufficient critical mass of neuroscientists in Australia for a third era to develop in which neuroscience became recognized as an interdisciplinary field in its own right. This led to the formation of centers and institutes of neuroscience in many universities, and to the establishment in 1981 of the binational Australasian Neuroscience Society (Abraham et al. 2021).

Almost a century and a half after the earliest Australian neuroscientists began work, the interdisciplinary field of neuroscience has emerged as one of the most productive areas of scientific endeavor in Australia. That is due, in no small measure, to the foundations laid by the early pioneers discussed here.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

The authors reported there is no funding associated with the work featured in this article.

ORCID

Nick J. Spencer http://orcid.org/0000-0003-2190-5303

References

Abraham, W. C., L. Geffen, E. M. McLachlan, L. J. Richards, and J. A. P. Rostas. 2021. A brief history of the Australasian neuroscience society. *Journal of the History of Neurosciences* 13 (4): 395–408. doi:10.1080/0964704X.2021.1970481.

Allen, J. 2010. The curious history of the Talgai skull. *Bulletin of the History of Archaeology* 20 (2):4–12. doi:10.5334/bha.20202.

Blainey, G. 1966. *The tyranny of distance. How distance shaped Australia's history*. Melbourne: Victoria Sun Books.

Boreck, C. 1998. John C. Eccles (1903–1997) neurophysiologist and neurophilosopher. *Journal of the History of Neurosciences* 7 (1):76–81. doi:10.1076/jhin.7.1.76.13093.

Campbell, A. W. 1905. *Histological studies on the localisation of cerebral function*. Cambridge: University Press.

Campbell, A. W. 1913. On localisation of function in the cerebellum. Transactions of the Ninth Session of the Australasian Medical Congress, Sydney, NSW.

Campbell, A. W. 1916. Remarks on some neuroses and psychoses in war. *Medical Journal of Australia* 1 (16):319–23. doi:10.5694/j.1326-5377.1916.tb17824.x.

Curtis, D. R., and P. Andersen. 2001. "John Carew Eccles" biographical memoirs. *Australian Academy of Science* 13 (4): 439–473.

Dale, H. H. 1954. The beginnings and prospects of neurohumoral transmission. *Pharmacological Reviews* 6 (1):7–13.

Dart, R. A. 1925. *Australopithecus africanus*: The man-ape of South Africa. *Nature* 1 (115):195–99. doi:10.1038/115195a0.
Dart, R. A. 1973. Recollections of a reluctant anthropologist. *Journal of Human Evolution* 2 (6):417–27. doi:10.1016/0047-2484(73)90120-6.
Dart, R. A., and D. Craig. 1959. *Adventures with the missing link*. New York: Harper & Brothers.
Dawson, W. R. 1938. *Sir Grafton Elliot Smith: A biographical record by his colleagues*. London: Cape.
Derricort, R. 2009. The enigma of Raymond Dart. *International Journal of African Historical Studies* 42:257–82.
Derricort, R. 2010. Raymond Dart and the danger of mentors. *Antiquity* 84 (323):230–35. doi:10.1017/S0003598X00099890.
Derricourt, R. 2012. Pseudoarchaeology: The concept and its limitations. *Antiguity* 86 (332):524–31. doi:10.1017/S0003598X00062918.
Eadie, M. J. 1981. A. W. Campbell: Australia's first neurologist. *Clinical and Experimental Neurology* 17:27–35.
Eadie, M. J. 2003. Alfred Walter Campbell (1868–1937). *Journal of Neurology* 250 (2):249–50. doi:10.1007/s00415-003-0899-1.
Eccles, J. C. 1972. *Nobel lectures, physiology or medicine 1963–1970*. Amsterdam: Elsevier Publishing Company.
Eccles, J. C. 1976. From electrical to chemical transmission in the central nervous system. *Notes and Records of the Royal Society of London* 30:219–30.
Eccles, J. C. 1994. *How the self controls its brain*. Berlin: Springer-Verlag.
Eccles, J. C., L. G. Brock, and J. S. Coombs. 1951. Action potentials of motoneurons with intracellular microelectrodes. *Proceedings of the University of Otago Medical School* 29:14–15.
Elliot Smith, G. 1902a. The primary subdivision of the mammalian cerebellum. *Journal of Anatomy Physiology* 36:381–85.
Elliot Smith, G. 1902b. On the natural preservation of the human brain in the ancient Egyptians. *Journal of Anatomy Physiology* 36 (Pt 4): 375.
Elliot Smith, G. 1919. *The evolution of the dragon*. Manchester: The University Press, Longmans, Green & Company.
Elliot Smith, G. 1924. *The evolution of man: Essays*. Cambridge: Cambrige University Press.
Elliot Smith, G. 1933. *The diffusion of culture*. 1st ed. London: Watts & Company.
Elliot Smith, G., and T. H. Pear. 1917. Shell shock and its lessons. *Nature* 100 (2500):64–66.
Foley, P. B., and C. E. Storey. 2010. Chapter 48: History of neurology in Australia and New Zealand. In *Handbook of Clinical Neurology*, 95:781–800. doi:10.1016/S0072-9752(08)02148-9. PMID: 19892151.
Forster, L. 1894. Muskelspindeln. *Virchow's Archiv* CXXXVII.
Forster, L. 1902. Note on foetal muscle spindles. *Journal of Physiology* 28 (3):201–03. doi:10.1113/jphysiol.1902.sp000909.
Forster, L. 1911. La degeneración traumatica en la medulla espinal de las aves. *Trabajos del Laboratorio de Investigaciones Biológicas de la Universidad de Madrid* 9:255–68.
Forster, L. 1918. Histological examination of the ovaries in mental disease. *Archives of Neurology and Pathology* 7:1–23.
Fulton, J. F. 1938. Alfred Walter Campbell: 1868–1937. *Archives of Neurology and Psychiatry* 40 (3):566–68. doi:10.1001/archneurpsyc.1938.02270090160010.
Garwin, L., and T. Lincoln. 2003. *A century of nature:Twenty-one discoveries that changed science and the world*. Chicago: University of Chicago Press.
Gine, E., C. Martinez, C. Sanz, C. Nombela, and F. de Castro. 2019. The women neuroscientists in the Cajal school. *Frontiers in Neuroanatomy* 13:72. doi:10.3389/fnana.2019.00072.
Head, H., and A. W. Campbell. 1900. The pathology of herpes zoster and its bearing on sensory localization. *Brain* 23 (3):353–523. doi:10.1093/brain/23.3.353.
Hill, J. P. 1949. James Thomas Wilson, 1861 - 1945. *Biographical Memoirs of Fellows of the Royal Society* 6 (18): 643–660.
Home, R. W. 1988. *Australian science in the making*. Cambridge: Cambridge University Press.

Jefferson, L., K. Bloor, and A. Maynard. 2015. Women in medicine: Historical perspectives and recent trends. *British Medical Bulletin* 114 (1):5–15. doi:10.1093/bmb/ldv007.

Jones, E. W. 1937. Grafton Elliot Smith. Life and work of a famous Australian. *Australian National Review*.

Keith, A. 1947. Australopithecenae or Dartians. *Nature* 159 (4037):337. doi:10.1038/159377a0.

Lorente de Nó, R. 1921. La regeneración de la médula espinal en las larvas de batracio. *Trabajos del Laboratorio de Investigaciones Biológicas de la Universidad de Madrid* 9:147–83.

Macmillan, M. 2009. Evolution and the neurosciences down–under. *Journal of the History of the Neurosciences* 18 (2):150–96. doi:10.1080/09647040701662377.

Macmillan, M. 2016. *Snowy Campbell: Australian pioneer investigator of the brain*. Melbourne: Australian Scholarly Publishing

Morison, P. 1990. Wilson, James Thomas (1861–1945). In *Australian dictionary of biography*, vol. 12. Melbourne University Press. Accessed February 15, 2023. https://adb.anu.edu.au/biography/wilson-james-thomas-9140/text16127 .

Morison, P. 1997. JT Wilson and the Fraternity of Duckmaloi, Rodolpi, Amsterdam-Atlanta Wellcome Institute series in the history of medicine. *Clio Medica* 42:i–xiii, 1–474.

Mott, F. 1921. The psychopathology of puberty and adolescence. *Journal of Mental Science* 67 (278):279–318. doi:10.1192/bjp.67.278.279.

Mott, F. W., and M. P. Such. 1922. Further pathological studies in dementia praecox, especially in relation to the interstitial cells of leydig. *Proceedings of the Royal Society of Medicine* 15:1–14.

Porter, R., R. Lemon, and Physiological Society (Great Britain). 1993. *Corticospinal function and voluntary movement*. Oxford, England: Clarendon Press. http://www.loc.gov/catdir/enhancements/fy0636/93014881-t.html.

Ramón y Cajal, S. 1914. *Estudios Sobre la Degeneración y Regeneración del sistema nerviosa*. Madrid: Imprenta de Hijos de Nicolás Moya.

Ramón y Cajal, S. 1917. *Recuerdos de mi Vida*. Madrid: Imprenta de Hijos de Nicolás Moya.

Serra, M. 1921. Nota sobre las gliofibrillas de la neuroglía de la rana. *Laboratory Investigations Biology* 19:217–29.

Sperry, R. W. 1980. Mind brain interaction. Mentalism yes Dualism no. *Neuroscience* 5 (2):195–206. doi:10.1016/0306-4522(80)90098-6.

Triarhou, L. C. 2020. Pre-Brodmann pioneers of cortical cytoarchitectonics II: Carl Hammarberg, Alfred Walter Campbell and Grafton Elliot Smith. *Brain Structure and Function* 225 (9):2591–614. doi:10.1007/s00429-020-02166-8.

Universität Bern: History of women as university students. Accessed July 12, 2023. https://www.unibe.ch/university/portrait/history/history_of_women_as_university_students/index_eng.html.

Wagner, R. L. 2017. Dr Laura Elizabeth Forster. *Sabretache* LVIII (4):26–38. https://13martyrs.files.wordpress.com/2018/02/forster-article.pdf .

Wheelhouse, F., and K. S. Smithford. 2001. Dart: Scientist and man of grit; biography of famous Australian paleoanthropologist. *Oceania* 72 (2).

Wilson, J. T. 1888. Observations on the innervation of axillary muscular arches (Achselbogen) in man, with remarks on their homology suggested by comparative considerations. *Journal of Anatomy* 22:294–99.

Wilson, J. T. 1889a. Further observations on the innervation of axillary muscles in man. *Journal of Anatomy and Physiology* 24 (Pt 1):52–60.

Wilson, J. T. 1889b. Two cases of variation in the nerve supply of the first lumbrical muscle in the hand. *Journal of Anatomy* 24:22–26.

Wilson, J. T. 1938. Sir Grafton Elliot Smith. 1871–1937. *Obituary Notices of Fellows of the Royal Society* 2:322–33.