

1.2 The Advent of Modern Neuroscience

Central to the structure of scientific revolutions lies the essence of metaphor [120, 328], and the evolution of ideas on brain and behaviour have been no exception. Theories of mind and brain have evolved with a continuous reformulation in terms of contemporary technologies.

A number of developments during the Eighteenth century contributed to a change in metaphor. In 1748, La Mettrie's publication of *L'Homme Machine* suggested the possibility of building a mechanical man as a manifestation of an automaton. Subsequently, the 1751 publication of *Experiments and Observations on Electricity* by Benjamin Franklin ushered in a new way to think about electrical phenomena. By the turn of the Eighteenth century, a major advance was made in the form of Italian scientist Luigi Galvani's experiments on muscles and nerve stimulation. The fluid-mechanical metaphor which dominated the thinking of the times, was gradually replaced by the nerve-as-wire metaphor. This marked a major paradigm shift.

Around 1810, Scottish physician Charles Bell and French physiologist François Magendie established strict one-way transmission along nerve fibres. French physiologist Marie-Jean-Pierre Flourens used the method of *experimental ablation* to establish a link between the cerebellum and coordination of movement, and the cerebrum and sensations in 1823. This opened up the way for the concept of *localization of function*. Flourens was also a vociferous critic of the pseudo-science of *phrenology* put forth by Franz Joseph Gall in 1809. Phrenology correlated the structure of the skull with personality traits, and died its natural death as scientific evidence on the brain accumulated over the years.

In 1848 a foreman called Phineas Gage was supervising the construction of the Burlington railroad in Vermont. While tamping down gunpowder with an iron rod into a hole in a rock which had to be blasted out of their way, a spark ignited the gunpowder. The three and a half foot rod weighing thirteen pounds shot from the hole like a projectile, and pierced through his skull from under his left eye. Although Phineas Gage survived, he was a completely different man, both in terms of his nature and his skills. His survival after such a devastating head injury, and his accompanying personality change from efficient and friendly foreman to evil tempered and clumsy child, created a radical change in man's understanding of the human brain. News about the incident soon spread, and neurologists began to observe the symptoms of human patients who suffered restricted damage to parts of the cerebral hemispheres, and suggested that the control of movement, sensations and speech were strictly *localized* within the brain.

The study of *aphasia* (*a* is Greek for "without"; *phasia* is Greek for "speaking") led to significant advances in the theory of localization of

For an anecdotal account of this incident see [43, 57].

function. An initial advance occurred in 1861 with the publication of a paper by the French neurologist Pierre Paul Broca where he described the case of a patient who could understand language but who had lost the ability to speak. Post mortem examination (see Fig. 1.2) revealed a lesion in the posterior portion of the frontal lobe of the brain, now called *Broca's area*.

Broca's aphasia is also called a motor or nonfluent aphasia. Patients suffering from this aphasia speak slowly and with great effort. Sounds are not clearly articulated and speech is grammatically incorrect, although comprehension remains relatively intact. Patients suffering from Wernicke's aphasia speak fluently but their comprehension is poor. Wernicke aphasics make paraphrastic errors, incorrectly sequence sounds and speak sentences that usually border on gibberish.

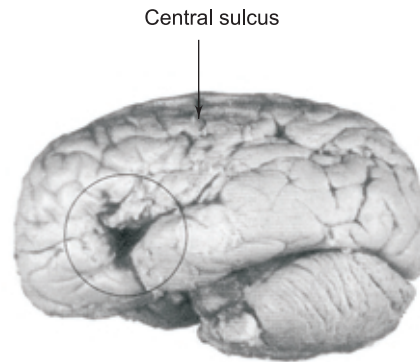


Fig. 1.2 The brain of Broca's patient showing the lesion in the posterior portion of the frontal lobe [111]

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In 1870, German physiologists Gustav Theodore Fritsch and Eduard Hitzig discovered that electrical stimulation of the *pre-central gyrus* in front of the *central sulcus* caused movements of the limbs in dogs. Removal of the same region caused paralysis. And in 1876, Karl Wernicke described a new type of aphasia that involved an impairment of speech comprehension in a patient who could speak clearly. The brains of people who suffered from Wernicke's aphasia revealed a lesion in an area now referred to as *Wernicke's area*. In patients suffering from Wernicke's aphasia, speech is fluent, but does not make any sense. He used his findings with those of Broca, Fritsch and Hitzig to argue that fundamental mental functions are discretely localized. Wernicke also suggested that the same function is processed in parallel over distributed regions of the brain. This is very similar to the underlying philosophy of *parallel distributed processing* which forms the basis of modern neural networks.

The final confirmation of the theory of localization of function came towards the middle of the Twentieth century. In the late 1950s Canadian neurosurgeon Wilder Penfield stimulated the cortex of conscious patients during brain surgery for epilepsy carried out under local anaesthesia. His findings based upon verbal reports of these patients, dramatically confirmed the theory of localization [497]. Tiny electrical stimulations at specific sites elicited diverse experiences: memories, smells, sounds and colours. Penfield

then went on to extend the work of Hitzig and Fritsch that body muscles mapped topographically on to specific cortical areas.

Research during the early Twentieth century put modern neuroscience milestones ahead on the road to understanding the working of the human brain. Advances in the histology of the nervous system provided a major impetus. Camillo Golgi developed the histological silver impregnation method that allowed visualization of the neuron with all its processes. Santiago Ramón y Cajal developed some of the key conceptual insights and much of the empirical support for the neuron doctrine—the principle that the nervous system is made up of discrete signalling elements called neurons. An example of one of his detailed drawings appears in Fig. 1.3.

Cajal is often known as the father of modern brain science. He called neurons “... the mysterious butterflies of the soul, the beating of whose wings may some day ... clarify the secret of mental life [146].” The investigations of these celebrated scientists (Golgi and Cajal) culminated in their sharing the sixth Nobel Prize for medicine in 1906. Finally, the physiological studies of Charles Sherrington on reflex behaviour led to an understanding of the inhibitory and excitatory nature of synapses—points at which neurons communicate [43].



The microscopic study of tissue structure is called *histology*. Although slices of brain tissue look uniform, pigmentation techniques in neurohistology allow the selective colouring of some neurons which have a diameter of about 0.01 to 0.05 mm. The Nissl stain employs Cresyl violet and reveals only cell bodies and some material surrounding the neuron. The Golgi stain works by soaking a slice of brain tissue in silver chromate solution whereupon some cells get darkly stained in their entirety.

Fig. 1.3 One of Cajal's drawings of neuronal circuits [125]
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