Peter M. Milner, 1919–2018

Peter Marshall Milner, a British-trained electrical engineer who worked on radar and atomic energy during the Second World War, who later trained as a neuroscientist at McGill University and then taught and did research there for many years, died on June 2, 2018, at the age of 98. He was best known as the co-discoverer of electrical self-stimulation of the brain, together with the late James Olds.[1] The discovery, which occurred as the result of a fortuitous accident,[2,3] was one of the first demonstrations of direct control over behaviour by artificial activation of specific parts of the brain that came to be known as "pleasure centres."[4] The publication of this finding in 1954 created much interest in the investigation of the neural basis of behaviour. The phenomenon was studied in laboratories all over the world, resulting in thousands of publications. Many students were attracted to study the brain–behaviour relationship by the demonstration of self-stimulation, and they became working neuroscientists who have made numerous contributions to all areas of neuroscience. The discovery helped to advance our understanding of how behaviour is controlled by its consequences and provided an important foundation for the study of drug addiction.[5–11]

Milner was born in 1919 in Silkstone Common and grew up in Barnsley, in south Yorkshire, England. He studied science at Barnsley Grammar School and graduated from Leeds University with a degree in electrical engineering in 1941. He was immediately given a position at the Air Defence Research and Development Establishment, where the first radar systems were being developed for defence against airborne attack. Milner was assigned to work on the method of displaying the array of aircraft flying in the vicinity to the operators. In this task he was helped by "a young Cambridge psychology graduate called Brenda Langford,"[12] who was in charge of testing the various versions of the display and controls on the operators. In the fall of 1944, with the war winding down, Milner was asked if he was interested in going to Canada for two years to work on atomic energy. By this time, he and Langford had "become close," and they decided to marry so that she could accompany him to Canada.

A nuclear reactor was built in Chalk River, Ontario, and Milner worked there for two years. Langford remained in Montreal during this time, teaching a course at the University of Montreal. She also took some courses at McGill, in particular a graduate seminar offered by D.O. Hebb, and became his graduate student. Milner read the material from Langford's courses, including the manuscript of a book Hebb had written, *The Organization of Behaviour*.[13] Milner was fascinated by the ideas in that book and he decided that studying them would be a more interesting way to spend his life than designing electrical components. Accordingly, he asked Hebb to supervise him as a graduate student. Hebb agreed, provided Milner took a year of undergraduate psychology courses first. McGill was setting up its research cyclotron at that time and, because of his experience at Chalk River, Milner was able to get a part-time job constructing instruments for them. He completed his qualifying year and became a graduate student. It was during his graduate student years that he and Olds collaborated on the discovery of self-stimulation.

Milner's doctoral thesis, *Effects of Intracranial Stimulation on Rat Behaviour*,[14] examined the effects of electrical stimulation of the reticular formation of rats on time estimation. After completing the thesis, Milner was given a postdoctoral position that included some teaching. One of his first contributions during this period was a paper, "The cell-assembly: Mark II,"[15] which proposed a modification of the theory of the neural control of behaviour Hebb had presented in his book. Hebb had postulated the "cell assembly," a connected network of neurons that represented a perception. These assemblies were created by recursive neural activity that recruited new neurons and strengthened the synaptic connections between them. Milner saw a parallel between this process and the atomic chain reactions he had been working with at Chalk River. An unrestrained chain reaction was a positive feedback system that resulted in an atomic explosion. One of the main problems in designing a reactor for peaceful purposes was to restrain the growth of the reaction. Milner saw that Hebb's proposal would result in similar unrestrained growth of cell-assemblies and proposed an inhibitory process that would limit their growth.

The ideas in Hebb's book and Milner's Mark II paper also interested a group of computer scientists at the IBM laboratories in Poughkeepsie, New York, where the first work on computers and what they could do was getting underway. Milner was hired as a consultant, on the basis of his paper and a recommendation from Hebb, in the field that would become known as artificial intelligence.

In 1956, Milner was appointed as an assistant professor in the McGill Psychology Department, with a full load of teaching and research supervision responsibilities. His major undergraduate course was called Physiological Psychology, and he began creating small booklets of notes explaining the topics covered. Milner was a shy man who did not take to lecturing naturally. During his lectures he often addressed the blackboard while writing key words and concepts or drawing simple diagrams to illustrate the results of experiments. In fact, it was often difficult for his students to follow what he was trying to say. Several of them, who were particularly interested in the subject, spent time in the library after each of his lectures reading the papers he had discussed and trying to understand them. So, inadvertently perhaps, those students got an excellent education in the subject.

In 1970, the various notes that Milner had provided to his classes were combined and published as a textbook, *Physiological Psychology*.[16] It was an unusual book because it did not simply recite facts, but attempted to present a consistent theoretical view of the subject. It was very highly regarded, dominated the market for several years and was translated into several languages.

Among other papers, in 1974 Milner published "A model for visual shape recognition,"[17] in which the problem of stimulus equivalence was explained on the basis of convergence and recursive feedback among the cell-assemblies representing visual perceptions. "Brain-stimulation reward — a review"[18] was published in 1991, and "The psychobiology of reinforcers"[19] (with N. White) was published in 1992.

Milner's last major publication (1999) was a short monograph, *The Autonomous Brain: A Neural Theory of Attention and Learning*.[20] In it, he reverted to his original interest in the field, using up-to-date information about the brain to understand the problems of perception, motivation and learning, in which his interest had initially been aroused by reading *The Organization of Behaviour*.[13] Milner posits that the main impetus for behaviour is not external stimulation (the "reflex model"), but the internal activity of the brain and its plans for action, often based on internal needs. This activity influences both the sensory systems to select percepts pertinent to a plan, and the motor system to select actions required to carry out the plan.

During his career at McGill, Milner trained a number of graduate students and postdoctoral fellows who went on to make their own contributions to various areas of neuroscience. They include John Pinel (University of British Columbia), W. Mac Burnham (University of Toronto), Ronald J. Racine (McMaster University), Richard J. Beninger (Queens University), Graham Goddard (Dalhousie University, University of Otago), Shinshu Nakajima (Dalhousie University), Michael Corcoran (University of Saskatchewan), Aaron Ettenburg (University of California, Santa Barbara), Patrick Mason (Air Force Research Laboratory), Imre Szabo (University of Pécs), Dale Corbett (Memorial University of Newfoundland) and Keith Franklin (McGill University).

In 2005, Milner received the Gold Medal for Distinguished Lifetime Contributions to Canadian Psychology from the Canadian Psychological Association. The award recognized both his major influence on the development of the field now known as behavioural neuroscience and his exceptional contribution of ideas to the understanding of basic psychological processes.

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