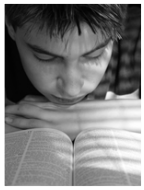
D.O. Hebb
1904-1985

The Legacy of Donald O. Hebb

Donald Hebb was born in Chester, Nova Scotia, in 1904.

Both his parents were country physicians.

The young Donald Hebb was a precocious and voracious reader.



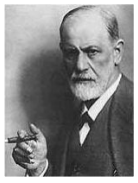
When he was 16, the family moved to Dartmouth NS and the following year, Hebb entered the Faculty of Arts at Dalhousie University in Halifax.

Hebb majored in English with the intention of becoming a novelist.

He graduated with a B.A. in 1925 and taught at his old school in Chester for a year. This was not a success and his novel writing did not progress.

He went out west and worked at harvesting in Alberta and then spent time as a labourer in Quebec

… and he began to read Freud!



Hebb approached the Chair of the Department of Psychology at McGill, W.D. Tait, about doing graduate work.

He was given a reading list, which included works by William James and the *Elements of Physiological Psychology* by G.T. Ladd and R.S. Woodworth, and was told to come back in a year.

A year later, in 1928, Hebb was accepted as a part-time graduate student.

At the same time, he obtained an appointment as headmaster of a working class school in Montreal

There was a high rate of absenteeism and poor performance in the school

Together with two professors from McGill, Kellogg and Clark, Hebb improved attendance by making the school work more interesting and using 'time-outs' for disruptive behaviour. It worked!

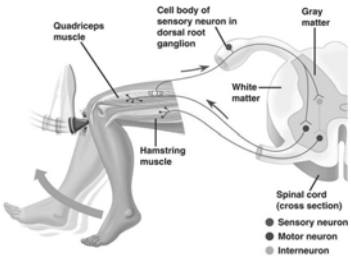
In 1931, Hebb was bedridden with a tubercular infection of the hip.

During this time he read Sherrington's "*Integrative Action of the Nervous System".*

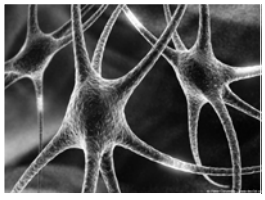
Sir Charles Sherrington
1857-1952

Sherrington, who was awarded the Nobel Prize for Physiology in 1932, was widely regarded as Britain's greatest physiologist.

He established the nature of spinal reflexes – and how they interacted in the production of more complex behaviour.

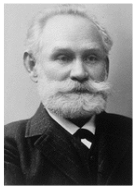


According to Sherrington, the nervous system acts as the coordinator of various parts of the body and that the reflexes are the simplest expressions of the interactive action of the nervous system.



His book *"The Integrative Action of the Nervous System"* is often compared to Newton's "Principia" in terms of its impact on the field.

Hebb also began to read Pavlov's *'Conditioned Reflexes'* which had been translated into English in 1927.



Ivan Petrovich Pavlov
1849-1936

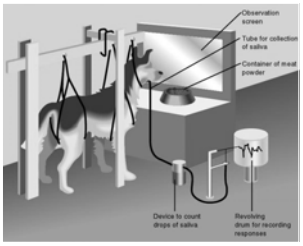
Pavlov's work was the culmination of a long physiological tradition in Russia in which physiologists attempted to explain complex behaviour by beginning with simple reflexes.

Pavlov was interested in gastrointestinal secretions -- how different parts of the gastrointestinal (GI) tract responded to food items.

In fact, he got the Nobel Prize in Physiology in 1905 for his work on the gastrointestinal tract

But that's not why he is famous of course.

In carrying out his work, Pavlov would make holes or fistula in different parts of the GI tract and put food (meat powder) directly into the mouth or stomach. He would then measure the time it took for secretions to be produced and how much was produced.

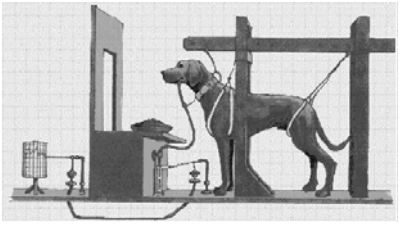


But he was bothered by a persistent phenomenon that would often disrupt his measurements.

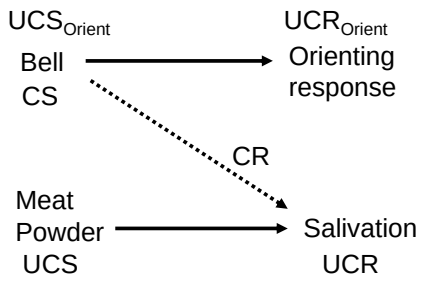
Sometimes the dog would start to salivate as soon as Pavlov walked into the room!

He called these secretions that occurred even before the meat powder was put into the dog's mouth, psychic secretions.

Pavlov soon realized that such secretions could be studied systematically and he spent many years studying them.



"Psychic Secretions"



The term 'psychic secretions' was eventually replaced with the term, conditioning, and eventually became known as Classical Conditioning or Pavlovian Conditioning.

A Clockwork Orange
Stanley Kubrick's 1971 film from a novel by Anthony Burgess

Hebb was enormously influenced by Sherrington and Pavlov – and embarked on what was to become an immensely successful career in studying the neural substrates of learning and perception.

He finished his M.A. thesis in 1931. It was a theoretical rather than an empirical thesis – and was called "*Conditioned and Unconditioned Reflexes and Inhibition".*

In that thesis, one can see the seed of his later ideas on what was to become known as "Cell Assembly Theory" or reverberating circuits.

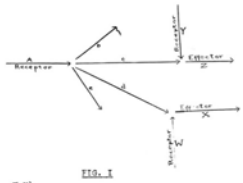


FIG. I

W-Y} reflex arcs.
Y-Z}

A is another receptor.
b,c,d,e, connecting neurons.
(Arrowhead gives direction in which impulses are transmitted.)

In Hebb's own words:

"An excited neuron tends to decrease its discharge to inactive neurons, and increase this discharge to any active neuron, and therefore to form a route to it,whether there are intervening neurons between the two or not. With repetition this tendency is prepotent in the formation of neural routes."

One can see the direct link with Pavlov and Sherrington -- and also with Ariëns Kappers who in 1928 published his theory of neurobiotaxis, proposing that axons, regardless of whether they are being fired, grow towards active cells during development.

The thesis was passed *cum laude* by two examiners – one of whom was Boris Babkin, who had worked with Pavlov in St. Petersburg

Boris Petrovich Babkin
1877-1950

Babkin arranged for Hebb to conduct research on Pavlovian conditioning with Leonid Andreyev, who had also come from Pavlov's laboratory to pursue his research at McGill.

In 1934, Hebb wrote an unpublished manuscript entitled *"Scientific Method in Psychology: A Theory of Epistemology Based on Objective Psychology".*

Many of the ideas that Hebb later incorporated into his famous 1949 book *"The Organization of Behaviour"* can be seen in this unpublished work.

But by 1934, Hebb had become disillusioned with Montreal and McGill. His wife had died on his 29th birthday, after a car accident. Moreover, he felt that the Pavlovian conditioning he was studying was sufficiently related to brain.

After deciding that he wanted to study the brain, Hebb wrote to Robert Yerkes at Yale, but in the end, on the advice of Babkin, he decided to go to the University of Chicago to work on his Ph.D. with Karl Lashley.

Lashley was a brilliant experimentalist who worked on memory and vision. He challenged the notion of localization of function and put forward the ideas of mass action and equipotentiality.

Karl Spencer Lashley
1890-1958

The principle of mass action states that in many types of learning the cerebral cortex acts as a whole.

Lashley argued that the brain is sufficiently plastic that when one region is damaged another region can take over the functions of that region. This is the principle of *Equipotentiality*. In its strongest form: any part of the brain can take on the function of another part.

Hebb's Ph.D. thesis was entitled *"The problem of spatial orientation and place learning".*

But before the research was completed, Lashley had accepted a position at Harvard. Hebb went with him and was accepted as a Ph.D. student at Harvard in 1935, but he had to change his research topic.

In the spring of 1936, Hebb submitted a thesis on the vision of rats reared in darkness, and he received a Harvard Ph.D.

In 1937, Hebb was appointed to a fellowship at the Montreal Neurological Institute. He was recruited to help Wilder Penfield assess the psychological effects of brain operations. He returned to Montreal with his new wife, Elizabeth.

Wilder Graves Penfield
1891-1976

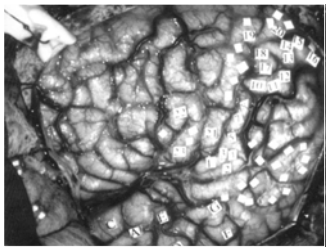
Penfield, an American who trained at Princeton, Oxford, and Johns Hopkins, was heavily influenced by Sherrington, who had met while at Oxford. In fact, after Penfield completed his M.D. at Johns Hopkins, he returned to Oxford for graduate studies in neurophysiology under Sherrington's supervision.

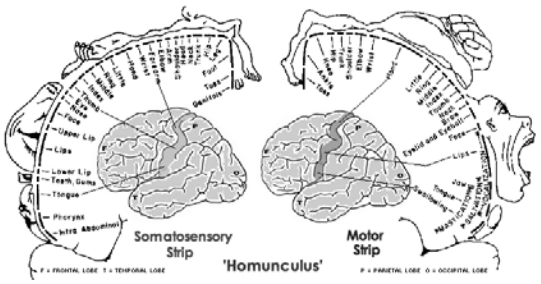
Merton College, Oxford

Penfield abandoned neurophysiology to become a neurosurgeon – in part because he wanted to learn more directly from the exposed brain ("neurology-in-action", he called it). He dreamed of an institute where teams of neurologists, neurosurgeons, and psychologists could work together to study the brain.

In 1934, with money from the Rockefeller Foundation, he founded the Montreal Neurological Institute (MNI).

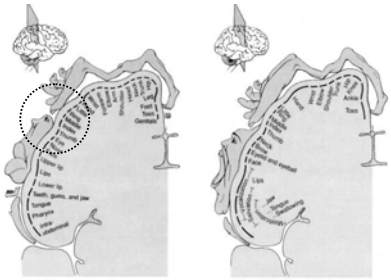
Penfield developed the technique of direct electrical stimulation of the brain, which he used during the operation to help plan the surgery.



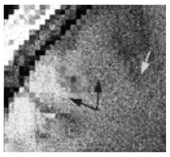


The Sensory Homunculus

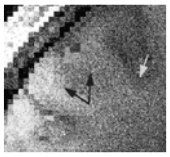
An error in Penfield's sensory map!



Servos, P., Engel, S., Gati, J., Menon, R. (1999). fMRI evidence for an inverted face representation in human somatosensory cortex. *NeuroReport* 14: 1393–1395



Forehead

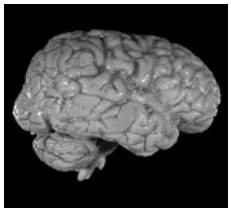


Chin

But back to Hebb.

To assess the effects of removing different parts of the brain, Hebb assembled a set of different psychological tests. This was the birth of neuropsychology at the MNI.

Hebb showed that the right temporal lobe played a role in visual perception and that the frontal lobes play their most important role in early learning.



Hebb became more and more interested in the effects of early experience on later cognitive performance. He compared learning in rats who were reared in normal cages with learning in rats who were kept in his home as pets.

Chester Nova Scotia
Summer 1942

Hebb concluded “there is a lasting effect of infant experience on the problem-solving ability of the adult rat.”

He also showed that the effects of brain damage on intelligence depended on the age at which the damage occurred.

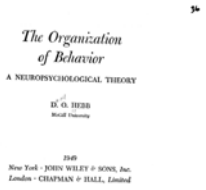
These ideas formed the basis of one of the most powerful ideas in developmental psychology: that early experience plays a powerful organizing role in later behaviour.

These ideas also led to the introduction of early instruction programs such as “Head Start”

In 1942, Karl Lashley took over as Director of the Yerkes Laboratories of Primate Biology at Orange Park, Florida. He invited Hebb to join him to study emotional and cognitive behaviour in chimpanzees.

In the five years he spent there, before returning to McGill, Hebb studied the expression of fear and anger in chimps. He showed that they had an apparently ‘innate’ fear of snakes and dead bodies.

All of Hebb’s thoughts on the formation of new brain circuits, perceptual learning, the influence of early experience, and the effect of brain lesions on behaviour were combined in his 1949 book “The Organization of Behavior”.

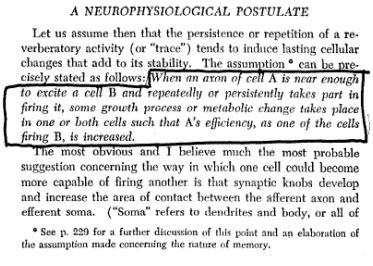

The Organization of Behavior

A NEUROPSYCHOLOGICAL THEORY

D. O. HEBB

1949

New York - JOHN WILEY & SONS, *Inc.*
London - CHAPMAN & HALL, *Limited*


A NEUROPHYSIOLOGICAL POSTULATE

Let us assume then that the persistence or repetition of a reverberatory activity (or "trace") tends to induce lasting cellular changes that add to its stability. The assumption * can be precisely stated as follows: *When an axon of cell* A *is near enough to excite a cell* B *and repeatedly or persistently takes part in firing it, some growth process or metabolic change takes place in one or both cells such that* A*'s efficiency, as one of the cells firing* B*, is increased.*

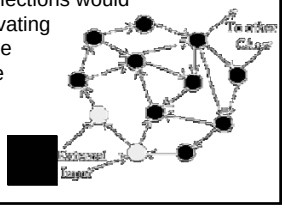
The most obvious and I believe much the most probable suggestion concerning the way in which one cell could become more capable of firing another is that synaptic knobs develop and increase the area of contact between the afferent axon and efferent soma. ("Soma" refers to dendrites and body, or all of

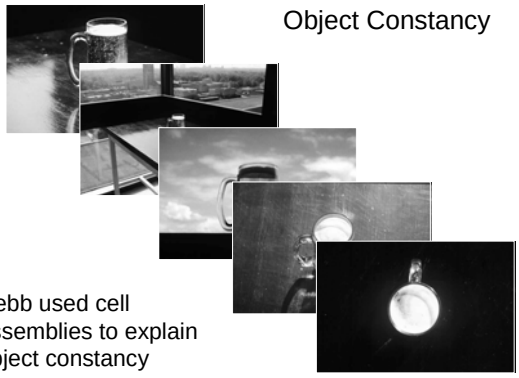
* See p. 229 for a further discussion of this point and an elaboration of the assumption made concerning the nature of memory.

The first idea was that connections (the synapses) between two neurons could alter with time. If the neuron providing the signal (the *pre-synaptic neuron*) and the neuron receiving the signal (the *post-synaptic neuron*) were both active, then the strength of the synapse would increase. This has become known as *Hebbian learning.* The idea was expanded later to include the strength of the synapse weakening if one neuron was active and the other was not.

The second idea was Hebbian learning would set up loops or cell assemblies, i.e. if neuron A fired and activated neuron B, which fired and activated neuron C, which in turn fired and activated neuron A again, then the synapses linking these neurons would all strengthen and increase the possibility of the whole thing happening again in the future.

In practice, *cell assemblies* would consist of many thousands of cells, but the connections would develop in such a way that activating any part of the loop would cause The rest of it to activate and the whole process would be self-sustaining.





Object Constancy

Hebb used cell assemblies to explain object constancy

Hebb argued that in infants and children, learning involves setting up new cell assemblies.

In adults, however, learning more often involves fine-tuning existing cell assemblies.

"The Organization of Behavior" was a book well ahead of its time.

It had a huge influence on the field of behavioural neuroscience, which in some ways Hebb can be credited with founding.

"Few people today would defend the nuts and bolts of Hebb's neuropsychological theory of perceptual learning, but it provided a goal towards which psychological theory should move, and showed what could be done as anatomical and physiological knowledge expanded. The ensuing progress in that direction more than justifies the acclaim that Hebb's speculations have enjoyed for the last half-century."

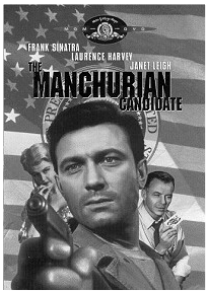
Richard Brown and Peter Milner. The legacy of Donald O.Hebb: more than the Hebb Synapse. *Nature Reviews Neuroscience* 4: 1013-1019.

Sensory deprivation

"The aim of the project was to obtain basic information on how human beings would react in situations where nothing was happening. The purpose was not to cut individuals off from any sensory stimulation whatever, but to remove all patterned or perceptual stimulation, so far as we could arrange it."

The research was sponsored by the Canadian Defense Research Board in an attempt to solve a specific problem: the effect of sensory deprivation on workers such as radar observers who have extremely monotonous jobs. These individuals sometimes see and hear things which aren't real and this can affect their performance.

It also offered the possibility of "breaking people down" during interrogation. All of this research was happening at the height of the Cold War, and it was rumored that the Soviets had developed sophisticated "brainwashing" techniques, as they were called.



Volunteer students placed in sensory isolation for over two to three days became depersonalized and unable to think, and they experienced hallucinations; they were then receptive to attitudinal change.

Hebb was an inspirational teacher who had a profound effect on the intellectual lives of many undergraduate and graduate students at McGill.

Hebb believed that graduate students should be judged on their intelligence and motivation to do research, and their ability to think and do, rather than on their ability to memorize the work of others.

Hebb trained many influential scientists:

Peter Milner and his student, James Olds

Self-stimulation for brain reward

Brenda Milner

Patient HM, memory, and the hippocampus

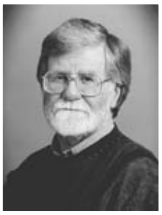
Mort Mishkin

Role of the temporal lobes in object recognition

Gordon Mogenson

Links between motivational brain and motor control

Case Vanderwolf



The organization of electrical activity in hippocampus and cortex

Doreen Kimura

Sex, cognition, and the brain

Ronald Melzack

Neural basis of pain

Stevan Harnad

Former Editor '*Behavioural and Brain Sciences*'

And a legion of others, including …

Rod Cooper

Woodburn Heron

Bernard Hymovitch

Seth Sharpless

Donald Forgays

Helen Mahut

Both the Canadian Psychological Society and the Canadian Society for Brain, Behaviour, and Cognition have research excellence awards named after Donald Hebb.

In Canada, many researchers in behavioural neuroscience (including me) are intellectual grandchildren or great-grandchildren of Donald O. Hebb

D.O. Hebb
1904-1985