Dynamic Psychology and Neuroscience

Different approaches to thinking about mind and the brain

Waseda University, SILS,
History of Modern Earth and Life Sciences

The mind and the brain

In the 20th century, there were two main trends in exploring the human mind. One – which we can regard as psychological – attempted to develop theories of the normal and pathological function of the mind based on *phenomenological* investigations of the patterns of human thought and behavior, largely from an observational perspective, but also involving experiments dealing with human behavior. The second – which we can call psychiatric or neurological – sought to develop low-level, or reductive, understanding of the *physiological* function of the nervous system and brain. This approach was based on the methodologies of experimental physiology, involving carefully controlled and reproducible experiments of physiological function.

Broadly speaking, psychology began by taking a fairly holistic approach while neurophysiology took a reductionist approach.

Dynamic psychology

Dynamic psychology arose around the end of the 19th century, out of a background of practices of animal magnetism and studies of hypnosis. In the first decade of the 20th century, a number of physicians and psychiatrists began publishing theories of human psychology that involved descriptions of a *subconscious* or *unconscious mind* and a dynamic tension between the thoughts, ideas and will of the conscious mind with the desires and impulses of the unconscious mind – implying that the two might be at odds with one another.

Dynamic psychology was articulated in a range of theories that attempted to describe the workings and failings of the human mind as a dynamic system with its own set of structures, principles and perhaps laws, that were not fundamentally determined by the physicality of human biological existence – or at least, could could be articulated without reference to any neurological basis.

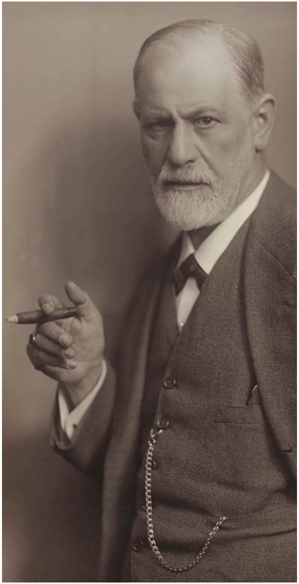
Psychological analysis

Pierre Janet (1859–1947) was a psychiatrist educated in philosophy and medicine at the Salpêtrière Hospital, Paris. He worked at the Sorbonne and the Collège de France as chair of experimental and comparative psychology.

He elaborated a theory of the two main neuroses of the time, *hysteria* and *psychasthenia* (or *neurasthenia*), using concepts like *psychological force* and *psychological tension* (individual's capacity to use such force). He hoped to make a *physics of mental illness* based on a lack of balance in these factors.

He stipulated a hierarchy of psychological tendencies: lower as reflective or sociopolitical, middle as reflective actions or beliefs, and higher as rational or experimental. This gave him an architecture to develop a *highly explanatory* theory in which he claimed that some actions and beliefs that functioned at lower levels are unconscious – what he called *idées inconscientes* or *idée fixe subconsciente*

Sigmund Freud (1856–1939)



- Born to a middle class Jewish-Austrian family.
- Took a degree in neurology and spent 6 years studying brains and nerve tissue.
- Switched to medicine, took an MD, and worked at Vienna General Hospital, publishing on cocaine and aphasia.
- Started a private practice specializing in nervous disorders and developed *psychoanalysis*.
- His writings on dynamic psychology attracted a wide readership.
- Died in Britain a year after fleeing the Nazis.

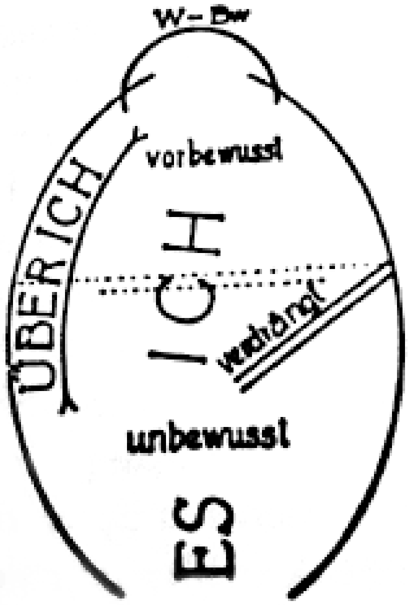
Psychoanalysis

After some time spent working with his patients using hypnosis, Freud developed a program of therapy that involved allowing his patients to talk freely without inhibition about whatever thoughts, memories or feelings came to them, through a kind of *free association*. He would then analyze this material, along with their accounts of their dreams, to try to *explain* their neuroses.

He developed the theory that all neuroses were the result of repressed feelings and memories, usually about things that had happened in one's childhood. He postulated the existence of a sexual mental energy, the *libido*, which generates erotic attachment, compulsive behaviors, hate, aggression and guilt. In particular, he proposed that the sexual feelings and experiences of one's childhood had a profound effect on later life. This lead to an elaborate theory of the unconscious and a model of psychic structure comprising *id*, *ego* and *super-ego*.

Freud's schema of the divisions of the self, with perception-conciousness on top, then pre-conciousness, then the *ego* (Ich) with repressed ideas and experiences going into the *id* (Es), and the *super-ego* (Überich) on the left.

He believed, or hoped, that some physiological structure in the brain would be later be found to confirm these ideas.



Individual psychology

Alfred Adler (1870–1937) was a Jewish-Austrian doctor and psychotherapist who emigrated to the US during the Nazi purges. He had worked with Freud but later moved away from his teachings.

He argued that personality should be explained *teleologically* as an attempt to convert feelings of inferiority, or inadequacy, into those of superiority, or completeness, by meeting social and ethical demands. When this failed to happen in a normal way, the individual developed an *inferiority complex*. He stressed the role of birth order in families in the development of one's personality.

He held strongly critical views on behaviors that he regarded as aberrant – such as prostitution, criminality and homosexuality.

Analytical psychology

Carl Jung (1875–1961) was a Swiss psychiatrist who had worked with both Janet and Eugen Bleuler (1857–1939). He had a long correspondence with Freud, followed by a dramatic falling out. Jung developed a psychology based on Romanticism and a return to the Germanic *Naturphilosophie*. In particular, he rejected Freud's overtly sexual ideas, such as the Oedipus complex and the libido.

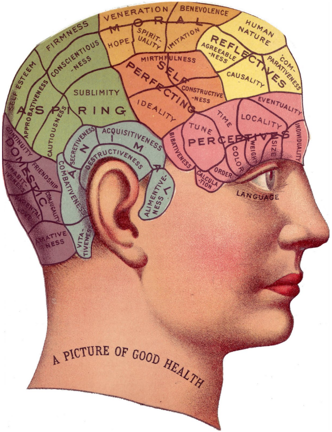
Jung developed a highly spiritual system of psychology centered around interpreting figures from myths and religions as universal *archetypes* that occur in dreams and form our concepts of ourselves and others – through both an *individual* and a *collective unconscious*. He considered the main task of human development to be *individuation* – the process of differentiation of the conscious self from both conscious and unconscious elements. The role of the psychologist was to help in this process.

The allure of explanation

The founders of dynamic psychology produced elaborate theories that had broad appeal and were able to explain many features of human behavior, whether normal, abnormal or pathological. This *power of explanation* was quite expansive and many people were convinced by this that these theories must be correct, or based on some truth.

There was concern, however, that these sorts of theories might be *too explanatory*. Especially in the hands of these masters, the mature theories of dynamic psychology seemed capable of *explaining everything*. The Austrian philosopher Karl Popper (1902–1994) recalled that when he was a young man he tried to raise counterexamples to Adler, for whom he worked, but Adler was always able to explain away every counterexample. If there was no possibility of a counterexample, how could one decide between different theories? People began to raise doubts that dynamic psychology was a science at all.

Phrenology



Phrenology was a medico-psychological discipline, which was started by Franz Gall (1758–1828), that became popular and widely practiced in the middle of the 19th century. Although never universally accepted, it was fairly successful for some decades, with meetings, societies and journals.

Phrenology attempted to locate mental faculties and personality traits with specific locations in the brain. In this sense, it was a *materialist* approach to thinking about psychological function.

Pierre Broca (1824–1880) was a clinical surgeon who later became a professor of pathology and surgery in Paris. After listening to a lecture on aphastic patients (showing various dysfunctions of speech), he encountered a patient who could only say the word "tan," although he seemed to understand language and to be intelligent. When Tan (Leborgne) died, Broca autopsied him and found a hole the size of an egg in his brain – publishing an account of his discovery in 1861. Over the next two years, Broca autopsied nine more aphasic patients and found that they all had brain damage in the same location in the brain. This region was later called Broca's area.

(Broca was also an extreme racist, who believed that humans are five or six *different species*, made up of many races, all of the same genus.)

Wernicke's area

In 1874, Karl Wernicke (1848–1905) published a study based on the results of his work under Theodor Meynert (1833–1892) in Vienna investigating a type of aphasia that involved fluent, but unintelligible, speech. This form of aphasia was associated with damage to a region of the brain where the auditory nerve joins the brain. In his work, he put forward a new theory of how language is handled by the brain – namely, that it is processed at one location and then produced at a separate location.

Based on this theory he predicted that there must be nerve fibers joining the two regions and that if this pathway were damaged a person would be unable to fluently or accurately repeat words that were spoken to them. Psychiatrists later identified patients of this type who cannot accurately repeat verbal material, especially abstract words, despite the fact that they are aware of their mistakes.

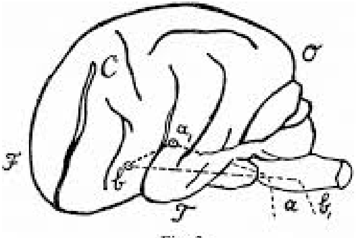


Fig. 3.

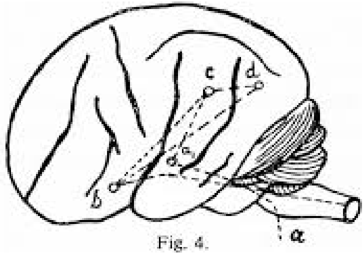


Fig. 4.

Wernicke's proposal for how language is processed: He argued that language is processed at a and a_1 (Wernicke's Area) and produced at b (Broca's Area).

The motor cortex

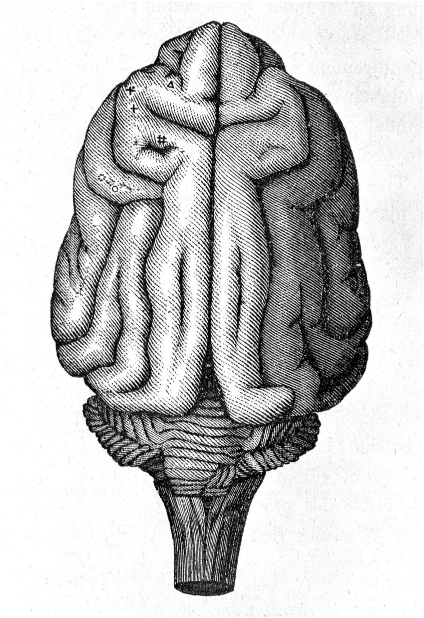
In 1870, Gustav Fritsch (1838–1927) and Eduard Hitzig (1838–1907) carried out a series of experiments in Hitzig's house, using his wife's dressing table, in which a dog was tied down, and part of its cranium was exposed – with no anaesthesia. Using a fine platinum electrode attached to a battery, they passed low current over the surface of the brain.

When a weak current was passed, they observed twitching in specific limbs on the opposite side of the dog's body, and when a stronger current was passed, they observed strong muscular contractions. In this way, they localized areas that controlled the movement of the neck, forearm, paws and face.

They confirmed these localizations by cutting out specific parts of the brain and observing that the dog was then unable to use the corresponding limb or location properly.

Dorsal view of a dog's cerebral cortex showing the areas that Fritsch and Hitzig stimulated to induce movement

(Diagram from one of their publications)

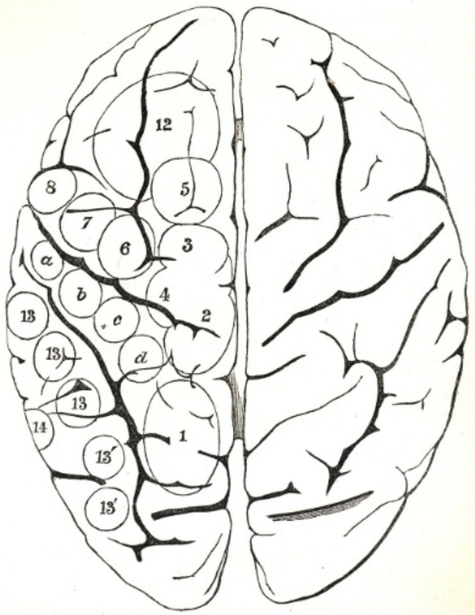


Localization in the primate brain

In the 1870s, David Ferrier (1843–1928), a Scottish physician working at King's College Hospital, London, carried out a long series of experiments on the localization of movement control in the brains of a wide array of experimental animals – and eventually, monkeys. He found that by using low levels of current and anaesthetizing the animals, he could produce fine motion and by combining different locations, he could produce complex motions such as walking, extension of the limbs, mouth opening and various facial expressions.

In 1874, Robert Bartholow (1831–1904), carried out similar experiments on a *consenting* human patient, Mary Rafferty, who was dying of an ulcer of the scalp that had worn away her skull. Bartholow describes in detail a harrowing series of experiments that confirmed motor control by specific locations in the brain. He later acknowledged that these experiments should not be repeated, and should never have been done at all.

Ferrier's localizations in the human brain, proposed on *analogy* with those in the monkeys that he studied



Electrical impulses

In the 1840s, two of Johannes Müller's students, Emil Du Bois-Raymond and Hermann von Helmoltz carried out a series of experiments that disproved their teacher's view that the nerves operated by a specific *nervous force* – in which each type of nerve pathway was thought to have a unique vital quality.

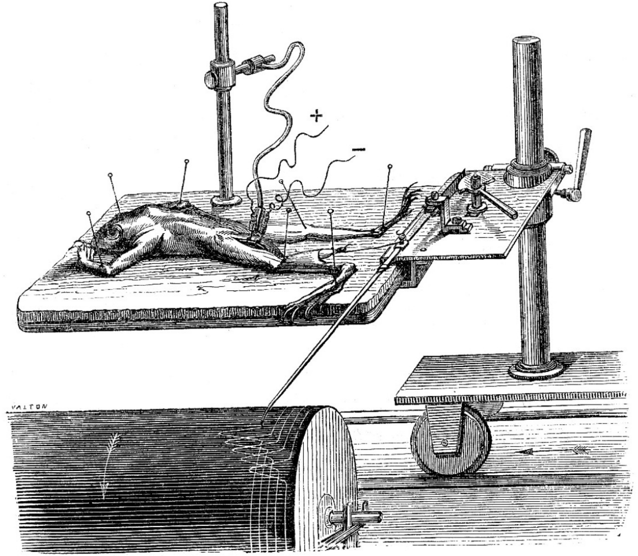
Du Bois-Raymond set up a device that applied an electrical shock to a nerve stump and then measured changes in current with external electrodes placed along the length of the exposed nerve. He found that a "wave of relative negativity" moved along the nerve – later called *action potential* – much as he had already found for muscles. He argued that this demonstrated "the identity of the nervous principle with electricity."

It was also shown that the action potential is an all-or-nothing reaction – it does not change in intensity and is either triggered or not triggered by an electrical pulse.

Measuring speed

Hermann von Helmholtz constructed a chronograph that could measure small fractions of a second for the purpose of measuring the speed at which the action potential moves along the nerve. He attached this to a galvanometer, and to a switch that would deactivate the deflection of the needle the moment a muscle twitched.

He then isolated a frog's motor nerve still connected to the gastrocnemius (calf of the leg) muscle and measured the time differences between the moment of electrical stimulation and the start of the muscular contraction. By varying the location of the electrical stimulation, he was able to compute the speed of the nerve impulse. He produced a value of 30m/s, which is fast but much slower than the propagation of electricity in, say, copper wires. (In fact, the speed varies with temperature and other factors, but is in any case much slower than a standard conductor.)

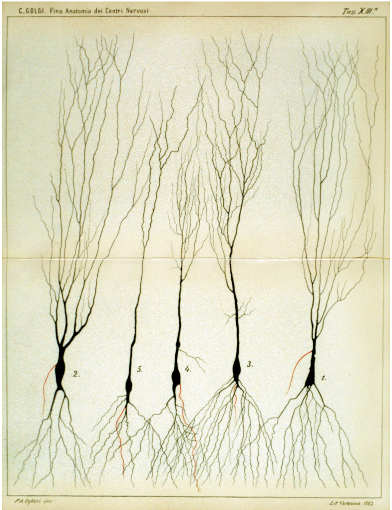


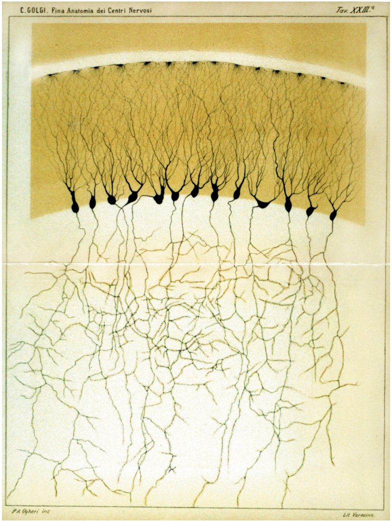
Étienne Jules-Marey's myograph used to reproduce Helmholtz's experiment on frogs

The Golgi stain

Although the cell theorists had studied nerve cells in the middle of the 19th century, a new method of staining developed by the Italian psychiatrist Camillo Golgi (1843–1926) in 1873 made it possible to see much more detail. Golgi made the discovery that when nerve cells were hardened with potassium dichromate and then stained with silver nitrate a small percentage of the cells were completely blackened, and hence stood out in sharp relief against the others.

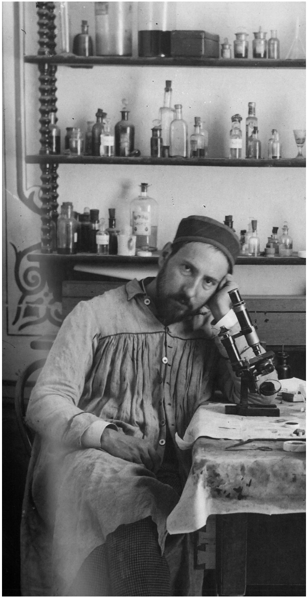
Golgi carried out a long series of anatomical investigations of the nervous system that showed that nerve cells have a central part, the *soma*, and two types of limbs, *dendrites*, which are very thin and often branch, and an *axion*, which is much thicker and only rarely branches. He also proposed that the whole nervous system was interconnected in a single *diffuse nervous network* – known as the *reticulum theory*.





Drawing made by Golgi of nerve cells highlighted by his staining technique

Santiago Ramón y Cajal (1852–1934)

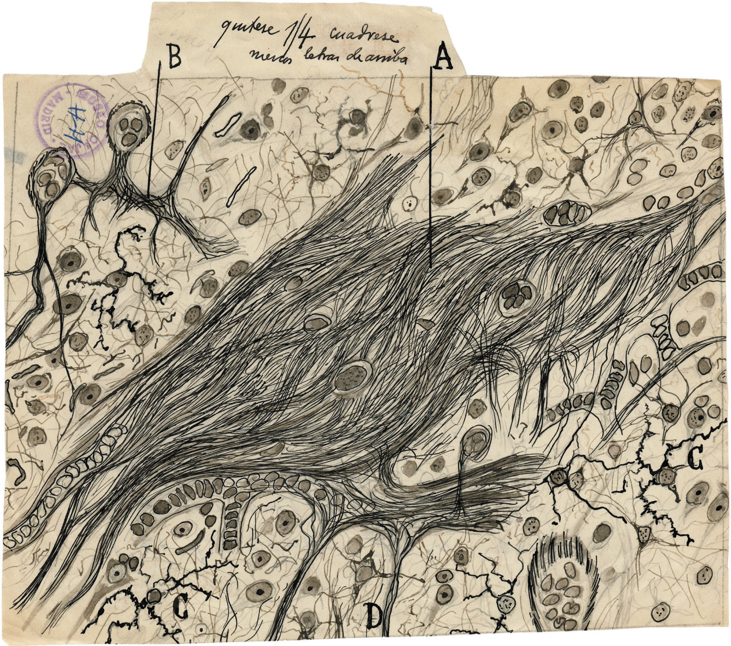


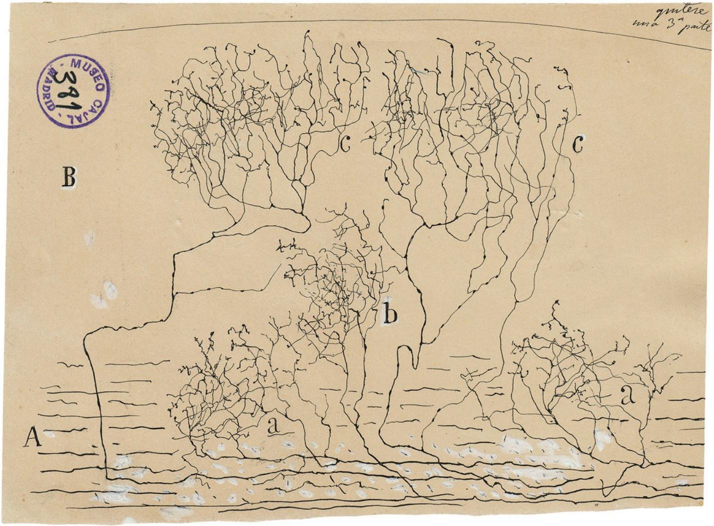
- Born to the family of a country doctor, he was apprenticed to a cobbler and a barber and wanted to be a painter.
- Took a medical degree and served in Cuba, where he contracted malaria and tuberculosis.
- He took a PhD and began teaching at Valencia, where he helped inoculate the city during a cholera outbreak.
- He worked at the Universities of Barcelona and Madrid.
- He improved the Golgi stain and carried out extensive studies of the nervous system.
- Replaced the *reticulum theory* with the *neuron doctrine*.

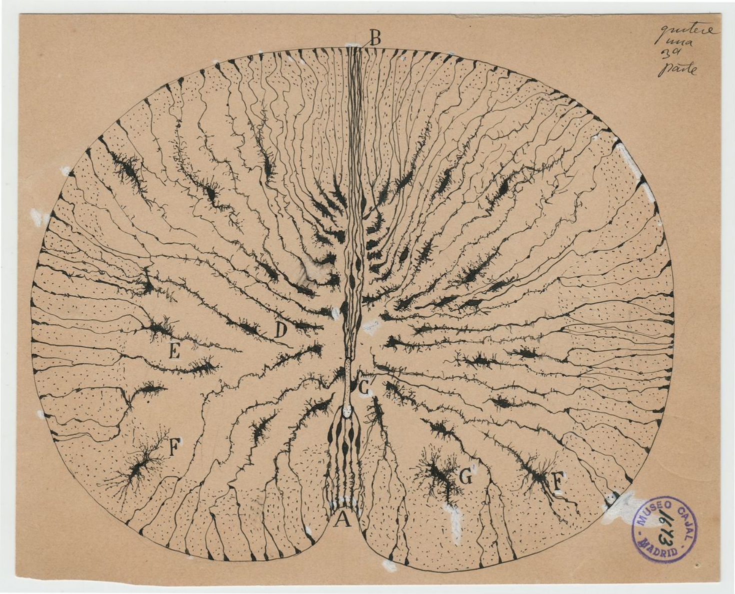
The neuron doctrine

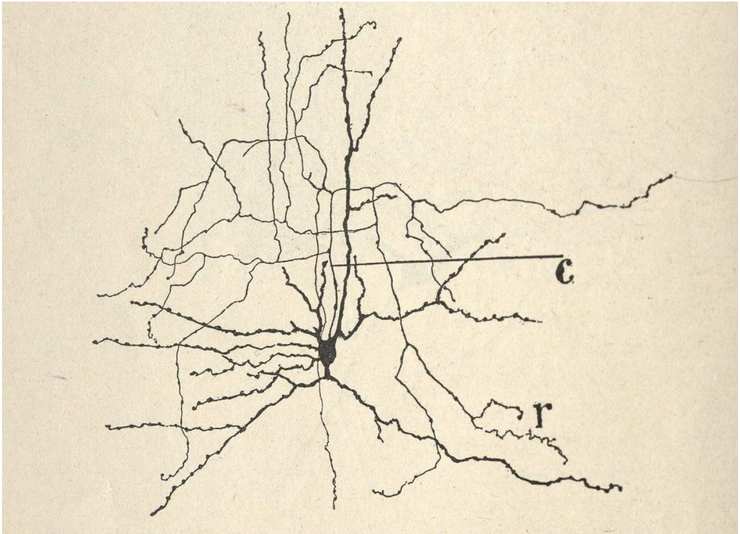
In the 1880s, Cajal's studies lead him to the conclusion that nerve cells, which he called *neurons*, come near each other but are *not continuous*, and that the axion of one neuron reaches out to the dendrites of other neurons. This lead him to hypothesize that neurons receive signals from dendrites and send out signals through axions.

Cajal proposed that neurons do not form a continuous net, but rather act as individual signaling locations in an overall *network* – the soma of the neuron collects signals from its dendrites, having received signals from other neurons, and then sends out signals along its axion(s) to other neurons. This became known as the *neuron doctrine*, and through his well-illustrated publications, Cajal convinced a growing number of neuroanatomists to develop it with him.


quítese 1/4 cuadrese
menos letras de arriba
B
A
C
C
D


MUSEO CAJAL MADRID
381
B
c
c
b
a
a
A


B
D
E
C
F
G
F
A
MUSEO CAJAL
MADRID

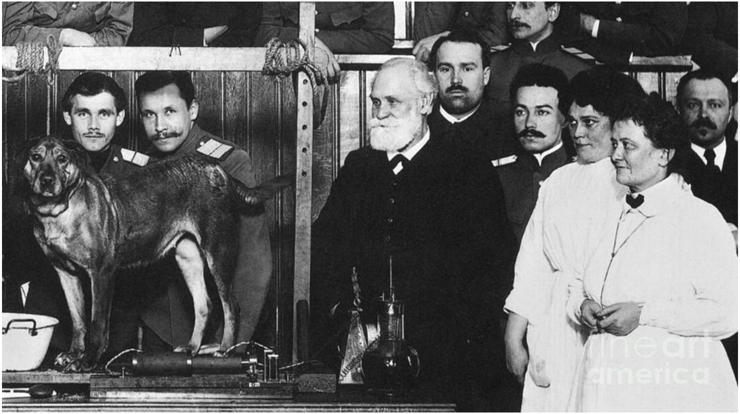

c
r

Reflex arcs

Ivan Pavlov (1849–1936) was a Russian physiologist, who took his degree from University of St. Petersburg and studied in Germany with Carl Ludwig and other mechanists. He did his first major work, in the 1880s, on the dynamics of blood circulation, and elucidating the nerve pathways by which the salivary glands are activated.

He is most famous, however, for a series of experiments carried out on conditioned reflexes. He showed that a dog could be conditioned to automatically salivate when a bell was rung, and he traced the reflex arc in the nervous system that produced this response. He argued that the conditioning produced temporary neural connections in the cortex which automated the response.

He rejected dynamic psychology as a science and advocated a model for learning and more complex behavior as built up of many reflex arcs. This larger project was never very successful.



Pavlov with his colleagues and an experimental dog

Nervous integration

C.S. Sherrington (1857–1952) was a Cambridge-educated neurophysiologist who spent two years in Germany working with Virchow, Koch, and others. He carried out a series of experiments on the knee-jerk and scratch reflexes in dogs in the 1890s. He was able to show that these involved a system of neurons interacting with one another based on a kind of switch that operated by passing an action potential over what he called a *synapse* – the gap between two neurons. This work showed that these reflexes were physically structured in the lower nervous system, and did not involve a signal to or from the brain.

Although Sherrington was a methodological reductionist who worked on the mechanics of the most simple reflex arcs, he was, in principle, antireductionist and was opposed to a simplified mechanistic view. This led him to study the reflex arc *in situ* and to avoid *in vitro* preparations.

Frequency signaling

In the 1870s, Francis Gotch (1853–1913) had followed up on the all-or-nothing feature of the nerve pulse and shown that a nerve could not be activated in the short interval of the action potential. This led him to propose that nerves must signal through *frequency*, not intensity.

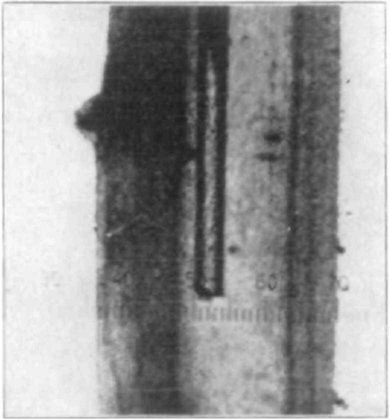
In the 1920s, Edgar Adrian (1889–1977) confirmed this. He recored the nerve activity of a frog's leg muscle and found that the frequency of the nerve pulses increased with the weight applied to the muscle. He also found that when touch nerves were activated, they pulsed rapidly and then subsided, even if contact remained – a phenomena that came to be known as "habituation." This suggested that the fundamental mechanism of signaling is *frequency*.

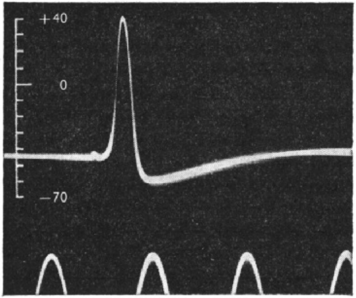
By recording pulses from a single axion, Adrian showed that the nerve impulse always has the same intensity and travels at the same speed – at up to 400 pulses per second.

The axion of the giant squid

In 1936, John Young announced at a symposium of the CSHL that the giant squid has an axion running the full length of its body that is up to 1mm thick. This meant that electrodes could be inserted into the axion, and that the chemical substances inside and surrounding it could be extracted. A number of groups used the giant squid as a *model system* to study its axion.

In a series of five papers, in 1952, A.L. Hodgkin (1914–1998) and A.F. Huxley (1917–2012) produced a full theory of the action potential of the "giant axion." They showed that the resting potential inside the axion is about -45mv, and that an influx of Na+ causes the potential to swing to +40mv and then an outflux of K+ causes the potential to swing back to -60mv and settle on -45mv, all within 2–3msec. They also proposed that this was caused by ion channels in the cell membrane, which was later confirmed. These unexpected results implied that the membrane was *under tension*.





Photomicrograph of an electrode in the axion of the giant squid (left), and an oscilloscope reading of the action potential inside the axion (right)

The autonomic nervous system

Back in the 1880s and 90s, John Langley (1852–1925), a Cambridge physiologist, had carried out a series of experiments involving the effects of various drugs and poisons – such as curare, atropine, nicotine – applied directly to the nervous system. This lead the conclusion that the *autonomic nervous system*, which controls organ function, is completely separate from the systems that deal with sensation and motor control, and moreover is divided itself into two separate systems: the *sympathetic system*, which excites, and the *parasympathetic system*, which sedates.

This lead Langley to explore the effects of electrical stimulation and drugs applied to the different systems. When he found that adrenaline caused an effect similar to the action of the sympathetic system, T.R. Elliot (1877–1961), a postdoc working in his lab, proposed that it did so as a *neurotransmitter* released into the synapses of the sympathetic nervous system.

Neurotransmitters

For some decades various researchers explored the effects of substances like adrenaline and acetylcholine on the autonomic nervous system, but it was still uncertain that these chemicals were really acting as *neurotransmitters*.

An important experiment was carried out by Otto Löwi (1873–1961), a Jewish-German pharmacologist in 1921. He removed a heart from a frog, still attached to is parasympathetic (vagus) and sympathetic nerves, placed it in a saline solution, and stimulated the vagus nerve which caused the heartbeat to slow. He then collected the solution and applied this to a second heart whose vagus nerve had been removed. The heartbeat of this second heart also slowed. Löwi published a short article, claiming to have demonstrated *chemical neurotransmission*.

(He later liked to recount how this experiment came to him in a dream – twice. He forgot the first dream, so it came again.)

Soup versus spark

Although neurotransmission had been established in some locations, many researchers still doubted that there would be significant chemical neurotransmission in the central nervous system, the brain and spinal column – supposing instead that the central nervous system functioned by direct electrical transmission. This was known as the *soup versus spark controversy*.

The two main proponents were the English physiologist Henry Dale (1875–1968), for soup, and the Australian neurophysiologist John Eccles (1903–1997), for spark. They disagreed vigorously in public, but were good friends and collaborators in private. This controversy went on for some decades, but it was only with the development of a micropipette electrode, smaller than the shortest wave length of visible light, that this question could be fully addressed.

A crucial experiment

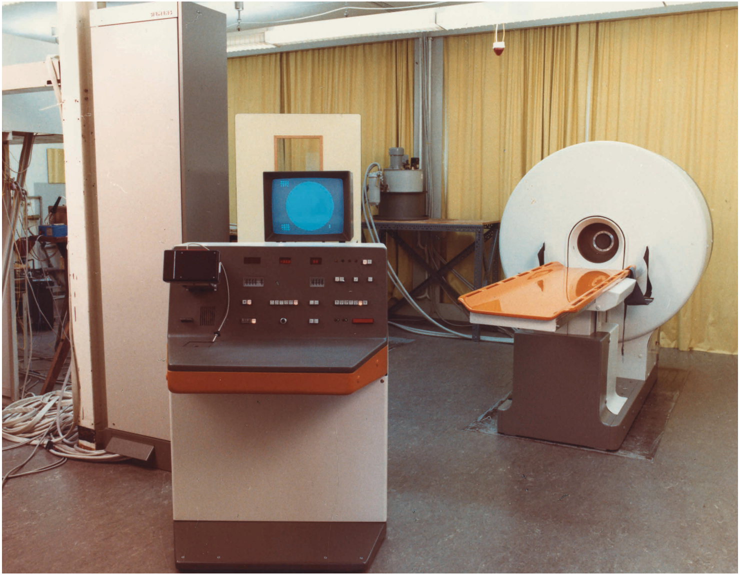
In 1950-51, Eccles had shown that a single synapse does not cause a motor nerve to fire, it simply produces a small momentary *increase* in the voltage. When this increase reaches +15mv, an action potential is triggered.

In 1952, he continued this work to investigate reciprocal muscle action. He put a micro-electrode in the quadriceps of an anaesthetised cat, but this time he stimulated the reciprocal muscle. Now he found that stimulation from just a single nerve caused very small momentary *decrease* in the voltage – that is, this served to inhibit the muscle from acting. This means that the motor neurons are taking in signals from both systems and acting or failing to act based on the sum of these signals.

Since this finding was incompatible with the spark hypothesis, he *changed his mind* to the position that signaling in the nervous system is controlled by neurotransmitters.

In the 1970s, computed tomography (CT) was developed, which resolved hundreds of x-rays into images of the soft tissue of the brains of living patients. Since this is a technology that depends on computation, it is now possible to rapidly produce highly precise images. (The first CT scan took 15 hours.)

In the 1980s, magnetic resonance imaging (MRI) was developed to take detailed images of living brains. Because oxygenated and deoxygenated blood gives off a different radio wave in a magnetic field, it is also possible to study brain function with these images, fMRI. In this way, researchers can monitor the blood flow and energy consumption in the brain and see what regions are involved in specific tasks.



CT scan technology under development in the Sieman's lab, 1972

Kahneman and Tversky

Around 1970, Daniel Kahneman (1934–) and Amos Tversky (1937–1996), both Israeli psychologists, began a close friendship and collaboration that was to last for some 15 years. They applied experimental techniques to cognitive psychology, studying how people think, the sorts of errors they make, and their emotional responses.

Over the next decades this lead to a revolution in psychology which had profound effects on many areas of the social and health sciences, such as economics, political science, medicine, public heath, and public policy.

Errors of the conscious mind

- Unlike the claims of the early 20th century dynamic psychology, the new psychology of the 1970s and 80s focused on the *errors of the conscious mind*.
  - Errors of small numbers; memory availability bias; stories about cause over statistical effects; errors of stereotype over base rates; in-group and out-group biases; inability to think statistically.
- The experiments were carried out on intelligent, well-educated people, and the errors were found to be consistent. It was very difficult for most people to believe, however, that these findings could have serious real-world implications.
- Although there have been many reproducibility findings with these results, these finding have been used in business and political propaganda to sway peoples' views and actions. They also help us understand the irrationality of economic markets.

Overview

- We have gone over the main theories of dynamic psychology.
- We have discussed some of the early experiments that indicated localization of brain function.
- We have covered the beginnings of neuroanatomy and neurophysiology.
- We have discussed neurotransmitters and the use of computers to investigate brain function.
- We have mentioned the new dynamic phycology that studies the conscious mind.