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Inhibition – an attributive function of the nervous system: from Hippocrates to I.M. Sechenov

Georgy Kh. Shingarov[1], Irina G. Tatarovskaya[2]

1 *Modern University for the Humanities*
32 Nizhegorodskaya St., building 4, Moscow 109029, Russia

2 *Institute for African Studies of Russian Academy of Sciences*
30/1 Spiridonovka St., Moscow 123001, Russia

Corresponding author: Irina G. Tatarovskaya (itatarovskaya@mail.ru)

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Abstract

The article demonstrates that inhibition is an attributive function of the nervous system. It notes that the idea of inhibition was first put forward by Hippocrates. The authors cite key aspects of Galen's ideas about excitation and inhibition. Descartes' views are analysed. The authors point out that the concept of "reflex" in the contemporary sense in the 18th century was introduced by Astruc. The Weber brothers' discovery of the inhibitory action of the vagus nerve on the heart in 1545 is considered the discovery of peripheral inhibition. The article stresses that I.M. Sechenov employed an original experimental method during his discovery of central inhibition in 1862. In his "Reflexes of the Brain", he demonstrated that reflexes underlie mental activity. Sechenov's approach to the problems of the theory of cognition, which distinguishes him as a philosopher, is analysed.

Keywords

history of medicine, inhibition, attributive function, brain reflexes, memory, perception, self-regulation, integrative activity

The problem of excitation and inhibition arose as an attempt to understand the phenomenon of the movement of humans and other animals. Hippocrates wrote about the "positive" and "negative" aspects of motion. To make at least a single step, a human being, or animal, tenses one muscle group and relaxes the other, most often antagonistic. The idea of the inhibitory action of one part of the nervous system on the other was put forward way back by Hippocrates. However, it only became a working physiological theory after Sechenov (Sherrington 1900, p. 837-838). "Through Ivan Mikhailovich", I.P. Pavlov wrote, "for the first time, Russian intellect participated in the development of one of the most important sciences – physiology. Such an endeavour required special qualities of the mind, special character, that were well represented in Ivan Mikhailovich. He not only founded Russian physiology but won it a place of honour right away" (Pavlov 1952, p. 265).

Galen's view reigned right until the late 16th century. According to Galen, anatomical structures exist to perform precise functions. Like Hippocrates and Plato, he believed that the brain controls functions that determine the activity of the living body. But what forces does the brain use to control said functions and how are these functions realised? Galen gives a clear answer to this question in the treatise "On the Doctrines of Hippocrates and Plato". For him and the majority of medieval anatomists and physicians, the body and its anatomical structures function not through intrinsic activity, but thanks to the special force of the brain. (Galen 2016, 2017).

For Galen, the "vital spirit" resides in the ventricles of the brain. The "vital spirit" flows from the brain into the muscles, and the muscles are excited and become active. When the "vital spirit" flows out of a muscle, it relaxes, and the inhibition period begins. Anatomical structures perform their functions not through intrinsic activity, but via the "vital spirit". Galen's views on the essence of excitation and inhibition prevailed right up to the 16th century.

New ideas about the essence of the living body emerged in the 16th century. In 1543, Dutch scientist A. Vesalius published his work titled "De humani corporis fabrica". He likened the living body to a factory, a kind of man-made mechanism. Because it was man-made, it could be studied using rigorous methods. Plato is the originator of the idea that rigorous scientific methods can be used to study only that which is man-made (Plato 1971, p. 72).

In the 17th century, two new areas of study – iatrophysics and iatrochemistry – emerged in biology and medicine. Descartes' views were closer to iatrophysics, according to which the living body functions according to the laws of physics. For Descartes, the living body was a kind of mechanism. "...The difference between the body of a living man and that of a dead man is just like the difference between, on the one hand, a watch <...> when it is wound up and contains in itself the corporeal principle of the movements for which it is designed, together with everything else required for its operation; and, on the other hand, the same watch or machine when it is broken and the principle of its movement ceases to be active" (Descartes 1989, p. 484). Sechenov highly regarded Descartes' idea about the "machineness" of the body, including the brain.

Descartes is the founding father of the doctrine that the nervous system functions by reflex. For him, reflex activity boils down to the following: the "vital spirit" flows through afferent nerves and, passing through the brain, flows into efferent nerves and then to the working muscle. For Descartes, the flow of the "vital spirit" via the corresponding nerve tubule through the brain is the "reflex".

We could not find in Descartes' work the excerpt where he discusses the exciting or inhibitory effect of the nervous system on any muscle or other part of the living body. This suggests that Descartes had not moved away from the previous prevailing ideas about the functions of the living body. In light of this, F. Fearing writes: "interestingly, the drainage system bears a clear resemblance with Descartes' concept of excitation and inhibition of muscles" (Fearing 1970, p. 204).

Underlining the difference between Descartes' views on excitation and inhibition in reflex action from the modern-day views, C.S. Sherrington writes: "There is a significant similarity between Descartes' scheme and the reciprocal innervation scheme, aside from the fact that Descartes imagined this mechanism as peripheral, and what we now refer to as inhibition, he localised in the muscle and not the nerve centres themselves" (Sherrington 1969, p. 272).

A new phase in the development of the reflex theory and ideas about excitation and inhibition began in the 18th century. The works of Dutch scientist J. Swammerdam, published in the mid-18th century, presented the results of his experimental studies. They showed that muscle activity depends not on the "vital spirit" entering them, but rather from the action of the nervous system. The term "reflex" was introduced into scientific usage by J. Astruc from Montpellier in the mid-18th century.

In 1845, the Weber brothers proved that stimulation of the vagus nerve leads to bradycardia, i.e., a reduced heart rate, right up to the cessation of its activity. This proved that the nervous system has a direct inhibitory effect on parts of the human body. This discovery could arguably be considered the discovery of peripheral nerve inhibition.

Ivan Mikhailovich Sechenov takes a special place among the distinguished figures of world culture and science, who made an invaluable contribution to the treasure-trove of the knowledge of the secrets of the human soul and brain activity: "Such a prominent, brilliant, and valuable figure as Ivan Mikhailovich Sechenov should live in the memory of posterity, serving as a constant agent of changing generations" (Pavlov 1952, p. 267). Sechenov's philosophical ideas, scientific discoveries, and methodological approach to studying the most complex phenomena of brain activity remain invaluable to this day.

Sechenov conducted his experiment to study central inhibition at Claude Bernard's laboratory in Paris in 1862. In his own words, this work had a "direct link to the acts of consciousness and free will" (Sechenov 1952, p. 184). To describe central inhibition, Sechenov imagined it as objects and phenomena perceived by the senses. Said objects and phenomena can be directly perceived by sensory organs and reflect the essential properties of the object under investigation. In his experiment, the objects perceived by the senses were the hind legs of a frog.

Sechenov carried out his experiment as follows. He removed the large cerebral hemispheres and other brain structures up to the thalami (*lobi optici*). At the beginning of the experiment, Sechenov determined the reaction time of the hind legs of the frog when dipped in a vessel with a sulphuric acid solution. He measured the time from lowering the legs into the vessel to their pulling out of the vessel. The time was measured using a metronome.

Under these conditions, the frog pulled out the legs from the vessel after 6-7 beats. When Sechenov placed a salt crystal on the thalami, the results were as follows: the frog pulled out its legs from the vessel, not after 6-8 beats of the metronome, but after 12-15-18 or more beats, i.e., the reaction time increased by at least 3-4 times. Chemical stimulation of the *lobi optici* had an inhibitory effect on the functioning of the frog's legs. Thus, Sechenov discovered central inhibition by transforming brain functions not perceived by sensory organs before the experiment into perceptible objects, which revealed the essential attributive functions of the brain in the form of inhibition. In Sechenov's experiment, we observe how a "thing in itself" becomes a "thing for us". As I.P. Pavlov writes, Sechenov's discovery of central inhibition "was Russian intellect's first contribution to a vital branch of science, which had just been greatly advanced by the successes of the Germans and the French" (Pavlov 1951, p. 15).

Sechenov's discovery of central inhibition is often dated as 1863 and not 1862 because he revealed his discovery in his work titled "Physiologische Studien über die Hemmungsmechanismen: für die Reflextätigkeit des Rückenmarks im Gehirne des Frosches", which was published in Berlin in 1863 (Setschschenow 1863).

After Sechenov's discovery of central inhibition, the history of the reflex theory can be divided into two basic periods – the pre-Sechenov period and the Sechenov period. First of all, his discovery showed that mental processes could be studied using scientific methods. Secondly, it became possible to study the integrative activity of the nervous system using rigorous scientific methods.

By proving the reflex nature of mental activity, Sechenov made a significant contribution to the knowledge of such fundamental concepts of psychology as sensation and perception, association, cogitation, motor action, etc. He paid particular attention to the study of memory. Sechenov believed that memory is based on the latent stimulation of nerve centres. Mental evolution is impossible without the preservation of everything valuable accumulated before. He assigned memory a vital role in the formation of such a mental process as perception since any perception of surrounding objects is impossible without comparing information from sensory organs with those already stored in memory.

In the early 1850s, Claude Bernard showed how self-regulation of blood sugar level occurs. The doctrine of the self-regulation of body functions similar to the automatic regulation of functions in man-made machines was born. Sechenov viewed the living body as a "self-operating machine", where the controls are automatic, i.e., they are set into action when the state or operation of the machine changes and action, aimed at rectifying the cause of the malfunctioning of the machine, is initiated. Therefore, according to Sechenov, the control must satisfy the following conditions: the tool must be sensitive to disruptions in the state or action, and should also facilitate the elimination of factors leading to said disruptions: "Only then is the self-acting control able to replace the hand of the operator, guided by the mind" (Sechenov 1956, p. 665).

Today, numerous scientific data show that links that connect an object and its image in human consciousness are not similar in their ontological status. Certain biocurrents, rather than visual images or optical waves, flow through the optic nerve. The same applies to other sensory receptors.

The essence of Sechenov's concept on the connection between cognitive processes and the formation of images in human consciousness lies in that, in the links that connect the original – the object – and its image in consciousness there are one-to-one transformations of the mediating physical phenomenon. He wrote: "As for the question of how to find conditions of similarity, it is most convenient to find out by examples of such physical combinations, where the initial cause and the final effect, which are similar to each other, are connected to each other by connecting links and, together with the latter, form the so-called causal series" (Sechenov 1952, p. 450). For instance, Sechenov believed that the transmission of the human voice via the telephone is initially the conversion of sound waves into electromagnetic waves, then their conversion to electric current, and then its conversion back to electromagnetic waves and sound waves.

These views expressed by Sechenov are close to the modern-day views on the invariance of information to its physical media. By studying the essence of processes occurring in sensory organs and the nervous system that link the perceived object with its image in consciousness, Sechenov turned the problem of perception into a problem of physiology and set the path towards its investigation using scientific methods. This distinguishes him not only as physiologist and psychologist, but also as a philosopher.

The discovery of central inhibition was crucial for the understanding of mental activity as reflex action. Sechenov placed great emphasis on this issue.

In late 1863, at the suggestion of N.A. Nekrasov, the chief editor of the magazine Sovremennik (The Contemporary), Sechenov wrote an article titled "An Attempt to Introduce the Physiological Bases for Psychological Processes". The censor of the magazine rejected the article. However, the article was soon later published in the Meditsinsky Vestnik (Medical Bulletin) under the title "Reflexes of the Brain".

The primary goal of this work was to prove that all acts of conscious and unconscious life are reflexes. The motor unit of the reflex is inhibited. In light of this, a thought can be considered the "first two-thirds of a psychical reflex", and the "desire in a passionate mental act is the same as a thought in the ordinary – the first two-thirds of reflex" (Sechenov 1952, p. 101, 110).

This article and its idea about the reflex nature of mental activity "nudged" creative thought towards the search for the new in science. I.P. Pavlov notes the significance of this work in his discovery of "conditioned reflex": "I think... that the most important impetus for my decision, although at the time an unconscious one, was the influence, from the long distant years of my youth, of the talented brochure of Ivan Mikhailovich Sechenov, the father of Russian physiology, entitled

“Reflexes of the Brain” <...> In this brochure, a brilliant attempt was made – a truly extraordinary attempt for that time (of course theoretically, in the form of a physiological scheme) to represent our subjective world in a purely physiological manner” (Pavlov 1951, p. 14).

We attempted to show that Sechenov’s discovery of central inhibition was a kind of response to the question posed by Hippocrates and rigorously debated upon throughout the many centuries of the study of the functions of the nervous system. This approach allows us to examine Sechenov’s discovery in the broadest historical perspective. In turn, this allows for a more accurate assessment of the significance of his fundamental scientific discovery – inhibition in the nervous system.

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About the authors

Georgy Khristovich Shingarov – Doctor of Philosophical Science, Professor, Head of the Department of Philosophy at the Modern University for the Humanities, Moscow.

Irina Gennadievna Tatarovskaya – Candidate of Philology, Doctor of Philosophical Science, Researcher at the Centre for History and Cultural Anthropology, Institute for African Studies of Russian Academy of Sciences, Moscow. Email: itatarovskaya@mail.ru