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## Lev Vygotsky on “psychological physiology”

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### Abstract

This article discusses the publication of Lev Vygotsky’s speech delivered at the debate held following Karl S. Lashley’s lecture on 20 April 1931. The evolution of the concept of psychological physiology in Vygotsky’s notebooks and the works of Alexander Luria is outlined briefly. The author demonstrates how Vygotsky resolved the problem of localising psychological functions – a subject of dispute between Karl Lashley and Ivan Pavlov. The principle of “chronogenic localisation” of higher psychological functions is adopted as a basis. This principle asserts that brain structures depend on the level of an individual’s cultural development. The concept of “extracerebral connections” between the human brain and the cultural environment is explored. These connections are responsible for higher psychological functions, and more broadly for all processes of conscious, voluntary human activity.

**Keywords:** psychophysical problem, higher psychological functions, chronogenic localisation, extracerebral connections, objectification, K.S. Lashley, A.R. Luria

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## Л.С. Выготский о «психологической физиологии»

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### Резюме

Комментарий к публикации стенограммы выступления Л.С. Выготского в прениях по докладу К.С. Лешли 20 апреля 1931 г. Кратко освещается развитие идеи психологической физиологии в записных книжках Л.С. Выготского и в работах А.Р. Лурия. В статье показано, как, в свете этой идеи, Выготский решает проблему локализации психологических функций, вокруг которой развернулся спор К.С. Лешли с И.П. Павловым. В основу кладется принцип «хроногенной локализации» высших психологических функций, утверждающий зависимость мозговых структур от уровня культурного развития личности. Раскрывается понятие «экстрацеребральных связей» человеческого мозга с культурной средой, благодаря которым осуществляются высшие психологические функции и вообще любые процессы осознанной, «произвольной» деятельности человека.

**Ключевые слова:** психофизическая проблема, высшие психологические функции, хроногенная локализация, экстрацеребральные связи, объективирование, К.С. Лешли, А.Р. Лурия

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## Introduction

This issue of the journal publishes the transcript of L.S. Vygotsky’s first public lecture on the physiology of nervous activity. The typescript is held in the Russian Academy of Sciences Archive (Fund 351, List 2, File 57, pp. 1–25). File no. 57 also contains the transcript of a report by I.D. Sapir<sup>12</sup>, a renowned psychoneurologist who worked at G.I. Rossolimo’s clinic for nervous diseases as chief physician, and alongside Vygotsky at the Psychological Institute on Mokhovaya Street<sup>13</sup>.

In spring 1931, K.S. Lashley, the president of the American Psychological Association, visited the Soviet Union to meet Academician Pavlov. Lashley agreed to give a report at a Society of Materialist Psychoneurologists meeting at the Komakademiya on Volkhonka Street. Vygotsky and Sapir were invited to participate in the ensuing debate. Two years later, K.S. Lashley’s book *Brain and Intelligence* was published in Russian. The translation was edited by L.S. Vygotsky, with a preface by I.D. Sapir (Lashley, 1933). The original title was *Brain Mechanisms and Intelligence: A Quantitative Study of Injuries to the Brain* (Lashley, 1929).

When reading the transcript of Vygotsky’s report, it is important to consider the character of the audience and the “flags” that have recently become dangerous to cross. Science has become an arena for fierce ideological battles, and attacks on “the allegedly cultural (*kul’turnicheskaya*) psychology of Vygotsky and Luria” have already begun<sup>14</sup>.

Most of the listeners among the “materialist psychoneurologists” were Pavlovians, while Lashley

openly challenged Academician Pavlov’s theory of the localisation of psychological functions in the cerebral cortex<sup>15</sup>. Vygotsky took an even more radical position on this issue, considering Lashley’s criticism insufficient and inconsequent, though he preferred to discuss the problem of localisation without mentioning Pavlov’s name (a cautious stance he would also maintain in the future).

At the same time, it would have been discourteous to give a harsh assessment of the views of the honoured American guest. Vygotsky merely refers to a “regrettable difficulty” that prevents Lashley from developing a “new trend in modern psychoneurology”. In two later reports, however, Vygotsky is more critical, describing Lashley’s “gross errors” and “false position” (which will be discussed below).

These two reports directly develop the ideas expressed by Vygotsky in 1931, so they deserve to be mentioned separately. The report “The Problem of the Development and Decay of Higher Psychological Functions” (Vygotsky, 1960)<sup>16</sup>, the last in his life, was presented at a conference of the All-Union Institute of Experimental Medicine (AIEM) on 28 April 1934. The management of the new scientific centre<sup>17</sup> invited Vygotsky to head the Department of clinical psychology. In his report, the results of his research in recent years were summarised. The theses of another report, “Psychology and the Theory of Localisation” (Vygotsky, 1934), were submitted to the First All-Ukrainian Congress of Neuropathologists and Psychiatrists, which took place shortly after the scientist’s death.

<sup>12</sup> Isaak Davidovich Sapir (1897–1976) collaborated closely with Academician A.M. Deborin’s philosophical circle. The persecution of Deborin’s followers began in 1931. A few years later, Sapir was arrested and exiled to Yakutsk, where he worked as a doctor in a polyclinic. After the war, he became a professor of neurology at the Krasnoyarsk Medical Academy.

<sup>13</sup> The name of the institute changed several times. Following an inspection by the Rabkrin commission in early 1931, it was reorganised and renamed the State Institute of Psychology, Pedology and Psychotechnics. At that time, L.S. Vygotsky, a senior employee, was promoted to the position of “full member of the Institute” (entry in his employment record book dated 1 March 1931).

<sup>14</sup> This wording is taken from the resolution of the General Meeting of the Institute of Psychology, Pedology and Psychotechnics, dated 6 June 1931.

<sup>15</sup> For more details on this topic, see Sapetsky, 1999.

<sup>16</sup> In the 1960 edition, the editors replaced the term “psychological functions” with “mental functions” in the title and text of the report, without providing any explanation or notifying readers. This change was also made in other posthumous editions of L.S. Vygotsky’s works, including the title of the manuscript *The History of the Development of Higher Psychological Functions*. Vygotsky himself defined “psychological” as the unity of mental and physiological processes (see Vygotsky, 1930). In humans, “psychological” also encompasses social connections and “cultural signs”, which are tools for controlling one’s behaviour.

<sup>17</sup> A 65-hectare scientific complex was built for the AIEM, where the country’s elite scientific personnel were gathered. At the end of the war, the USSR Academy of Medical Sciences was established on its basis.

## I

Vygotsky spoke after Sapir and, judging by the transcript, not for long, about 15 – 20 minutes. He began with an overview of the evolution of Lashley's views and scientific discoveries, which Vygotsky considered to be the most important in light of his own ideas about the main path of development of the physiology of nervous activity. This was not merely a characterisation of Lashley's personal teachings, but rather an analysis of the “historical turn” in modern psychoneurology, which was closely linked to the “psychological crisis” that Vygotsky had pondered for a long time.

The symptoms of the crisis in neurology were vividly outlined in Lashley's speech at the Psychological Congress in New Haven. The American scientist acknowledged with complete candour that he was unable to offer a concrete solution: “We seem to have no choice but to be vague or to be wrong, and I believe that a confession of ignorance is more hopeful for progress than a false assumption of knowledge” (Lashley, 1930, p. 23). The only clear thing is that we need to reconsider the prevailing view of how the brain functions, as well as the established relationship between psychology and neurology.

Vygotsky, for his part, is convinced that he knows the real way out of the crisis. He believes that the principles and laws of brain activity can only be understood from the perspective of “historical psychology”. This is particularly relevant when it comes to solving the problem of localising psychological functions, including not only higher functions of cultural origin, but also other “complex living psychological formations”.

Following Marx's precept, he seeks the key to understanding the lower forms (“the anatomy of the monkey”) in the laws of the highest form of development (“the anatomy of man”). The scientific mind must take into account the vector of the subject's upward development at every step. This also applies to the subject that interested Vygotsky the most: the development of the child's psyche should be considered and evaluated from the perspective of an adult's developed psyche.

In order to solve the problem of localising psychological functions, it is first necessary to study these functions themselves, and only then attempt to determine their location under the skull.

Even with Ivan Pavlov's genius, it is impossible to solve the problem of localisation in reverse order. As our Academician was guided by an untenable psychological

theory, he had no chance of solving the problem of localisation.

Concluding his discussion of Lashley's report, Vygotsky suggests that in the field of the physiology of nervous activity, we should “proceed directly from data discovered in psychology, in complex living psychological formations, and then reveal their physiological organisation – much like a chemist solving biological problems”. He coined the term “psychological physiology” for this new scientific discipline (by analogy with biochemistry).

Physiologists are encouraged to use *psychological theory* as a basis for, and a starting point in, their research into nervous activity.

But which theory specifically? Certainly not behaviourism and reflexology, which are familiar to most researchers of “brain mechanisms”, including Lashley. These naturalistic psychological teachings arose from the misconception that the psyche is a manifestation of nervous activity<sup>18</sup>.

When Vygotsky speaks of “data discovered in psychology”, he has in mind *his own* theory of the cultural-historical development of higher psychological functions (as it is called in his 1931 work<sup>19</sup>). Psychological physiology is conceived as the application of this psychological theory to the study of the brain.

Psychoneurology itself is spontaneously drawn to the discoveries of psychologists, as Vygotsky demonstrates using the example of the evolution of Lashley's views (the name of Kurt Goldstein, who was oriented towards Gestalt psychology, is mentioned nearby). However, spontaneous movement in science, as in ordinary life, is fraught with vacillations, wanderings, reversals and similar “regrettable difficulties” on the way to its objective goal. Vygotsky seeks the straightest and shortest path.

## II

If we delve deeper into the analogy between psychological physiology and biochemistry, we can see that it holds the key to solving the *psychophysical problem*.

Vygotsky considers mental life to be a higher level of evolution compared to physiological processes. The relationship between the psyche and “physics” is that between two stages (higher and lower) in the development of living nature. The same relationship exists between biological processes and chemical reactions, or between the cultural and organic development of the child's psyche, for example. These processes intertwine

<sup>18</sup> Lashley understood this well. He began his speech by criticising the misconception that “the final explanation of behavior or of mental processes is to be sought in the physiological activity of the body and, in particular, in the properties of the nervous system” (Lashley, 1930, p. 1).

<sup>19</sup> “In essence, the so-called theory of historical (or cultural-historical) development in psychology is *the theory of higher psychological functions... – no more, no less*” (Vygotsky, Leontiev, 2003, p. 200).

to form a dialectical unity, in which the lower is “sublated” in the higher and the higher is realised through the lower, subordinating the latter’s development to its higher needs. In particular, the psyche intentionally alters the morphology of the brain and establishes the neural connections necessary for its own work and self-development. This thesis provides the key to solving the problem of localising psychological functions and can be considered the cornerstone of psychological physiology.

After identifying three of Lashley’s key ideas that should be incorporated into the psychological physiology, Vygotsky then turns to the general idea of the cerebral cortex operating according to the principle of a telephone exchange. This metaphor can be found as early as in William James’s *Principles of Psychology* (1890). In Russia, it was adopted and reinforced by Ivan Pavlov, who likened unconditioned reflexes to direct, permanent connections between telephone sets, and conditioned reflexes to temporary connections via a “central exchange” (the cortex).

Vygotsky notes that this view prevails among our materialists. Initially, in *Pedagogical Psychology*, Vygotsky himself approved of the telephone metaphor, using it to explain the infinite variety of human behaviour. In his subsequent work from the same period, *Consciousness as a Problem of Behavioural Psychology*, he found it to be insufficiently accurate, instead offering the metaphor of a “narrow doorway”. A few years later, in *The History of the Development of Higher Psychological Functions*, Vygotsky emphasised the importance of considering the “work of the telephone operator” — a person who establishes connections in the brain through signs (signification). In *Concrete Psychology of Man*, the “telephone operator” is characterised as a “social personality” — a cluster of social relationships that grow into our natural psychophysiology.

“The question boils down to personality. Pavlov compared the nervous system to a telephone; however, the uniqueness of human psychology lies in the fact that it combines the telephone and the telephone operator (the device and its human controller) in one being” (Vygotsky, 1986, p. 57). Humans control brain activity from the outside through artificial stimuli. Vygotsky adds that it is ridiculous to look for special centres in the cortex in order to locate higher functions, for example when Pavlov localises generalisation operations in the frontal lobes.

In his notebooks, Vygotsky uses the term “extracerebral connections”. Higher psychological functions are not localised solely in the brain; they reside in the entire world of culture, where the human brain becomes a component of social relations and a tool for solving social problems. In this case, the neural connections are established not within the brain itself, but *between one human brain and another*, via cultural symbols — primarily words.

“For us, central in localization are the extracerebral connections. <...> *In the naturalistic plane*, there are no brain structures or functions that correspond to speech; they arise from above — from psychological structures (two brains interacting via the historical-cultural environment). In the word lies the source of new brain structures” (Vygotsky, 2017, p. 482).

To understand *higher* nervous activity, we must view the workings of the brain *from above*, from outside the skull. Higher functions are formed in my brain only in the process of cooperation with another person and another brain. Although our two brains exist physiologically separately, they form a single “interpsychological” system. This is why only *psychological* physiology can solve the problem of localising higher functions.

According to the “general genetic law of cultural development”, external psychological connections between people become internalised, ingrowing into individual consciousness. A similar process occurs in the nervous system: the extracerebral connection formed through words and other cultural “peripheries” between my brain and someone else’s brain is internalised. This opens up the possibility of reflection and self-understanding.

“While understanding [the outside world. — A.M.], another person stimulates the connections in my brain — I am his prey; in understanding myself, one part of the brain communicates with another part via the periphery. Mediation creates fundamentally new types of connections in the nervous system. What is impossible for one person is possible for two. Regulation via the periphery is a frequent principle in the organisation of the nervous system” (Vygotsky, 2017, p. 482).

In the human nervous system, in addition to the direct connections between different parts of the brain, there are also *higher-level* connections that are mediated via the “periphery”. It is precisely these types of connections and brain structures that are involved in “understanding myself”, i.e. the processes of self-awareness and voluntary control of one’s higher functions. All conscious, volitional human activities are realised through these connections (especially verbal ones).

It should be noted that the “periphery” is not merely a *means* of regulating nervous processes. For Vygotsky, words are the *source* of new, higher-order brain structures, and the social environment is not merely a “setting” or an external factor in the development of personality, but the source of the emergence and development of all its specifically human qualities.

Lashley’s works give no reason to believe that he shared this view. Indeed, he claimed that psychology had surpassed brain physiology, stating that “the study of psychological processes furnishes a mass of factual material to which the laws of nervous action in behaviour must conform” (Lashley, 1930, p. 24). However, it quickly becomes apparent that he is referring to naturalistic research, such as behaviourism, Gestalt psychology and Edward Tol-

man’s “purposive psychology”. Furthermore, Lashley argues that none of these theories satisfactorily explains the entire body of factual data on how the brain works.

Real progress in the field of psychological physiology, as conceived by Vygotsky, was achieved by his colleagues: Nikolai Bernstein, Aleksandr Luria, Aleksei Leontiev and Aleksandr Zaporozhets. Piotr Anokhin’s theory of functional systems also made a significant contribution to the field, despite being quite distant from the cultural-historical understanding of human psychology.

Vygotsky (as well as Sapir) criticised Lashley’s scientific approach for its lack of historicism. Lashley’s thesis that there are no fundamental differences in the way the nervous system functions in humans and animals, even lower species, allows experimental data obtained from operations on animals’ brains to be transferred directly to clinical research on the human brain. This thesis “can lead to nothing but gross errors” (Vygotsky 1934, p. 41).

For his part, Vygotsky develops a variant of the principle of “chronogenic localisation” of higher psychological functions, which asserts the dependence of the “melody” (dynamic configuration) of cerebral connections on the individual’s level of cultural development. By virtue of this principle, for example, damage to the same areas of the brain leads to different consequences and is compensated for in different ways in children and adults. In a person with developed thinking, “the concept of objects can even act as the main means of compensating for the defect” (Vygotsky, 1960, p. 379).

As proof, Vygotsky cites cases from clinical practice, including his own, which demonstrate that patients with agnosia can identify an object through reasoning, despite being unable to recognise it visually.

Lashley challenged not only the traditional doctrine of localisation, but also raised his sword against the Holy Grail of physiologists: the theory of reflexes. He declared that this theory had exhausted its heuristic potential. “In the study of cerebral functions we seem to have reached a point where the reflex theory is no longer profitable either for the formulation of problems or for an understanding of the phenomena of integration. And if it is not serviceable here, it can scarcely be of greater value for an understanding of the phenomena of behavior” (Lashley, 1930, p. 12).

The influence of neurological theories on the development of psychology has had, and still has, deplorable consequences, says Lashley. He cites the visceral theory of emotions and the doctrine of “the intelligent solution of problems” through random activity and selection as examples of this; both are “largely a deduction from the reflex theory”. But even worse things happened. Lashley remained silent about the direct incursions of physiolo-

gists into the field of psychology, which give rise to such fables as the reflexes of purpose and freedom or the “what is it?” reflex (also known as the “exploring”, “searching” or “orienting” reflex)<sup>20</sup>.

While Pavlov created psychology *from the bottom up* (“physiological psychology”, as Wundt called it), Lashley was guided by the first commandment of psychological physiology: the anatomy of the psyche is key to understanding how the brain works. His theory is built *from the top down*. This is despite him putting the nervous systems of rats and humans on the same level and having no idea of the extracerebral localisation of higher psychological functions: “two brains interacting via the historical-cultural environment”.

### III

The term “psychological physiology” appears only once in Vygotsky’s published works, and he uses it in a different sense than in his debate with Lashley. An equal sign is placed between “psychological physiology” and “physiological psychology”, with no hint of the primacy of psychological theory in the study of nervous system development (see Vygotsky 1930, p. 53). Perhaps this work, *Psyche, Consciousness and the Unconscious*, was written much earlier than its publication date.

In his 1928 notebook, he already expresses the idea that “we need not physiological psychology (Wundt), but psychological physiology... This will overturn all points of view in psychoneurology: Pavlov, Jentsch and Gestalt theory are all different forms of psychological physiology [without a clear concept of the psyche — A.M.]. It is necessary to move from a system of clear (psychological) concepts towards physiology” (Vygotsky, 1977, p. 94).

By “system of clear concepts”, Vygotsky undoubtedly means *his own* psychological theory, from which he intends to “move towards physiology”. In 1928, the construction of such a system had only just begun. Only two years later would he start researching “psychological systems”: (i) the various types of connections between psychological functions; (ii) the processes of development and decay of psychological formations; and (iii) the “meaningful system of connections and organisation of consciousness” (in the last two years of his life).

In a note dated October 1932, the concept of psychological physiology is presented in the most precise and considered terms in the light of his theory of the “systemic and meaningful structure of consciousness”.

Vygotsky begins by reiterating what has already been said. “*Our point of view*: the unity of psychophysiological

<sup>20</sup> For more details, see Maidansky, 2021.

processes and the primacy of the psychic moment; the study of *psychological* processes; the height point of view in the psychophysiological problem” (Vygotsky, 1982, p. 66). As mentioned above, Vygotsky calls “psychological” not purely mental, but rather psychophysiological processes. The mental constitutes only the “psychic moment” of the psychological. However, he gives this moment “primacy” over the physiological moment within their unity, calling it the “height point of view” in psychophysiology (just as the primacy of the biological moment over the chemical moment is the “height point of view” in biochemistry).

Further down in the same note, it is described how *consciousness* alters psychophysiological processes by establishing new *systemic* relationships between psychological functions. This system of interfunctional connections arises through communication and develops not organically but historically. It is localised in the brain in a completely different way to that of lower, “elementary” psychological functions.

“The *main thing* is the possibility, brought about by consciousness, of new movement, new changes in psychophysiological processes, new connections, a new type of function development – particularly *historical*, involving a change in interfunctional connections, – *a case that is impossible in terms of organic development*: psychological systems... The possibility of *social* conscious experience, and hence the primacy of conscious structures formed from the outside, through communication: what is impossible for one is possible for two. This point of view is concretised in the problem of psychological development and localisation; cf. extracerebral connections. The idea of psychological physiology” (Vygotsky, 1982, p. 66).

This term will be encountered again 45 years later in Aleksandr Luria’s last work, *On the Problem of Psychologically Oriented Physiology* (Luria, 1977). His archive contains an early version of this article entitled *On the Problem of “Psychological Physiology”* (1974), co-authored with Evgenia Khomskaia.

Luria traces the history of this discipline back to Ivan Sechenov. It required considerable insight to discern the embryo of psychological physiology in a line or two from the lecture course *Physiology of Nervous Centres* (1890). However, for some reason, Luria does not mention who first introduced the term “psychological physiology” into circulation and with what intention.

An interesting detail is that this term appeared in Luria’s report while Vygotsky was still alive, around the time when Lashley came to Moscow. During the infamous discussion “On the Situation on the Psychological

Front” in Kharkov on 12–13 June 1931<sup>21</sup>, a Ukrainian comrade informed the audience: “Relatively recently, we had a representative of Moscow psychological thought, Prof. Luria, who gave a report on experimental psychology. Undoubtedly, the report was interesting. <...> However, what he presented gave us little in the field of psychology or physiology. Luria called it ‘psychological physiology’ – a term that was also not entirely clear to us” (Discussion, 1931, p. 30). In short, it was interesting to listen to, but of little use, and it remained unclear what this new physiology was, psychological...

Why did Luria stop using this term, and then suddenly remember it at the end of his life? And why did he not mention that the idea of psychological physiology had been shared with him by his friend and teacher, Vygotsky? I cannot understand this. Let us consider it a riddle.

In fact, from the 1920s onwards, Luria devoted his research to nothing other than psychological physiology, studying neurodynamic processes and motor reactions “on the path of psychological experimentation”. In particular, he considered “motor skills as a system reflecting the structure of hidden psychological processes” (Luria, 2002, p. 37).

In the author’s preface to the American edition of *The Nature of Human Conflict* (1932), the credo of psychological physiology is clearly and unambiguously declared: “It is more probable that elementary neurodynamics, as observed in the human, is comprehensible only by an analysis of those higher forms of organised behaviour connected with the culturally created psychological functions” (Luria, 1932, p. 17). The word “elementary” seems unnecessary here, as it greatly narrows the scope of psychological physiology. But Luria was probably referring to his criticism of the “objective schools in psychoneurology”, which were armed with the idea of the brain as a telephone exchange and wanted to explain every act of behaviour in terms of elementary processes of excitation and inhibition.

And what is the construction of bypasses to restore movement, speech and other higher psychological functions in patients with brain injuries if it is not *psychological physiology in action*? Work in this area has brought Vygotsky’s students well-deserved fame.

Back in the 1920s, Vygotsky himself was engaged in the restoration of motor functions in patients with Parkinson’s disease by laying out cards on the floor (a clear example of the construction of an extracerebral connection compensating for impaired automatic reactions). A few years later, he formulated the compensatory principle for higher psychological functions in cases of damage to the mature brain: “Objectifying the disrupted function, bringing it out into the open and transforming it into ex-

<sup>21</sup> Aleksander Talankin, the incoming Moscow inquisitor, condemned the “Vygotsky-Luria group” and called for “serious opposition to the cultural-psychological theory”. The next speaker swiftly added Vygotsky and Luria to the list of “extremely dangerous eclectics” (see Discussion, 1931, pp. 15, 27).

ternal activity is one of the main ways of compensating for these disorders” (Vygotsky, 1934, pp. 40–41).

According to Tatyana Akhutina’s authoritative testimony, the described “exteriorisation” remains the “main psychotechnical approach” for students of A.R. Luria and L.S. Tsvetkova to this day (Akhutina, 2004, p. 41).

After sharing the story of how Luria corrected his name to Vygotsky’s in the section of her Ph.D. abstract discussing primacy in the development of the principles of neuropsychology, Tatyana Vasilyevna asks the question: how did Vygotsky arrive at his discoveries in this field? I would like to hope that my research on the project of psychological physiology will add important details to the answer to this question.

### Conclusion

After Vygotsky’s death, Luria made considerable efforts to publish a commemorative collection (*Festschrift*)

featuring contributions from many distinguished scientists. The 1936 campaign against pedology, which resulted in Vygotsky’s books being removed from libraries, made such a publication impossible. Nevertheless, Luria’s archive contains the replies of the authors he invited to contribute to the collection, including Lashley. We do not know how Lashley reacted to Vygotsky’s report, nor whether he could appreciate the concept of psychological physiology, but the words in his letter speak volumes: “Vygotsky’s death, which I did not know about before, has deeply saddened me. He seemed to me to be one of the most charming and brilliant people I have ever met, and his death is a very serious loss to science. I would consider it an honour to be allowed to participate in the collection dedicated to his memory” (Levina, Morozova, 1984, p. 86).

The dialogue with Lashley was not continued, but Vygotsky left psychological physiology in reliable hands. The seed he sowed bore fruit of which Russian science can be justifiably proud.

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