E-JOURNAL (2023)
12. JAHRGANG / 1

FORUM INTERDISZIPLINÄRE BEGRIFFSGESCHICHTE (FIB)

LEIBNIZ-ZENTRUM
FÜR LITERATUR- UND
KULTURFORSCHUNG

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IMPRESSUM

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Gestaltung	KRAUT & KONFETTI GbR, Berlin
Layout/Satz	Tim Hager
Titelbild	D. M. Nagu

ISSN 2195-0598

INHALT

›OBMEN VESHCHESTV‹ – THE RUSSIAN AND SOVIET CONCEPT OF METABOLISM AND BEYOND

Mieka Erley

INTRODUCTION

Metabolism has long served as a broad organizing concept in Russian and Soviet culture for the exchange of material and energy between organisms and their environment. The Russian term *obmen veshchestv*, literally meaning »exchange of substances«, semantically ranges beyond the Latinate *metabolizm* (metabolism) and provides a framework for reflecting on bodies and material objects as open systems engaged in a constant process of transformation. *Obmen veshchestv* appears in public discourse in mid-19th century Russia as a calque from the German term *Stoffwechsel* (or *Wechsel der Materie*). Its usage in Russia reflects the enduring influence of German science.[1] In this entry, I will explore the development and expansion of this concept of material and energy exchange between organisms and their environment in Russia and the Soviet Union. In the course of a century, metabolism migrated from discussions of plant nutrition into physiology, thermodynamics, and ultimately into the Soviet practice of state economic planning. This entry will therefore pay particular attention to the early Soviet period when existing debates on metabolism took on new urgency as tools for praxis on every scale, from the body of the individual worker to humanity's future collective management of planetary material and energy flows.

PHYSIOLOGICAL MATERIALISM FROM GERMANY TO RUSSIA

To establish the concept's origin and lines of influence in the Russophone world, it is necessary to begin with early 19th-century German thought and research on metabolism and its reception. Among the influential German scientists who conducted and advanced research in the field were the cell biologist Theodor Schwann (who coined the term *metabolische* in 1839), physiologist Friedrich Tiedemann, physician Robert Mayer, and popular chemist Justus Liebig. Liebig contributed most significantly to the migration of the concept of material exchange from German into Russian, as parts of his works were translated and widely read as early as the 1840s. Liebig made important contributions to the study of metabolism in plants and animals, introducing such terms as *Stoffwechsel* and *Metamorphose* to describe the chemical, physical, and energetic transformations and exchanges within organisms and between organisms and their environment. In contrast to the specialized Latinate scientific terms *metabolische* and *Metabolism*, *Stoffwechsel* and *Metamorphose* in German and *obmen veshchestv* in Russian were artifacts from the era before the disambiguation of modern scientific fields. They remained a rich discursive and conceptual resource for those who believed in the unity of science and who sought to integrate the laws of chemistry, physics, and biology. The persistence of the term *obmen veshchestv* into the Soviet period signaled an affiliation with Marx and Engels who had extrapolated the concept into political economy.[2] For all these reasons, over the next centuries, metabolism became an inspirational and productive concept in Russian and Soviet intellectual life.

Liebig's mineral theory of plant nutrition revolutionized agriculture, displacing German agronomist Albrecht Thaer's »humus theory«, which had asserted that it was only the top layer of organic material in soil or humus that nourished growing plants.[3] Liebig observed that chemical and gas exchanges were constantly taking place between plants and the »non-living« material in soil and he proposed that plants and animals alike metabolized inorganic substances to sustain life processes. Moreover, this metabolic process depended on the recycling of minerals

1 For a forensic investigation of the German terms, see Franklin C. Bing: »The History of the Word ›Metabolism‹«, in: *Journal of the History of Medicine and Allied Sciences* 26 (1971), no. 2, pp. 158–180.

2 The Latinate *metabolizm* did not come into common usage in Russian until the 1960s–1970s.

3 A[leksei] A. Rode: *Soil Science*, Jerusalem: Israel Program for Scientific Translations 1962, p. 5.

DOI: 10.13151/fib.2023.01.05

back into the soil, a process involving numerous social and economic exchanges. It was this vision of the political economy of material exchange that would significantly influence Marx, Engels, and many Russian political radicals, resulting in Liebig's induction into the Soviet pantheon and the republication of his works in multiple Soviet editions. This connection will be discussed further on.

In addition to his research on agriculture and plant nutrition, Liebig worked on the issues of animal chemistry, shaping the public understanding of nutrition, diet, and health. He even publicized a method of producing meat extract and lent his name to the commercial product, which was marketed with illustrated trade cards that are collectors' items today. (see fig. 1[4])

Fig. 1: A Russian-language trade card for Liebig's Meat Extract: »Liebig's Meat Extract: the best seasoning that gives an outstanding taste to soup, vegetables, sauces, and meat dishes«.

In the scientific domain, Liebig's most significant work concerned the source of animal heat, which vitalists had long regarded as evidence that living organisms possessed a »vital« essence. In forming his conclusion that animal heat must originate solely in the chemical reaction of food with oxygen, Liebig drew on Antoine de Lavoisier's insight that respiration was a form of combustion as well as Michael Faraday's theory that power cannot be created ex nihilo.[5] In turn, Liebig's work on animal heat influenced two of the crucial works that established the law of conservation, Robert Mayer's »Organic Motion in Its Relation to Metabolism« and Hermann Helmholtz's *On the Conservation of Force*.[6]

Liebig stood between the German romantic *Naturphilosophie* of Friedrich Schelling and Lorenz Oken and the new scientific materialism that would follow. Although Liebig renounced the *Naturphilosophie* of his youth in favor of rigorous experimentation and empirical data, he himself would be criticized as a vitalist and romantic by the younger generation of scientific materialists in Western Europe. In Russia, however, Liebig's ideas found fertile ground, and the younger Russians of the 1860s still venerated Liebig as an avatar of materialism. Among other things, the physiological materialists that followed Liebig set out to establish the human body as an object of scientific study, an object comprehensible within the framework of universal physical laws and explicable without any recourse to supernatural or spiritual causes. In 1855, the German physiologist Rudolf Wagner wrote a letter to Liebig in which he complained about the atheism and »materialism of Vogt-Moleschott-Büchner, which threatens us with a new era of barbarism«.[7] The three »barbarians« in question were the zoologist Karl Vogt, the physiologist Jakob Moleschott, and the physician Ludwig Büchner, all of whom enjoyed a wide and controversial reception in Russia. Exemplifying an irreverent materialism, Moleschott famously intoned, »Ohne Phosphor, kein Gedanke!« [No thought without phosphorus!], and Ludwig Büchner described animal life (and implicitly human life) as a »chemical laboratory«.[8]

4 »Miasnoi ėkstrakt'' Libikha« (Russian-language trade card for Liebig's Meat Extract), year unknown (about 1900), Russian National Electronic Library of Book Monuments, R0 no. 2/15, https://kp.rusneb.ru/item/material/myasnoy-ekstrakt-libiha-luchshaya-priprava-pridayushchaya-otlichnyy-vkus-supu-ovoshcham-sousam-i-myasnym-blyudam-luchshaya-priprava-pridayushchaya-otlichnyy-vkus-supu-ovoshcham-sousam-i-myasnym-blyudam (last accessed 01.04.2023).

5 Justus Liebig: »Zehnter Brief«, in: id.: *Chemische Briefe*, Heidelberg: C. F. Winter 1844, p. 117; Shaul Katzir: »Employment Before Formulation: Uses of Proto-Energetic Arguments«, in: *Historical Studies in the Natural Sciences* 49 (2019), no. 1, pp. 1–40.

6 P[eter] M. Heimann: »Mayer's Concept of ›Force‹: The ›Axis‹ of a New Science of Physics«, in: *Historical Studies in the Physical Sciences* 7 (1976), pp. 277–296.

7 Qtd. in Claus Spenninger: »A Movement That Never Materialized: The Perception of Scientific Materialism as a Secular Movement in Nineteenth-Century Germany«, in: *Freethinkers in Europe: National and Transnational Secularities, 1789-1920s*, ed. by Carolin Kosuch, Berlin: DeGruyter 2020, pp. 273–296, here p. 273.

8 Ludwig Büchner: *Kraft und Stoff: Empirisch-naturphiloso-*

In the domain of belles-lettres, where the liveliest intellectual debate took place in Russia, the physiological materialists were seen to be united in their attack on idealism and religion. In Ivan Turgenev's novel *Fathers and Sons* (1862), the younger generation reads Liebig's works and urges the older generation to set Pushkin aside and take up Buchner's *Kraft und Stoff*. In Dostoevsky's *Demons* (1871–1872), a character irreverently throws out an Orthodox icon and instead places »the works of Vogt, Moleschott, and Büchner on stands like three lecterns«.[9] Some Russian commentators believed that experimental physiology violated the values of Christianity, and indeed, Moleschott wrote that it was »matter«, not God, that »rules over men«.[10] Human metabolism was a dangerous, even taboo subject and its study was associated with a radically new worldview and the dawning of modernity in Russia.

The first of Russia's own physiological materialists was Ivan Sechenov, who studied with Karl Ludwig and Hermann Helmholtz in Germany and with the physiologist Claude Bernard in France. Although Sechenov is largely remembered for his work on the physiology and reflexes of the nervous system, he also carried out extensive work on the physical chemistry of the body, particularly gas exchanges in the blood.[11] In his authoritative Brockhaus-Efron encyclopedia entry on metabolism, titled »Exchange of Matter *and Forces* in the Animal Organism« (emphasis mine), Sechenov introduces energy exchange as a co-factor of metabolism, shifting the focus of the concept from matter to energy, or »force«. He writes that

»alongside metabolism, there is an exchange of energy between the animal organism and its external environment. The fact is that the substances of food and drink capable of burning, as well as the oxygen of the inhaled air, are carriers of energy, serving, during their transformations in the body, as a source of living forces, a source of all internal and external work of the body«.[12]

Sechenov focuses on »living forces« and their capacity to produce work. It should be remembered that Sechenov studied in Heidelberg with Hermann Helmholtz, a co-discoverer of the law of the conservation of energy. Helmholtz had followed Liebig's investigations of animal heat and metabolism, and he proposed that just as perpetual motion machines were impossible, so, too, was it impossible that animals were able to produce heat without fuel. Instead of possessing a »vital« force, organisms drew life energy from their environment through metabolic processes. Helmholtz's work was an important intervention in the vitalist controversy and further supported the theory of the conservation of energy—in both the inorganic and organic domains. Following this thermodynamic line of approach to metabolism, Sechenov quantifies the amount of energy that may be produced by the »human engine«. He notes that for the hourly work of a person of 24,000 kilogram-meters, »an extra 8.2 grams of fat burns in the body more than at rest«. For an eight-hour workday, the worker would, therefore, require an extra 64 grams of fat.[13] Such calculations of the metabolic cost of work were foundational to the study of nutrition and would also serve state biopolitical projects of managing resources and human bodies, a kind of management that suggests the Greek root of economy and ecology—oikos. We might further take note of the application of this technology of rule in the management of camps, penal colonies, and labor projects of the 20th century, where it was an institutional practice to ration calories per unit of labor. In an age when machine power was replacing human and animal labor, Sechenov closes his discussion with a rallying approval of the efficiency of the »working animal« relative to a machine:

»in the matter of utilizing energy, the working animal is superior to the steam engine in two respects: the engine utilizes only 8%, and the animal 25% of the total income; in the machine, 92% of the heat is wasted, and in the body, the corresponding excess goes to maintain normal body temperature«.[14]

Efforts to optimize the human motor, fueled by processes of digestion and metabolism, would find full expression in the Soviet period, in such Taylorist projects as Aleksei Gastev's Institute for the Scientific Organization of Work and the Mechanization of Man.

phische Studien, Leipzig: Theodor Thomas 1864, p. 221.

9 Fyodor Dostoevsky: *Demons*, trans. by Richard Pevear and Larissa Volokhonsky, New York: Vintage Books 1994, p. 346.

10 Qtd. in Michael Holquist: »Bazarov and Sečenov: The Role of Scientific Metaphor in *Fathers and Sons*«, in: *Russian Literature* 16 (1984), pp. 359–374, here p. 365.

11 See Galina Kichigina: *The Imperial Laboratory: Experimental Physiology and Clinical Medicine in Post-Crimean Russia*, Amsterdam; New York: Rodopi 2009.

12 I[van] M. Sechenov: »Obmen veshchestv i sil v zhivotnom organizme« [Metabolism and Forces in the Animal Organism], in: *Entsiklopedicheskii slovar'* [Encyclopedic Dictionary], vol. 21, St. Petersburg: Brokgauz i Efron, 1897, pp. 530–533, here p. 530. All translations by the author unless otherwise noted.

13 Ibid., p. 532. The kilogram-meter was a new unit that measured the work done by a kilogram force over the distance of a meter.

14 Sechenov: »Obmen veshchestv« (note 12), p. 533.

 DOI: 10.13151/fib.2023.01.05

METABOLISM: FROM MATTER TO ENERGY

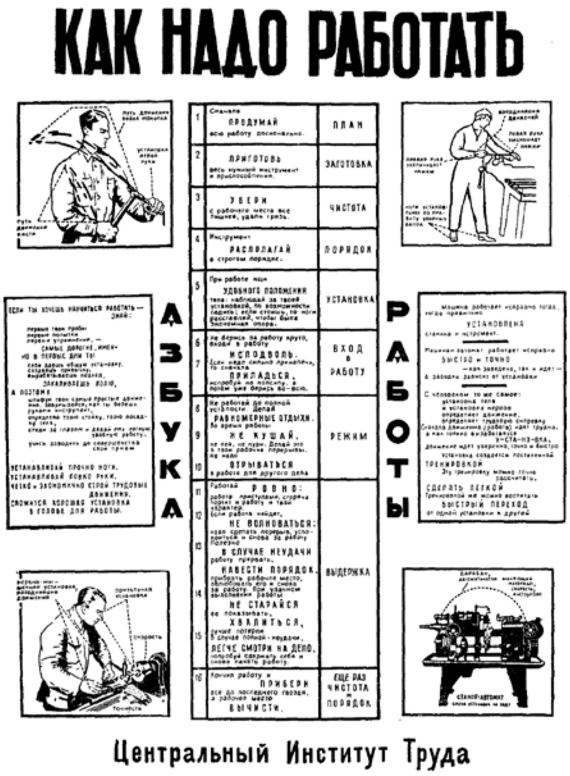

Fig. 2: An image from Gastev's *How to Work*

Gastev saw himself as both the engineer and the poet of the age of the human engine. In the book *How to Work*, he asks, »Why are there mountains of books written about thermal energy, about furnaces, boilers, steam engines, electricity, anthracite, hydraulic power, electrification, and yet nothing is written about the energy of the worker?«[15] He envisions the human body as the primary source of energy required to build socialism, an engine that can be brought into optimum efficiency by the mechanic and the engineer. Gastev writes,

»The science of the nourishment of a working organism should be as precise as the science of thermodynamics, as the science of the nourishment of a steam engine, of the nourishment of an electric motor; the consumption of human energy must be measured using scientific instruments down to the thousandths of even the smallest calorie«.[16]

Reducing human physiology to a mechanism, Gastev writes that »in the domain of machine production, biology is subordinated to the priorities of the engineer«. He refers to Sechenov's work approvingly, noting that it was no coincidence that the biologist acquired his first degree from an engineering school. (See fig. 2)[17]

Gastev's proposed methods of harnessing human energy provoked violent debate in the early 1920s. His Taylorist mode of organizing labor was opposed by the so-called »Group of Communists«, lead by Pavel Kerzhentsev, a former member of Proletkult, the Proletarian culture organization founded by the Bolshevik intellectual Aleksandr Bogdanov.[18] Kerzhentsev dismisses Gastev's laboratory-based research on the working body as a »vulgar fetish« and writes that Gastev overemphasizes muscular work relative to other factors of production.[19] Proletkultists like Kerzhentsev and Bogdanov were suspicious of Taylorism as a capitalist import whose sole aim was to make its workers sweat as much as possible, but they nonetheless recognized the importance of the scientific organization of labor under socialism. Bogdanov shared Gastev's thermodynamic vision of labor, although it was subsumed within a larger and more complex system of organization that he called »tektology«. Bogdanov's systems theory was inspired by Wilhelm Ostwald, whose energetic worldview framed the body as a system that maintains dynamic equilibrium through metabolic processes. In *Tektology*, Bogdanov writes,

»It is not so easy to account for the total needs of a worker, they are complex and diverse: food in its various forms, clothing, housing, cultural needs, and others. Of these needs, the easiest to trace quantitatively is nutrition. It is most convenient to start with actual muscular work. It results from the energy of oxidation, ›combustion‹ in the body of carbon-containing substances absorbed from food. Therefore, the role of food is quite similar to the role of fuel for a steam engine; and in exactly the same way as is being done with regard to fuel, the value of food as a source of energy for work is measured in calories, i.e., units of thermal energy«.[20]

15 A[leksei] K. Gastev: *Kak nado rabotat'. Prakticheskoe vvedenie v nauku organizatsii truda* [How to work. Practical Introduction to the Science of Organizing Labor], Moscow: Ėkonomika 1972, p. 46.
16 Ibid., p. 51.
17 Ibid., p. 2.
18 Kendall Bailes: »Alexei Gastev and the Soviet Controversy over Taylorism, 1918–24«, in: *Soviet Studies* 29 (1977), no. 3, pp. 373–394, here p. 389.
19 P[laton] M. Kerzhentsev: *Printsipy organizatsii* [Principles of Organization], Moscow: Ekonomika 1988, p. 312.
20 A[leksandr] A. Bogdanov: *Tektologiia: Vseobshchaia organizatsionnaia nauka* [Tectology: The Universal Organizational Science], Moscow: Ėkonomika 1989, p. 262.

As Bogdanov notes, the same measure of energy – the calorie – may apply to the work of a machine or the digestion of a biological organism, making these activities fungible within an energy economy.

While this thermodynamic understanding of labor was most practically applied to the human worker, it was perhaps more obvious in the case of photosynthesizing plants, which are the foundation of all energy exchange and metabolism on Earth. Where Sechenov extolls the efficiency and »forces« of the »working animal«, Russia's leading plant physiologist Kliment Timiriazev does so for the humble »working plant«. He praises the efficiency of the plant, noting that, unlike animals, plants produce almost no waste – only carbon dioxide and water. Timiriazev, like Sechenov, studied with both Hermann Helmholtz and Claude Bernard and he applied his background in chemistry and physics to the study of plant metabolism. This yielded new insights, particularly into photosynthesis and its metabolites. It is precisely the green plant's capacity to transform solar energy into bodies that gives it, in Timiriazev's words, a »cosmical function«.[21] He observes that »the plant is the intermediary between heaven and earth. It is the real Prometheus, stealing fire from heaven. The ray of sun stolen by it burns both in the flickering light of a candle and in the dazzling spark of electricity. The ray of sun sets the enormous flywheel of the gigantic steam engine in motion, the painter's brush, the poet's pen«.[22] Timiriazev's praise of the plant precedes the Soviet rhetoric of Prometheanism, but it may still be read as a cheeky retort to the valorization of the human subject. Even if plants do not possess the »living force« that Sechenov attributes to animals, Timiriazev reminds us that the basis of all the »manifold manifestations of life in our planet« and all production, from the steam engine to art, rests upon the metabolic work of the plant.

SCALING UP: METABOLISM OF THE BODY, THE STATE, AND THE PLANET

Around the same time that Timiriazev was carrying out his research in the 1880s, the Ukrainian socialist and founder of ecological economics, Serhiy Podolynsky expanded the thermodynamic vision of plant metabolism into a comprehensive system of agricultural energetics. Podolynsky addressed not only the conservation of energy, but also the struggle against entropy within his system. Podolynsky's entropic vision was clearly exemplified in his discussion of the useful chemical work of the plant. He writes that the »sun's rays that arrive to us, warm, illuminating, and chemically effective, are so received by matter that they are transformed into free chemical affinity or into mechanical movement«.[23] He describes the plant kingdom as a »powerful ally of humanity« because it prevents solar energy from dissipating into useless heat, and instead renders it useful to humanity through metabolic transformation. In his essay on »Socialism and the Unity of Physical Forces« (1880), Podolynsky sketches a thermodynamic history of the universe, from the birth of the solar system to the complete dissipation of energy and the impossibility of any further transformation of matter. However, Podolynsky doesn't mourn the distant heat death of the universe; instead, he sets the goal of minimizing waste and maximizing the efficient use of the universe's finite energy to benefit humanity. He is optimistic that humans can accumulate useful energy by managing labor efficiently, thereby rendering **humanity activity** close to the »perfect engine« as imagined by Sadi Carnot.[24] Since activities related to nutrition are both the main source of energy and the main energy *expenditure* for humanity, Podolynsky seeks to optimize caloric inputs and outputs. He imagines that, under socialism, this kind of management of material and energy resources would be possible:

> »A higher level and a more equitable division of the quality and quantity of foodstuffs would inevitably bring about an increase in the muscular and nervous force of humanity. From that would spring a new growth of production and a greater accumulation of energy on the earth's surface«.[25]

Podolynsky was sharply criticized by Engels, who argued that he had »confused physics with economics«.[26] As we are about to see, Marx and Engels preferred to »confuse« soil chemistry with economics. Podolynsky's work was not actively pursued in state agriculture after the revolution,

21 Kliment Timiriazev: *The Life of the Plant*, trans. by A. Sheremetyeva, Moscow: Foreign Languages Publishing House 1958, p. 341.
22 K[liment] A. Timiriazev: »Stoletnie itogi fiziologii rastenii [A Century of Results in Plant Physiology]« (1901), in: id.: *Sobranie sochineniia v chetyrekh tomakh* [Collected Works in Four Volumes], vol. 2, Moscow: OGIS-Sel'khozgiz 1948, pp. 359–404, here p. 382–3.

23 Sergei Podolinsky: »Human Labor and the Unity of Force«, trans. by Peter Thomas, ed. and annotated by Paul Burkett and John Bellamy Foster, in: *Historical Materialism* 16 (2008) no. 1, pp. 163–183, here p. 166.
24 Ibid., p. 182.
25 Ibid., p. 183.
26 Letter from Frederick Engels to Karl Marx, London, December 19, 1882, trans. by Dona Torr, From Marx-Engels Internet Archive, https://www.marxists.org/archive/marx/works/1882/letters/82_12_19.htm (last accessed 01.04.2023).

DOI: 10.13151/fib.2023.01.05

but it continues to stimulate interest and debate in ecological economics.[27]

Metabolism is a concept in Marx and Engels' work, although it was more in line with Liebig's soil and social economy than Podolynsky's energetics. In *Dialectics of Nature*, which was published in the Soviet Union in the 1930s and had a significant impact on Soviet intellectual life, Engels provided a definition of life that Soviet schoolchildren would later recite aloud: »Life is the mode of existence of protein bodies, the essential element of which consists in continual metabolic interchange with the natural environment outside them«.[28] Engels also provided an evolutionary argument about diet in »The Part Played by Labour in the Transition from Ape to Man«, where he speculates that a meat diet introduced the »chemical premises for the transition to man«, leading to both new technologies and a qualitatively new physiology.[29] Eco-Marxist John Bellamy Foster has argued that the concept of metabolism is the very basis of Marx and Engels' broader ecological vision.[30] Marx followed the advances in agricultural chemistry and wrote to Engels that »the new agricultural chemistry in Germany, especially Liebig [is] more important than all the economists put together«.[31] Marx extended Liebig's political economy into what Foster calls the »theory of metabolic rift«.[32] In his popular writings on chemistry, Liebig had criticized modern agricultural and sanitation practices as a mismanagement of »material exchange« between city and country. Referring to the example of England, Liebig wrote that

»elements of soil indispensable to plants do not return to the fields – contrivances resulting from the manners and customs of English people […] render it difficult, perhaps impossible, to collect the enormous quantity of the phosphates which are, as solid and liquid excrements, carried into the rivers on a daily basis«.[33]

In Liebig's view, natural mineral cycles were being actively disrupted, leading to imbalances in both the soil economy and the social economy. Marx extends this critique in *Capital*, where he notes that agricultural conditions under capitalism have created

»an irreparable rift in the interdependent process of social metabolism [*Stoffwechsel*], a metabolism prescribed by the natural laws of life itself. The result of this is a squandering of the vitality of the soil, which, through trade, is carried far beyond the bounds of a single country (Liebig)«.[34]

This use of »metabolism« was more than a metaphor, as both Liebig and Marx understood these material and mineral flows as the basis of human nutrition, agriculture, and economy alike. Engels carried out his own exposition of Liebig's political economy in formulating his ideas about the »antithesis of town and country«. Engels writes that no one has called for the resolution of the contradictions between town and country

»more energetically than Liebig in his writings on the chemistry of agriculture, in which his first demand has always been that man shall give back to the land what he takes from it, and in which he proves that only the existence of the towns, and in particular the large towns, prevents this«.[35]

This critique of the »metabolic rift« between city and country exerted a particular influence on Russian radicals of the late 19th century, including Dmitrii Pisarev, Nikolai Chernyshevskii, Aleksandr Engelgardt, and Vladimir Lenin. After the revolution, the call for the unification of town and country (*smychka goroda i derevni*) would become a prominent political slogan, and Lenin was empowered to scale up the management of »metabolic« functions to

27 See Joan Martinez-Alier: *Ecological Economics*, Oxford, UK: Basil Blackwell, 1987; John Bellamy Foster/Paul Burkett: »Ecological Economics and Classical Marxism: The ›Podolinsky Business‹ Reconsidered«, in: *Organization & Environment* 17 (2004), no. 1, pp. 3–60.
28 Frederick Engels: *Dialectics of Nature*, trans. by Clemens Dutt, New York: International Publishers 1940, p. 195–197.
29 Ibid., p. 286.
30 See John Bellamy Foster: *Marx's Ecology*, New York: Monthly Review Press 2000.
31 Karl Marx/Frederick Engels: *Selected Correspondence, 1846–1895*, New York: International Publishers 1942, p. 204.
32 See John Bellamy Foster: »Liebig, Marx, and the Depletion of Soil Fertility«, in: id.: *Ecology Against Capitalism*, New York: Monthly Review Press 2002, pp. 154–170; »Marx's Theory of Metabolic Rift: Classical Foundations for Environmental Sociology«, in: *American Journal of Sociology* 105 (1999), no. 2, pp. 66–405. See also Joan Martinez Alier: »Marxism, Social Metabolism, and International Trade«, in: Alf Hornborg/J. R. McNeill/Joan Martinez Alier (eds.): *Rethinking Environmental History: World-System History and Global Environmental Change*, Lanham: AltaMira Press 2007, pp. 221–237.
33 Justus Liebig: *Familiar Letters on Chemistry in Its Relations to Physiology, Dietetics, Agriculture, Commerce, and Political Economy*, London: Taylor, Walton, and Maberly 1851, p. 473.
34 Karl Marx: *Capital: A Critique of Political Economy*, vol. 3, trans. by David Fernbach, ed. by Frederick Engels, London: Penguin Books 1991, p. 949.
35 Friedrich Engels: »The Housing Question« (extract), in: Karl Marx/Friedrich Engels/V[ladimir] I. Lenin: *On Historical Materialism: A Collection*, compiled by T. Borodulina, New York: International Publishers 1974, pp. 155–158, here p. 158.

the level of centralized state planning. The Marxist vision of social metabolism would be applied to the material exchanges between town and country, as well as among national republics in the all-union division of labor.[36]

The Soviet biogeochemist Vladimir Vernadsky's concept of the noosphere may be considered the ultimate expression of the ambition to rationally manage metabolism—not just at the level of the state, but at the level of the entire planet. In his work *Biosphere* (1926), Vernadsky posited that living matter was a geological force on earth that had shaped the conditions of its own development, transforming the geosphere into the »biosphere«. Vernadsky writes of the metabolism within the biosphere: »Between its inert lifeless part, its inert natural bodies and living substances that inhabit it, there is a continuous material and energy exchange, materially expressed in the movement of atoms caused by living matter«.[37] As the most active substance in the biosphere, living matter has long directed the movement of inert matter. The transformative action of living matter upon inert matter results in increasing complexity, culminating in the stage of natural history that Vernadsky calls the »noosphere«. As Georgy Levit explains, the noosphere is not a new geological surface, but rather a qualitatively different state of the biosphere, in which the mind, as a naturally emergent property of living matter, directs the planet's flows of material and energy.[38] This constant management of the »biogenic flow of atoms« results in a dynamic equilibrium. Life and mind thus potentiate their own increasing complexity while continuously re-balancing the metabolism of the larger biogeochemical system that is the planet.

CONCLUSION

Metabolism was intentionally employed as an interdisciplinary concept by those seeking to integrate and unify the increasingly specialized knowledge generated within the fields of biology, chemistry, physics, and the social sciences from the 19th century onwards. The concept of metabolism was multi-scalar, trans-species, and disciplinarily promiscuous, and in this lay its value. Metabolism offered a particular way of thinking about the *ecology* and *economy* of nature, by focusing specifically on exchange—exchange of matter and energy between organisms and their environment at multiple scales and across the divide of living and non-living substances. Economy is rooted in the Greek *oikos*, which refers to the household and the activities of budgeting, saving, spending, and managing the flows of the household and all its members and constituent parts. Economy and metabolism are thus conceptually related, and it is here that we can see the particular appeal of the concept for 19th-century radicals and Soviet Marxists as it offered a vision of material flows that encompasses the human body, nature, and the state, holding the promise of rationalizing these flows within a single managed economy. Metabolism was a preferred concept for describing processual change in Marxist and Soviet thought precisely because it emphasized exchange, a fundamentally economic concept that reflected a Marxist view of life processes. In this we might see what Reinhart Koselleck calls »the convergence of concepts and history«.[39] The Soviet Union gave shape to the radical visions of the metabolic economy of the 19th-century, and the ambition to integrate natural science, social science, and policy contained within the concept of metabolism turned the Soviet Union into fertile ground for the emergence of planetary ecology.

36 For an extended discussion, see Mieka Erley: *On Russian Soil: Myth and Materiality*, Ithaca, NY: Cornell University Press 2021, pp. 34–48.

37 V[Ladimir] I. Vernadskii: *Nauchnaya mysl' kak planetnoe iavlenie* [Scientific Thought as Planetary Phenomenon], Moscow: Nauka 1991, p. 15.

38 Georgy Levit: »The Biosphere and the Noosphere Theories of V.I. Vernadsky and P. Teilhard de Chardin: A Methodological Essay«, in: *Archives internationales d'histoire des sciences* 50 (2000), no. 144, pp. 160–176, here p. 165.

39 Reinhart Koselleck: »Introduction (*Einleitung*) to the *Geschichtliche Grundbegriffe*«, in: *Contributions to the History of Concepts* 6 (2011), no. 1, pp. 7–25, here p. 21.

DOI: 10.13151/fib.2023.01.05