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The evolutionary synthesis and Th. Dobzhansky

HISTORY OF EVOLUTIONARY BIOLOGY, and first of all formation of “an evolutionary synthesis” were discussed many times and by many authors.¹ A special attention was given to the contribution of main founders of “an evolutionary synthesis” including Th. Dobzhansky.² American historians of science, particularly W. Provine, maintained a thesis that cardinal turn in the origin of Dobzhansky’s evolutionary concept has occurred already in the USA mostly as a result of Sewall Wright’s direct influence.³ According to some Russian biologists and historians of science⁴ Th. Dobzhansky, on the contrary, has brought the basic ideas of the future synthesis to the US. I’ll try to argue that these two approaches are complementary and not contradictory. In the US Dobzhansky’s basic ideas have received a further development, and, not without the influence of new American⁵ colleagues of Th. Dobzhansky were transformed into his theory of microevolution⁶ which was presented publicly in his world known book *Genetics and the Origin of Species* published in 1937.⁷

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¹ See, e.g., Ya. M. Gall, A. B. Georgievskii, “Synteticheskaya teoriya evolyutsii kak sovremenniy etap razvitiya darwinizma” [“Synthetic theory of evolution as modern stage of darwinism”] (1973), *Biologiya v shkole*, No. 3, pp. 7–15, No. 4, pp. 5–15; K. M. Zavadskii, “Evolutsionnaya teoriya [Evolutionary theory]” (1975), *Istoriya biologii. S nachala XXveka do nashikh dnei*, pp. 362–386.; *Razvitie evolyutsionnoi teorii v SSSR [The development of evolutionary theory in the USSR]* (1983); *Metodologicheskie problemy evolyutsionnoi teorii [Methodological problems of evolutionary theory]* (1984); N. N. Vorontsov, “Razvitie evolyutsionnykh idei v biologii” [“The development of evolutionary ideas in biology”] (1999); E. Mayr and W. P. Provine W. P. (eds.), “The Evolutionary synthesis: perspectives on the unification of biology” (1980); J. Mlikovsky and V. J. A. Novak (eds.), “Towards a new synthesis in evolutionary biology. Proceedings of the Int. Symposium, Praha, 5–11 July 1987” (1987); M. B. Adams, “A missing link in the evolutionary synthesis” (1988), *Isis*, Vol. 79, No. 297, pp. 281–284; J. Cain, “Common problems and cooperative solutions. Organizational activity in evolutionary studies, 1936–1947” (1993), *Isis*, Vol. 84, pp. 1–25; R. E. Kohler, “Drosophila and Evolutionary Genetics” (1991), *History of Science*, Vol. 29, Part 4, No. 86, pp. 335–375; E. Mayr, “The growth of biological thought. Diversity, evolution, inheritance” (1982); E. Mayr, “One long argument: Charles Darwin and the genesis of modern evolutionary thought” (1991).

² See Ya. M. Gall, M. B. Konashev, “Klassik [classic]” (1990), *Priroda*, No 3, pp. 79–87; I. A. Zaharov, “K 100-letiu Feodosiya Grigorievicha Dobzhanskogo [“To the century of Dobzhansky”] (2000), *Genetika*, No. 2, pp. 297–298; M. B. Konashev, “F. G. Dobzhanskii: genetik, evolyutsionist, gumanist” [“Th. Dobzhansky: geneticist, evolutionist, humanist”] (1991) in *VJET*, No. 1, pp. 56–71; M. B. Konashev, “Po tu i po etu storonu okeana (Feodosii Grigor’evich Dobzhanskii: 1900 – 1975)” [“On that and on this sides of the ocean”] (1996), *Vydaushiesja otechestvennye biologii*, pp. 45–58.; A. B. da Cunha, “On Dobzhansky and his evolution” (1998), *Biology and philosophy*, Vol. 13, No. 2, pp. 289–300.; U. Hossfeld, “Dobzhansky's Buch 'Genetics and the Origin of Species' (1937) und sein Einfluss auf die deutschsprachige Evolutionsbiologie” (1998), *Jahrbuch fuer Geschichte und Theorie der Biologie*, Bd 5. S. 105–144; R. C. Lewontin, “Introduction: The Scientific Work of Th. Dobzhansky” (1981), *Dobzhansky's genetics of natural populations I–XLIII*, pp. 93–115; H. A. Orr, “Dobzhansky, Bateson, and the genetics of speciation” (1996), *Genetics*, Vol. 144, No. 4, pp. 1331–1335.

³ W. B. Provine, “Origins of the genetics of natural populations series” (1981), *Dobzhansky's genetics of natural populations I–XLIII*, pp. 1–83.

⁴ Such opinion, in particular, was adhered by N. N. Vorontsov, K. M. Zavadsky, I. A. Zaharov, Yu. I. Poljansky.

⁵ Not all of them, however, were Americans. One of closest friends and adherents of Th. Dobzhansky was taxonomist from Germany E. Mayr. About E. Mayr see, e.g., E. I. Kolchinsky, M. B. Konashev, “Tvorcheskoe dolgoletie v nauke [Creative longevity in science]” (2004), *Priroda*, No. 9, pp. 71–72.

⁶ See Ya. M. Gall and M. B. Konashev, “O formirovani sinteticheskoi teorii evolyutsii: Znachenie knigi F. G. Dobzhanskogo “Genetika i proiskhozhdenie vidov” [“On formation of the synthetic theory of evolution: The

To answer the question what intellectual load has been taken away by Th. Dobzhansky from Russia it is necessary to describe some traits of so-called “the crisis of Darwinism”.⁸ It was not only the critical period of a transition from classical Darwinism to Darwinism of 20th century, but also a decisive time of Th. Dobzhansky’s origin as a geneticist, an evolutionist and theoretical and philosophical thinker.

When in 1915 Th. Dobzhansky being a teenager and a grammar-school boy had read Charles Darwin’s “Origin of Species”, Darwinism was already under a fire of criticism in Russia and in other countries. A little is known how this critics had affected Th. Dobzhansky. In his memoirs he speaks about the influence of Yurii A. Filipchenko’s two articles published in very popular Russian journal “Priroda” on him.⁹ Results of genetical researches of Thomas Hunt Morgan and his colleagues, described in these articles, not only determined Th. Dobzhansky’s decision to become a geneticist, but also helped him to define the subject of his first genetical research. It should be said too that Th. Dobzhansky was much more optimistic than Yurii A. Philipchenko, his future patron in Leningrad University when estimated these results and their value for the evolutionary theory.¹⁰ As soon as possible Th. Dobzhansky went to Moscow where Sergei S. Chetverikov gave him strains of *Drosophila* for his experimental study. Chetverikov himself received these strains from one of Morgan’s colleagues, Herman Meller who visited Moscow University in 1922. After reading this Dobzhansky’s article Yurii A. Filipchenko invited him to the first Russian laboratory of genetics in Petrograd (later Leningrad) university. Thus Dobzhansky received good opportunity to do what he want and to go ahead in his genetical and evolutionary studies.

One can see that already at this first stage of his way to the “evolutionary synthesis” Th. Dobzhansky formation as a scientist was a “synthetic” process itself in which it is impossible to separate a national and international elements.

Filipchenko’s role, however, consisted not only in an invitation of Th. Dobzhansky and a supplying him with favorable conditions for work and even mutual criticism despite of the difference in age and in scientific and administrative status. It is very probable that Th. Dobzhansky read all or most all of Filipchenko’s previous works on the problems of inheritance, variability and evolution. What valuable could and did find Th. Dobzhansky in Filipchenko’s works if Filipchenko was very skeptical in his opinion about Darwinian theory of evolution and the very opportunity of synthesis of genetics and Darwinism?

In 1913 Filipchenko began to lecture a special course on heredity and evolution.¹¹ Possibly, during the preparation of this course he wrote an extensive article devoted specially an evolutionary theory.¹² Filipchenko’s article starts with a recognition of Charles Darwin’s evolutionary concept as a true scientific theory.¹³ Then Filipchenko shows, on the one hand, that the Darwinian mechanism of evolution by means of natural selection of favorable traits is not proved from the point of view of the data received by new experimental biology, and, on the other hand, the data of the same experimental biology demonstrate an existence in the nature of another mechanism of evolution through mutations and autogenesis. Correctness or inaccuracy of this non-Darwinian mechanism of evolution is not found out yet.

How under these conditions achievements of genetics allow to resolve a problem of the origin of species? According to Filipchenko in the simplest case one elementary species will differ from another one “only by one elementary property”.

meaning of Dobzhansky's book *Genetics and the Origin of Species*] (1979), *Voprosy razvitiya evoliutsionnoi teorii v XX veke*, pp. 74–84.

⁷ Th. Dobzhansky, *Genetics and the origin of species* (1937).

⁸ See, e.g., K.M. Zavadskii, “Evolutsionnaya teoriya [Evolutionary theory]” (1975), *Istoriya biologii. S nachala XX veka do nashikh dnei*, pp. 362–386, in particular pp. 364–368.

⁹ Yu. A Filipchenko, “Khromozomy i nasledstvennost [Chromosomes and heredity]” (1919), *Priroda*, No. 7–9, pp. 327–350; idem, “Zakon Mendelya i zakon Morgana [Mendel’s law and Morgan’s law]” (1922), *Priroda*, No. 10–12, pp. 51–66.

¹⁰ Th. Dobzhansky, “The Reminiscences of Theodosius Dobzhansky” (1962), at p. 32.

¹¹ N.N. Medvedev, “Yurii Aleksandrovich Filipchenko” (1978), at p. 12.

¹² Yu. A. Filipchenko, “Ocherki po voprosam evoliutsii i nasledstvennosti [Sketches on problems of evolution and heredity]” (1913), *Russkoe bogatstvo*, No. 1, pp. 113–133, No. 2, pp. 109–126.

¹³ *Ibid*, p. 113.

[Then] a matter of the origin of species is replaced with a matter of the origin of the most lowest classification groups within the limits of one species, and if a distinction between them consists in the presence of one property we come eventually to a question about how this new property or group of new properties arise. Having answered on it ... we shall find out also the main essence of evolution.¹⁴

Thus Filipchenko, perhaps, not realizing, has specified a way of research of evolution and its mechanism in empirical, experimental and exact way. Tracing and measuring strictly quantitatively individual changes of elementary units of hereditary variability (or any sets of such units) it is possible to track and to count up an origin of the new forms from simplest to highest including species.

However Filipchenko himself has not gone on this way of the study of evolution for some reasons. Dobzhansky has gone instead of him. In his article published in 1924 he considered comprehensively a meaning of mutations for evolution. He begins with an analysis of those arguments which were put forward against such meaning, specifying that the objection based on a rarity of mutations, is already removed by works of many geneticists, and first of all of American geneticists of T. H. Morgan's group.¹⁵ Confirming to such statement Th. Dobzhansky referred that for 15 years of studying of only one species of drosophila, *Drosophila melanogaster*, it has been found "already over 200 mutations differing from normal ('wild') fly in various traits".¹⁶ Among mutated flies "even such traits, as life's duration, instincts, fertility" have been found out. Moreover, similar mutations have been discovered at other drosophila species (*D. simulans*, *D. willistoni*, *D. obscura*, *D. repleta*, etc.).¹⁷ Dobzhansky added that "for last years mutations have been found out at a number of objects, except of drosophila", that "mutations are not a rarity", mutations differ slightly each other very often, and "changes, produced by mutation, are founded out only with a careful studying of an organism". Therefore, Dobzhansky concluded, a value of mutations for evolution

consists in that their traits which being combined with each other (according to Mendel's laws), become a material for the action of natural selection (and with assistance of man for artificial selection as well).¹⁸

Then Dobzhansky specially described how mutations play this role of a material for selection:

the continuous reshuffling of genes occurs everywhere before our eyes, and a huge quantity of combinations of genes appears; at that it can easy occur that some combinations will be more harmonious, better, more adapted for a life, than others. Owing to an action of natural selection, some of these combinations will die out, others will be indifferent, the third useful. The new mutation at once after its occurrence gets in this sorting device of combinative variability and selection, and when a harmonious combination will be created it will become stronger in the nature, and the stage of evolution will be made.¹⁹

Therefore for Dobzhansky a problem of mutations as material for Darwinian selection has been removed. It was showed that mutations can be such material, and, most likely, they are. This supposition allowed Th. Dobzhansky to conclude his article in next words:

a contribution of genetics is that it has put on a true way of empirical research difficult problems of biology — a heredity and evolution.²⁰

But what matter needed such research? What difficult problems concerned simultaneously to a heredity and to evolution, had to be solved? Firstly, it was required to estimate precisely, including from the

¹⁴ *Ibid*, p. 128.

¹⁵ F. G. Dobzhanskii, "Nasledstvennost i mutatsii [Heredity and mutations]" (1924), *Chelovek i priroda*, No. 5–6, pp. 417–426, at p. 420.

¹⁶ *Ibid*, at p. 421.

¹⁷ *Ibid*, at p. 422.

¹⁸ *Ibid*, at p. 424.

¹⁹ *Ibid*, at p. 424.

²⁰ *Ibid*, at p. 425.

evolutionary point of view, quantity and quality of this mutational material. These task and methods of its decision have been formulated by S. S. Chetverikov as a research program in his well-known article published two years later in 1926. This Chetverikov's program was carried out by his pupils N. P. Dubinin, D. D. Romashov and N. N. Timofeev-Ressovsky in second half of 1920s — first half of 1930s.²¹ Owing to their works a new vision of the species problem was formulated by two of them in 1932.²² And these works were referred by Th. Dobzhansky in his book *Genetics and the Origin of Species*.²³ Secondly, it was necessary to confirm an efficiency of natural selection operating with this material. This part of researches was accomplished also by other scientists. At last, thirdly, it was necessary to prove, that there are species traits among the properties changed by mutations in this material. The most important task was to demonstrate experimentally that selection of these traits under certain conditions leads finally to formation of a new high-grade (normal) species, and to define these specific conditions of speciation. Th. Dobzhansky began to realize this third task already in 1922–1924.

From this point of view his another article under the characteristic title “Mutation and speciation” is especially interesting. It begins with the statement:

Among problems of the evolutionary doctrine a problem of the origin of new species have one of the first places.²⁴

Presenting Darwinian model of speciation, Th. Dobzhansky noticed:

Similarly it is easy to imagine a splitting of one species into two or more new species: selection splits originally homogeneous species population at first into some races, and then these races, becoming more and more various, transform already into different species.²⁵

After an analysis of objections against mutations as a material for the action of natural selection and having shown their full inconsistency in a view of last given genetic researches, and demonstration that mutations is a unique source of hereditary distinctions (almost whole article is devoted to this subject),²⁶ Th. Dobzhansky defines the process of speciation in conclusion:

a process of mutations delivers those hereditary distinctions which, being summarized owing to action of natural selection, give beginning of species distinctions. Various species, even rather close to each other, always differ in a lot of various hereditary factors. Meanwhile a factorial mutation [despite of its sharp distinction from original form and its taxonomic value nevertheless leads to formation of a form which are distinct from initial form only in

²¹ The data on obtaining of mutations by researchers of Chetverikov's group see: A. S. Serebrovskii, N. P. Dubinin, I. I. Agol, V. N. Slepikov and V. E. Altshuller, “Poluchenie mutatsii rentgenovskimi luchami u *Drosophila melanogaster*” [“Obtaining of mutations by X-rays at *Drosophila melanogaster*”] (1928), *Zhurnal eksperimentalnoi biologii*, Vol. 4, No. 3/4, pp. 161–180; A. S. Serebrovskii, N. P. Dubinin, “Iskustvennoe poluchenie mutatsii i problema gena” [“Artificial obtaining of mutations and problem of a gene”] (1929), *Uspekhi eksperimentalnoi biologii*, Vol. 8, No. 4, pp. 235–247. The data on mutations in natural populations of drosophila see: N. P. Dubinin, M. A., Geptner, S. Ja. Bessmertnaya and others, “Eksperimentalnyi analiz ekogenotipov *Drosophila melanogaster*. Chast 1.” [“The experimental analysis of ecogenotypes of *Drosophila melanogaster*. Part 1.”] (1934), *Biologicheskii zhurnal*. Vol. 3, No. 1, pp. 166–206; N. P. Dubinin, N. S. Nikoro and others, “Eksperimentalnyi analiz ekogenotipov *Drosophila melanogaster*. Chast 2.” [“The experimental analysis of ecogenotypes of *Drosophila melanogaster*. Part 2.”] (1934), *Biologicheskii zhurnal*. Vol. 3, No. 1, pp. 202–216; The review of Chetverikov school's works see: Adams M. B. “The founding of population genetics: Contribution of the Chetverikov school, 1924–1934”, *J. Hist. Biol.*, 1968. V. 1. N. 1. p. 23–40.; V. V. Babkov, “Moskovskaya shkola evolyutsionnoi genetiki” [“Moscow school of evolutionary genetics”] (1985).

²² N. P. Dubinin, D. D. Romashov, “Geneticheskoe stroenie vida i ego evolyutsiya” [“Genetic structure of species and its evolution”] (1932), *Biologicheskii zhurnal*, Vol. 1, No. 5–6, pp. 52–95.

²³ Th. Dobzhansky, “Genetics and the origin of species” (1937), at p. 42, 43, 46, 63, 81, 87, 95, 117, 120, 128–130, 132, 137, 272 (Dubinin), 43 (Gershenzon), 20, 21, 24–26, 30, 35–37, 41–46, 154–156 (Timofeev-Ressovsky).

²⁴ F. G. Dobzhanskii, “Mutatsii i vidoobrazovanie” [“Mutation and speciation”], *Priroda*. No. 5–6, pp. 31–44, at p. 31.

²⁵ *Ibid*, at p. 31.

²⁶ *Ibid*, pp. 32–44.

one factor. It is important, however, that through selection of mixed material the various forms differing from each other in any quantity of genes can be created. This process of a gradual differentiation of the mixed population, taking place in the nature, also is a process of speciation.²⁷

In this article Th. Dobzhansky formulated not only his own concept of speciation, but also offered for himself and others the new program of research of this process of speciation. This program consists of studying: a) an individual and racial hereditary variability in natural populations; b) a disunity of a homogeneous specific population into two and more races; c) a gradual divergence of races; d) a transformation such races into separate species. It is remarkable, that by the moment of publication of this article Dobzhansky already has begun to realise the program and has received the first results though at the same time he has confronted with first inevitable difficulties.

Thus Th. Dobzhansky had an understanding of all basic problems which it was necessary to solve on a way to evolutionary synthesis. He had also all basic elements of the future evolutionary concept before his departure to the USA. However he could not carry out the synthesis because he did not have a suitable experimental material for his research, effective methods of research including theoretical ones, and an elaborated model for studying. All these necessary elements have been got by Th. Dobzhansky indeed already in the USA, but not only as a result of S. Wright influence. What Th. Dobzhansky took from S. Wright was only a mathematical confirmation of his own ideas which have grown from assumptions of Yu. A. Filipchenko about possible legitimacy of the Darwinian theory of evolution at certain conditions. The same confirmation, only without mathematics, was also S. S. Chetverikov's article and an experimental data of his followers.

What difficulties have prevented Dobzhansky to start "construct" his own evolutionary concept and to do research of natural populations of *Drosophila*? In 1924 Dobzhansky has come to two cardinal for the origin of his evolutionary concept conclusions: 1) there is no essential distinction between variability of geographical races and individual variability within the limits of a population, and 2) variability within the limits of a population is often caused by distinction in one gene whereas geographical races usually differ in complexes or sets of genes. In other his work on *Drosophila* Dobzhansky has shown that each gene influence, possibly, on all parts of a body, and gives pleiotropic, plural effects.²⁸ Thus, he has connected together two directions of researches, having assumed, that genic complexes on which races differ, are harmonious or interconnected owing to action of natural selection.²⁹ Dobzhansky has reproduced these ideas in his article of 1933 on the ladybirds,³⁰ written firstly in the form of report for International Entomological congress. In this article there was not only whole future evolutionary genetics in condensed form, but also "the biological concept of a species".³¹

The key used by Th. Dobzhansky for resolving species problem as an evolutionary one was Lancefield's discovery of two "races" of *Drosophila*. Th. Dobzhansky wrote about the meaning of this discovery to Yurii A. Filipchenko on July, 14th:

Lancefield has found a thing which has no price. He has found two races of *Drosophila obscura* which are fertile *inter se*, but semi-fertileless at crossing. *Dr. obscura* is already enough well studied and having this material it is possible to undertake a study of the problem of an origin inter-species sterility in terms of drosophila genetics, instead of genetics of willows, rye-wheat hybrids and radishes and cabbages. One may to regret only, that this fact has been found by Lancefield ... I have such impression that he himself does not understand what he holds in hands. And in fact an interspecific sterility is ... something

²⁷ *Ibid*, p. 44.

²⁸ Th. Dobzhansky, "Über der Bau des Geschlechtsapparats einigen Mutanten von *Drosophila melanogaster* Meig." (1924), *Z. Indukt. Abstamm. Vererbungslehre*. B. 34. S. 245-248.

²⁹ W.B. Provine, "Origins of the genetics of natural populations series" (1981), *Dobzhansky's genetics of natural populations I-XLIII*, pp. 1-83, at p. 11-12.

³⁰ Th. Dobzhansky, "Geographical variation in lady-beetles" (1933), *Amer. Natural.* Vol. 67, pp 97-126.

³¹ W.B. Provine, "Origins of the genetics of natural populations series" (1981), *Dobzhansky's genetics of natural populations I-XLIII*, pp. 1-83, at p. 21-22.

like precious treasure ways to which are known else by nobody. And if only this outlet would be possible to crack, the genetics of speciation would be absolutely clear.³²

In other words, Th. Dobzhansky has have, so to say, at least in a latent condition during this period from 1928 up to 1932 a guide of research and a method of the study of species problem and some other problems of evolution.

Why having in his mind the instruction on in what research direction including experimental one and in what way it is necessary to move Th. Dobzhansky has postponed a movement on this road? The problem consisted in that Th. Dobzhansky has formulated his understanding of the decision of species problem in an article devoted Coccinellids, whose genetics was practically unknown and he did not have simply any opportunity to study of genetics of racial and specific distinctions of this object; even at drosophila the genetic analysis of specific distinctions was impossible, as there were no two species which it would be possible to cross and receive fertile descendants.³³ In other words, in 1928, and even in 1932, when Th. Dobzhansky received S. Wright's help, Th. Dobzhansky has have a general theoretical and methodological understanding of how it is possible and it is necessary to solve a problem of speciation. But he did not have a concrete tool, an instrument, a practical means (that is a corresponding material and technics, a technology of research) of the decition of species problem in an experiment.

The further study of this species of drosophila that is *D. pseudoobscura*, during those 4 years that Th. Dobzhansky did not start evolutionary researches, have confirmed not only a correctness of a way and a method chosen by Th. Dobzhansky, but also have given him a concrete, effective technology of experimental evolutionary research.³⁴ Firstly Th. Dobzhansky constructed this technology in his mind, made it ideally. Then he wrote the project of the reseach as a study of genetics of natural population, and, to realize this program in his mind, theoretically,³⁵ and results of this theoretical study presented in his Jesup lectures and after discussion with his colleagues and friends (Milislav Demerec, Leslie C. Dunn, Ernst Mayr and Sewall Wright at last) wrote down as a book.

Thus Th. Dobzhansky's way to evolutionary synthesis consisted not only in an individual inspiration, but also in the invention of a material, equipment and the technology of research of that evolutionary problem without which it was impossible to come to the "evolutionary synthesis", to the new evolutionary theory, and to new type of research activity of an evolutionary biologist³⁶. So Dobzhansky road to "evolutionary synthesis" was itself a deep synthesis of several Russian and (or European and American) scientific and cultural elements.

³² *U istokov akademicheskoi genetiki v Sankt-Peterburge* [At the sources of academic genetics in Saint-Petersburg] (2002), p. 78.

³³ W.B. Provine, "Origins of the genetics of natural populations series" (1981), *Dobzhansky's genetics of natural populations I–XLIII*, pp. 1–83, at p. 22–23.

³⁴ About research "industry" of studying of genetics of drosophila see: R.E. Kohler, "Drosophila and Evolutionary Genetics" (1991), *History of Science*, Vol. 29, Part 4, No. 86, pp. 335–375. About this system of "manufacturing" of the genetic knowledge see in detail: R.E. Kohler, "Lords of the fly" (1994).

³⁵ About development of the plan of researches and some aspects of its realization see: W.B. Provine, "Origins of the genetics of natural populations series" (1981), *Dobzhansky's genetics of natural populations I–XLIII*, pp. 1–83, at p. 41–45, 63–73.

³⁶ Briefly this feature of "evolutionary synthesis" was considered in: M.B. Konashev, "Nekotorye aspekty stanovleniya "evolutsionnogo sinteza" ["Some aspects of "evolutionary synthesis"] (2004), *Nauka i tekhnika: voprosy istorii i teorii*. No. XX, pp. 82–83.