Chaos
An Interdisciplinary Journal of Nonlinear Science

RESEARCH ARTICLE | JULY 30 2025

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Chaos 35, 073151 (2025)
https://doi.org/10.1063/5.0254960

Chaos ARTICLE pubs.aip.org/aip/cha

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Cite as: Chaos 35, 073151 (2025); doi: 10.1063/5.0254960
Submitted: 25 December 2024 · Accepted: 23 May 2025 ·
Published Online: 30 July 2025

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ABSTRACT

The now generally accepted eponym "*Belousov–Zhabotinsky reaction*" for a specific type of chemical nonlinear system was not used immediately. It evolved over time from the simple name "*Belousov reaction*" through combinations using one, two, or three scientists' names to the nowadays accepted name "*Belousov–Zhabotinsky reaction*." The scientists' names used in these eponyms in the last 50 years were Boris Belousov, Art Winfree, Albert Zaikin, and Anatol Zhabotinsky. We present the development of this decades-long journey and discuss the reasons for the inclusion of the two scientists and the exclusion of others. In addition, we present the myriad of spellings of the eponymous name "*Belousov–Zhabotinsky reaction*" used in the last 50+ years, systematically discuss possible reasons for these name variations, and, whenever possible, offer a linguistic explanation for variations.

In the 1950s, Boris Belousov discovered an oscillatory chemical reaction. Anatol Zhabotinsky started working with this system in the 1960s and published many articles in the following years, co-authored by several other scientists. We present and discuss all eponymous names used for this reaction and why the scientific community settled on "Belousov–Zhabotinsky (BZ) reaction." In addition, we list the more than 130 spelling variations we found mainly in the English literature and present, as much as possible, reasons and linguistic explanations.

I. WHICH NAME(S) TO PICK?

Anatol Zhabotinsky was the first to add a scientist's name to the chemical nonlinear system he was working on in the early 1960s. He titled his 1964 (Biofizika) article "Periodic course of oxidation of malonic acid in solution (Investigation of the kinetics of the reaction of Belousov)."[1] Following this first eponym *Belousov reaction*, different names were used in the following decades, finally resulting in the now accepted eponym *Belousov–Zhabotinsky reaction*. Through conscious author decisions about whom to include, different transliterations from Cyrillic to English, at times mediated by another language, and the unavoidable typos in the last 50+ years created a myriad of spelling variations.

Finding the name for the BZ reaction was a process. For the last two centuries, a scientific concept has sometimes been named after the author(s) of the initial publication(s) or by an overarching author, as with the Bray–Liebhafsky reaction. Belousov's unfortunate efforts to publish in reputable scientific journals is the reason why he was left out in some early naming efforts. However, it became clear that Boris Belousov was the discoverer of the BZ reaction and Anatol Zhabotinsky was the main initial developer of the system who also continued working on this system for more than 40 years. Figure 1 is a picture of Boris Belousov sitting at

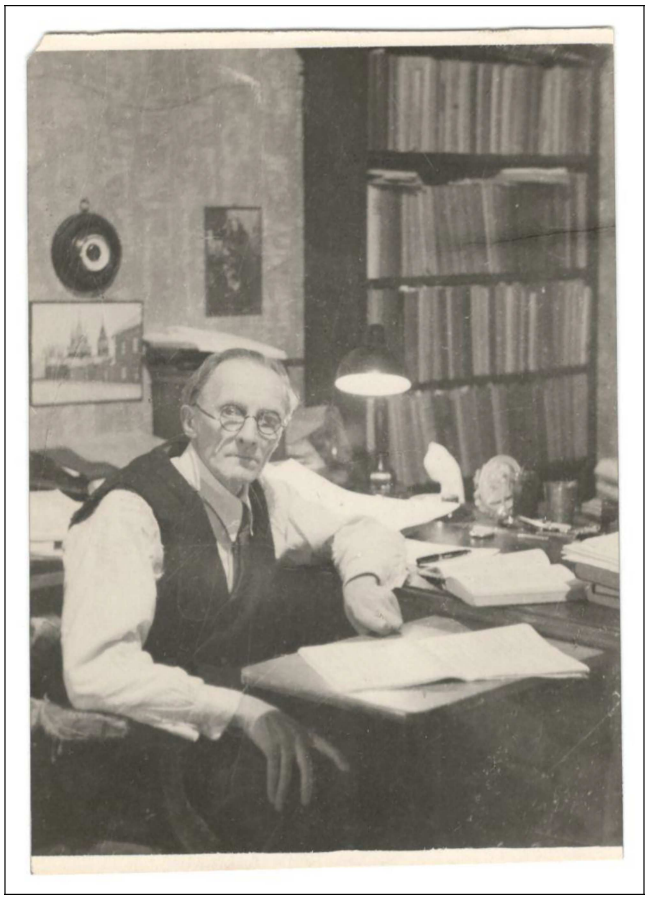

FIG. 1. BORIS P. BELOUSOV (1893–1970) reading at his desk in the late 1950s (Courtesy and copyright by SIMON SHNOLL).

his desk at about the time of his discovery in the 1950s and Fig. 2 shows two lesser known images of ANATOL ZHABOTINSKY during his visits to Germany.

The discussion of why ALBERT ZAIKIN's name (see Fig. 3) had not been added to the eponymous name is sometimes based on the argument that he did not continue working in the field of chemical nonlinear reactions. However, he was an integral part of the active research collaborations in the late 1960s which resulted in being the first author in the famous 1970 Nature article by ZAIKIN and ZHABOTINSKY.[2]

HANKE *et al.*, for example, wrote in their 2009 article's introduction:[3]

> "By far the best understood model system for all these processes is the Belousov–Zhabotinsky (BZ) reaction (Belousov 1959; Zaikin and Zhabotinsky 1970)."

Following other examples in the scientific literature, one could think that these two mentioned articles from 1959 by BELOUSOV[4] and from 1970 by ZAIKIN and ZHABOTINSKY[2] are the first two publications and, therefore, the system should be named the BELOUSOV–ZAIKIN–ZHABOTINSKY (BZZ) reaction. This option has been used (see Sec. IV B in the article) but it did not get traction and the problem using the same Latin letter [Z] for two different Cyrillic letters [З] and [Ж] will be discussed in Sec. III.

The more important counterargument is the fact that the 1970 Nature article was not the first publication after BELOUSOV's 1959 article, though the publication in the most prestigious journal, and with the largest audience, until WINFREE's 1972 Science publication.[5] In Sec. II B, we list all early publications by ZHABOTINSKY and his co-workers. It becomes clear that ZHABOTINSKY's 1964 article[1] in Biophysics (Moscow) should be considered one of the two *founding publications*, and, therefore, the eponymous name should be BELOUSOV–ZHABOTINSKY. All articles in the Russian journal Биофизика were also published in English in the journal Biophysics (Moscow) and were, theoretically, accessible for scientists outside Russia.

Another early collaborator of ANATOL ZHABOTINSKY at the Institute of Biophysics at the Academy of Sciences of the USSR in Pushchino was VASILY VAVILIN (see Fig. 4), whose name was never part of this "naming process." However, VAVILIN, as ZAIKIN, continued their scientific career in other fields.

Some researchers also suggested that SIMON SHNOLL, who gave BELOUSOV's recipe to ANATOL ZHABOTINSKY, should have his name "connected" to this reaction because he was the impetus for ANATOL ZHABOTINSKY to start working with this system.[6] However, there is no evidence that the name of a "coordinator" of something important got ever immortalized in a scientific eponymous name.

However, Shnoll himself wrote in his 1982 paper:[7]

> "Число публикаций, посвященных реакции Белоусова–Жаботинского (таково общепринятое название Этого класса колебательных химических процессов), . . ."
>
> "The number of publications dedicated to the Belousov–Zhabotinsky reaction (this is the generally accepted name for this class of oscillatory chemical processes), . . ."

II. THE Belousov–Zhabotinsky REACTION

A. What is a BZ reaction?

Unlike for the BRAY–LIEBHAFSKY reaction[8] (and also for its later modification, the BRIGGS–RAUSCHER reaction,[9] which is better suited as a classroom demonstration), there is no standard recipe for the BELOUSOV–ZHABOTINSKY reaction. In fact, not only the concentration of the reactants but even the chemical composition may vary in different systems. SHNOLL was absolutely right stating (see Sec. I) that the eponym "BELOUSOV–ZHABOTINSKY reaction" is rather a generally accepted name for a given class of oscillatory chemical processes.[7] The common characteristics of this class are the following: (i) the oxidant is the acidic bromate ion, (ii) the reducing agent is some organic compound (in most of the cases, it is the malonic acid, first applied by ZHABOTINSKY[1]), and (iii) the catalyst is the Ce^{3+}-ion (used by BELOUSOV[4]) or, for example, the $Fe(phen)_3^{2+}$-complex ferroin (first used by ZHABOTINSKY[1]).

The common chemistry behind the oscillatory behavior can be understood by the Field-Kőrös-Noyes (FKN) mechanism of the BZ reaction (see, for example, Ref. 10). There are three major

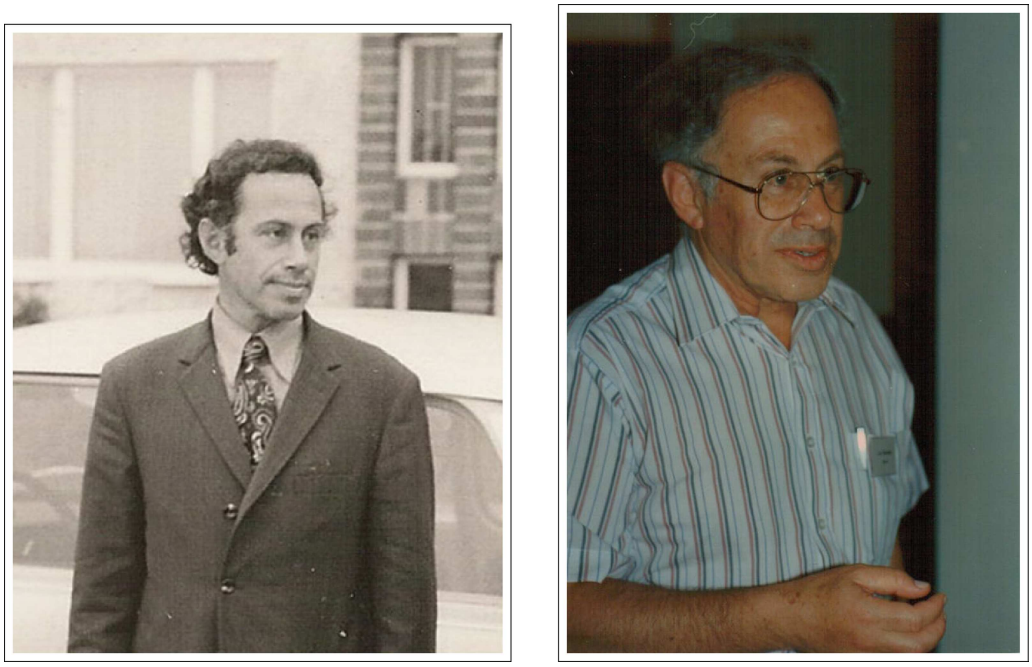

FIG. 2. Pictures of ANATOL ZHABOTINSKY (1938–2008). Left: in Rostock, GDR in 1978 (Courtesy and copyright by WERNER EBELING). Right: At the *Dortmunder Dynamische Woche* 1992 in Herdecke (Courtesy and copyright by STEFAN C. MÜLLER).

stoichiometric processes: Process A is the reaction between bromate and bromide ions in strongly acidic medium that produces bromous acid as one of the intermediates; Process B is the autocatalytic production of bromous acid catalyzed by Ce^{3+} (or ferroin, etc.) that also produces Ce^{4+} [or $Fe(phen)_3^{3+}$, ferriin, etc.] and results in the depletion of bromide ion from the system. However, at this low level of bromide ion concentration, the bromous acid is becoming also depleted via a moderately fast disproportionation reaction; and Process C is the reduction of the oxidized form of the catalyst by the partly brominated organic compounds in the system that results in a delayed feedback of bromide ion back to the system. The oscillation is, therefore, the result of the "competition" between bromide ion and bromous acid. When the concentration of bromide ion is high, the concentration of bromous acid is low and the opposite, when the concentration of bromide ion is low, the concentration of bromous acid is high. This "sew-saw" kind of change in the concentration of the major intermediates then results in the change of the oxidative state of the catalyst, which brings about the oscillating color change of the medium. One can imagine the moment of surprise when BELOUSOV first observed this fascinating series of events. It is no wonder that so many researchers have gotten interested in studying the BZ reaction for more than half a century. The rich dynamics of the BZ reaction in closed systems, its chaotic behavior in open systems, its sensitivity to light, and the pattern formation (traveling circular and spiral waves) in spatially distributed quasi-two-dimensional media, etc. are all well documented in the literature. In this article, we focus on the origin and development of the eponym only.

B. Early BZ publications

Publishing in Russian-language Soviet journals gained popularity among Russian scientists in the 1960s and 1970s, with its peak of about 20% in 1970.[11] This is also the reason, why—at that time—many Western scientists did not know about the BZ reaction. VAVILIN, ZAIKIN, and ZHABOTINSKY, for example, published all, except one, of their work in either the purely Russian journal Журнал физической химии (Journal of Physical Chemistry) or in *Кинетика и Катализ* (*Kinetics and Catalysis*), which also translated and published their original Russian articles in English.

The only other exceptions where (i) ZHABOTINSKY's 1964 article in *Biophysics (Moscow)*[1] (The Russian journal *Биофизика* also published each article in Russian and English but was wider known to Western scientists than *Kinetics and Catalysis*) and (ii) the seminal 1970 Nature article by ZAIKIN and ZHABOTINSKY.[2] These two articles are, therefore, cited, most of the time, when scientists would like to cite the early work by ZHABOTINSKY.

The following is a list of the early publications related to the BZ reaction and important for our discussion:

- Белоусов (BELOUSOV),
  Периодическая действующая реакция и ее механизм, (*Periodically acting reaction and its mechanism*), Сборник рефератов по радиационной медицине за 1958 год (Collection of abstracts on radiation medicine of 1958) (1959)[4]
  This is BELOUSOV's only publication for this system. His original, longer, never accepted manuscript was posthumously published in 1981,[12] 1982,[13] and FIELD 1983.[14]

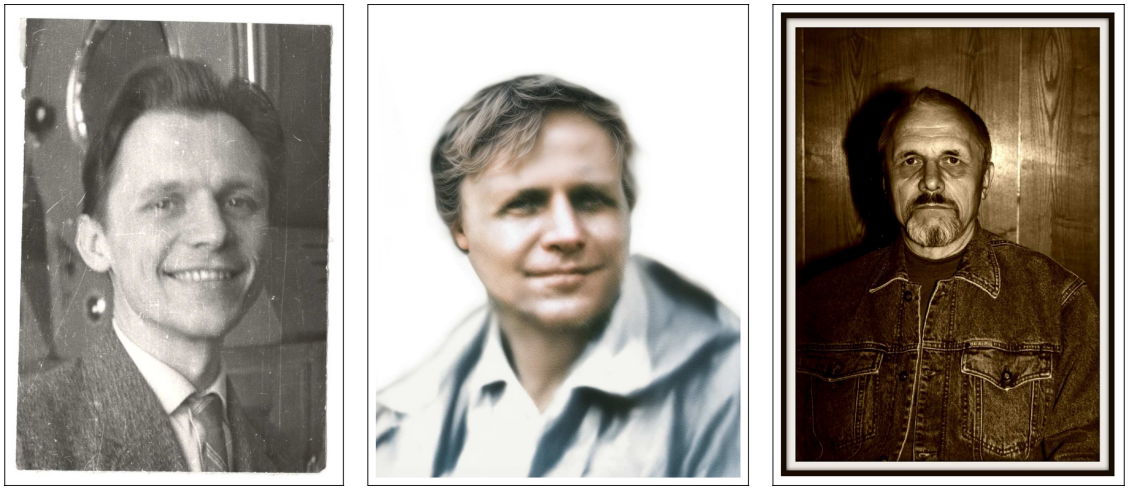

FIG. 3. Pictures of ALBERT ZAIKIN (1934–2019). Left: in a lab near a small drying oven. Either in a laboratory in the Department of Biophysics of Moscow State University or the laboratory of Chemical Biophysics of the Institute of Biophysics of the USSR Academy of Sciences in Pushchino in the 1960s–1970s (Courtesy and copyright by SIMON SHNOLL); Center: about 1980; Right: about 1985 (Courtesy and copyright by ELENA ZAIKINA).

- ZHABOTINSKY,
  Periodic course of oxidation of malonic acid in solution (Investigation of the kinetics of the reaction of Belousov) Biophysics (Moscow) (1964)[1]
- Жаботинский (ZHABOTINSKY),
  Периодические окислительные реакции в жидкой фазе, (*Periodic liquid-phase oxidation reactions*), Доклады Академии Наук СССР (Proceedings of the Academy of Sciences USSR) (1964)[15]
- VAVILIN, ZHABOTINSKY, ZAIKIN,
  Effect of ultraviolet radiation on the oscillating oxidation reaction of malonic acid derivatives, Russian Journal of Physical Chemistry (1968)[16]
- Вавилин, Гулак, Жаботинский, Заикин (VAVILIN, GULAK, ZHABOTINSKY, ZAIKIN),
  Комплексные ионы железа - катализаторы автоколебательной реакции окисления малоновой кислоты и ее аналогов броматом (*Complex iron ions as catalysts for the autooscillating oxidation of malonic acid and its analogs with bromate*), *Известия Академии Наук СССР, Серия Химическая* (Bulletin of the Academy of Sciences of the USSR) (1969)[17]
- VAVILIN, ZHABOTINSKY,
  Autocatalytic oxidation of trivalent cerium by bromate. I, Kinetics and Catalysis (1969)[18]
- VAVILIN, ZHABOTINSKY,
  Induced oxidation of tribromoacetic and dibromomalonic acids, Kinetics and Catalysis (1969)[19]
- ZAIKIN, ZHABOTINSKY,
  Concentration Wave Propagation in Two-dimensional Liquid-phase Self-oscillating System, Nature (1970)[2]
- Вавилин, Жаботинский, Заикин (VAVILIN, ZHABOTINSKY, ZAIKIN),
  Автоколебания концентрации иодид-иона в ходе реакции разложения перекиси водорода, катализируемой иодатом, (*Self-oscillation of iodide ion concentration during the iodate-catalyzed decomposition of hydrogen peroxide*), Журнал физической химии (Journal of Physical Chemistry) (1970)[20]
- Заикин, Жаботинский (ZAIKIN, ZHABOTINSKY), *Распространение концентрационных волн в двумерной жидкофной автоколебательной системе*, (*Propagation of concentration waves in a two-dimensional liquid-phase self-oscillating system*), Журнал физической химии (Journal of Physical Chemistry) (1971)[21]
- VAVILIN,
  Formation of a cellular structure during the autocatalytic oxidation of ferroin by bromate, Kinetics and Catalysis (1971)[22]
- VAVILIN, ZAIKIN,
  The effect of solution stirring on the rate of autocatalytic reaction, Kinetics and Catalysis (1971)[23]
- ZHABOTINSKY, ZAIKIN, KORZUKHIN, KREITSER,
  Mathematical model of a self-oscillating chemical reaction (Oxidation of bromomalonic acid with bromate, catalyzed by cerium ions), Kinetics and Catalysis (1971)[24]
- ZHABOTINSKY, ZAIKIN,
  Autowave processes in a distributed chemical system, Journal of Theoretical Biology (1973)[25]
- ZHABOTINSKY,
  Self-wave processes in distributed systems with diffusion coupling, Radiophysics and Quantum Electronics (1974)[26]
- Жаботинский (ZHABOTINSKY),
  Концентрационные автоколебания (*Concentrational self-oscillations*), Наука, Москва (Science, Moscow) (1974)[27]

Another interesting aspect of the collaborative work at the Institute of Biophysics at the Academy of Sciences of the USSR in Pushchino, where ZHABOTINSKY worked, is the slate of contributions to the 1966 *All-Union Symposium on Oscillatory Processes in*

FIG. 4. VASILY A. VAVILIN (left) and ANATOL M. ZHABOTINSKY (right) in the EPSTEIN lab at Brandeis University in February 2002 (photograph courtesy and copyright by VASILY A. VAVILIN).

Biological and Chemical Systems in Pushchino, USSR. At this conference, ZHABOTINSKY had two single-author contributions,[28,29] one contribution as the first author together with KORZUKHIN,[30] and three additional contributions with VAVILIN as the first author.[31–33] All conference contributions have been published in a booklet by GLEB M. FRANK as the Editor-in-chief and ZHABOTINSKY as one of the other four editors.[34] The three images in Fig. 5 were all taken at this conference and picture SIMON SHNOLL, VASILY VAVILIN, and ANATOL ZHABOTINSKY during their presentations. The last image in Fig. 5 is probably the earliest picture showing the chemical equations of the Belousov–Zhabotinsky reaction on a black board.

During the second conference in Pushchino in 1970, ZHABOTINSKY presented three papers together with ZAIKIN[35–37] and one four-author contributions with ZAIKIN as the second author.[38] These conference contributions have been published in a booklet with SEL'KOV, ZHABOTINSKY, and SHNOLL as editors.[39]

Between the 1966 and 1970 conferences in Pushchino, the famous *Conference on Biological and Biochemical Oscillators* took place in Prague in 1968. It was a satellite conference of the 5th meeting of the Federation of European Biochemical Societies and brought together scientists working on either purely chemical oscillatory systems or biochemical/biological oscillatory systems. It was the first conference on this topic at which scientists from each side of the Iron Curtain met and, therefore, is considered the *year of an explosion of interest in nonlinear chemical systems*. The conference contribution by 54 scientists had been published five years later in 1973 (*Biological and Biochemical Oscillators*),[40] which shows that ZHABOTINSKY had a single-author contribution, one as the second author with ZAIKIN, and a third one with VAVILIN as the first and ZAIKIN as the third author.

At the 1968 Prague conference, no article named the chemical reaction using an eponym. HEINRICH-GUSTAV BUSSE, for example, had the title "Some experiments of a chemical periodic reaction in liquid phase"[41] and introduced the reaction as

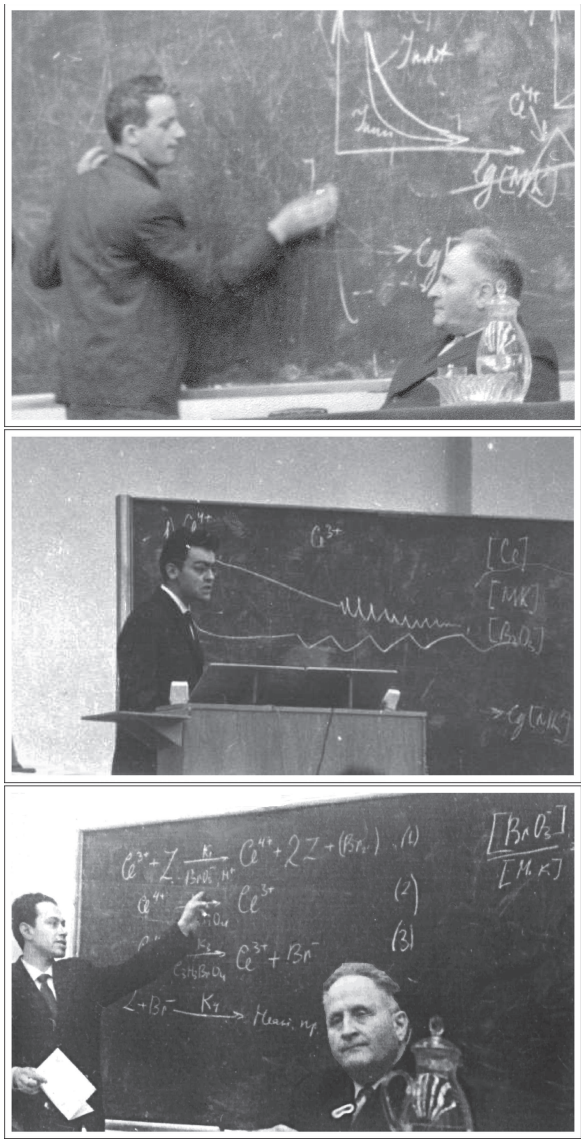

FIG. 5. Presentations at the 1966 Pushchino conference. From top to bottom: S. E. SHNOLL, V. A. VAVILIN, and A. M. ZHABOTINSKY (D. A. FRANK-KAMENETSKII's head had been manipulated (pre-Photoshop) in the last picture, because he was blurry in the original image. However, the first image shows that he was sitting at the desk (top photograph courtesy and copyright by MAXIM D. FRANK-KAMENETSKII, and center and bottom photograph courtesy and copyright by VASILY A. VAVILIN).

> "Zhabotinsky (1) described in 1964 a large number of similar systems, the first of which was described by Belousov (2) in 1958."

This reference is also the only one mentioning BELOUSOV's name. The three contributions by VAVILIN, ZAIKIN, and ZHABOTINSKY did not give a name for the reaction they were reporting on and did not cite BELOUSOV's original work.[42–44]

In 1969, the conference *Biochemical Oscillators and Chemical Instabilities* took place in Hanko, Finland, about 80 miles west of Helsinki. The Hanko conference contributions were published in the same 1973 book as the Prague conference contributions. Comparing both contributions, the importance of the 1968 Prague conference becomes clear: None of the earlier mentioned Russian scientists, who attended the conference in the Czech Republic attended the following meeting in Finland.

C. The rise of Belousov's discovery

When ANATOL ZHABOTINSKY started his graduate studies at Moscow State University, SIMON SHNOLL remembered that he had BELOUSOV's recipe and unsuccessful manuscript and gave those to ZHABOTINSKY. In the following years, ZHABOTINSKY showed that the oscillatory effect is real and not the result of some inhomogeneities or contamination as suggested by the reviewers of BELOUSOV's two unsuccessful manuscript submissions.

The fact that SHNOLL asked ZHABOTINSKY to work on a specific problem is known to most scientists starting their Ph.D. in a research lab. Sometimes, this collaboration results in a discovery of a phenomenon or theory and a co-authored publication. This first publication will often be the reason for a two-name eponym. However, SHNOLL never had a conference contribution or published an article with ZHABOTINSKY on this topic. This might be the reason why the question raised by some scientists to add SHNOLL's name to the reaction never attracted much attention. This situation is also different than the development of the now called *Ising* model for ferromagnetism. The scientific problem was given to ERNST ISING by his Ph.D. advisor WILHELM LENZ, who first published about this problem in 1920.[45] ISING solved the one-dimensional mathematical model in his 1924 Ph.D. thesis[46] and also published a single-author paper in the *Zeitschrift für Physik* in 1925.[47] Because LENZ started this model and Ising solved it, at least for the one-dimensional case, it is also sometimes called the Lenz–Ising model.[48,49] This idea of a *discoverer* and a *developer* is the main idea behind the name BELOUSOV–ZHABOTINSKY reaction.

As mentioned before, ZHABOTINSKY made several improvements to the recipe and defended his Ph.D. thesis [Кандидат наук (Candidate of Sciences)] under the guidance of SIMON SHNOLL.[15] This was the first post-graduate scientific degree offered in the USSR [the second, Doctor of Sciences Доктор наук, required production of a much larger thesis or a cumulative collection of publications and is approximately equivalent to tenure in the US or habilitation (Dr. habil.) in Germany]. Shortly after, ZHABOTINSKY joined the Institute of Biophysics of the USSR Academy of Sciences in Pushchino where he started collaborating with GENRIKH IVANITSKIY, VALENTIN KRINSKY, and ALBERT ZAIKIN on the new oscillatory chemical reaction. Because of their important scientific contributions, these four scientists (and Belousov posthumously) received the Lenin Prize in 1980, the highest medal in the USSR for individuals with outstanding accomplishments, for their combined pioneering work on chemical oscillatory reactions. Figure 6 shows ALBERT N. ZAIKIN, GENRIKH R. IVANITSKIY, ANATOL M. ZHABOTINSKY, and VALENTIN I. KRINSKY after the award ceremony on the Red Square in Moscow.

FIG. 6. ALBERT N. ZAIKIN, GENRIKH R. IVANITSKY, ANATOL M. ZHABOTINSKY, and VALENTIN I. KRINSKY on the Red Square in Moscow after being awarded the Lenin Prize on April 22, 1980 (photograph courtesy MICHAEL BUKATIN and copyright by SIMON SHNOLL).

One argument why ZAIKIN's name had not been added to the eponym is the fact that he did not continue to work in this field. This argument is not quite right because he continued his research at the Institute of Biological Physics on the BZ reaction in the following years. Between 1975 and 1977, he published three articles in his series "*Instability and excitation propagation in a catalytic reaction model*" in the journal Биофизика [Biophysics (Moscow)] with "I. Model of a system with concentrated parameters"[50] and "II. Distributed system model"[51] in 1975 and "III. Non-trivial regimes of propagation of excitation"[52] in 1977. In 1976, he published the article "Wave conditions in bromomalonic acid oxidation when catalyzed by complexed iron ions"[53] and the following year a two article sequence with his Polish collaborator on the "Special Effects in Active Chemical Systems" with the additions "I. Model of Leading Center"[54] and "II. Model of Stationary Periodical Structure,"[55] in which they used the term "BELOUSOV–ZHABOTINSKII reaction" for the system they were reporting about. This clearly indicates the time, when the naming decision seemed to have finished and all attempts for other two- or three-name eponyms had to fight a very steep uphill battle.

III. FROM A CYRILLIC NAME TO AN ENGLISH NAME

The evolution from *Belousov reaction* to *Belousov–Zhabotinsky reaction* included many intentional variations of one-, two-, or three-name eponyms. In addition to a multitude of variations and typos throughout the decades, the transliteration (Romanization) of BELOUSOV and ZHABOTINSKY's original Cyrillic spellings of Белоусов and Жаботинский, respectively, added another layer of complexity.

We determined five larger categories to distinguish between different conscious choices, real typos, and other reasons.

I. **Acceptable English transliterations**

Translation from one language into another is defined and standardized—but changing over time, and people also made their own decisions how to change their names. The current system for transliteration from Russian Cyrillic to English is defined by the Library of Congress (LOC). LOC uses the *American Library Association and Library of Congress* (ALA-LC) Romanization Tables for many languages. It is largely the same as when first introduced in 1941. However, it was not always applied consistently for a variety of reasons. Current practice in Slavic Studies in the United States permits usage of a modified LOC system that omits diacritics (additional marks differentiating pronunciation of a letter from a version without it, such as [ą], [č], [ö], or [ő]). For example, it is more common to write [й] as [i] and not as [ĭ], though diacritics are often retained for Slavic and non-Slavic languages that use them in a Roman alphabet (Czech, Polish, Hungarian, Latvian, etc.). However, other conventions and *ad hoc* rules persist. It is also common to retain widely accepted spellings of names that do not align with the LOC system (e.g., Dostoevsk[y] instead of Dostoevsk[ii] or Dostoevsk[iĭ]).

The LOC system also calls for use of a single apostrophe to indicate the Russian soft sign and a double apostrophe to indicate the hard sign, but these also are frequently omitted. One example is ILYA ROMANOVICH PRIGOGINE. His original Russian name was Илья Романович Пригожин. Strict adherence to LOC transliteration should result in the Romanized form Il'i͡a Romanovich Prigozhin. The soft sign ь in his first name (indicating palatization of the preceding consonant, referred to as a soft consonant as opposed to hard), which is the apostrophe in the correct translation, had often been ignored but the now unfamiliar spelling of his first name can still be found in his early publications. The surname, we are now used to, is an adaptation to his new life (and work) in Brussels, Belgium and distinguishes him from others with the same Russian family name Пригожин. However, the standard English transliteration PRIGOZHIN can still be found in book searches of Russian publications and has been used in the reference lists of some English publications (e.g., Ref. 53). This last name is one example that clearly reflects the difference between French and English transliterations, even as the French transliteration may be commonly used in English. The use of the original Cyrillic spelling for scientists' names in English also depends on the Latin transliteration (Romanization) of the Russian alphabet. The Romanization changed over time and different entities use different Romanization tables. One of the three "classical" variations of ZHABOTINSKY's original Russian name Жаботинск[ий], transliterated into ZHABOTINSK[I] is based on the Soviet passports, in which names where transliterated in a French-style system. In this case, the Cyrillic ending [ий] transliterated simply to [i] because of the preceding [и] before the [й].

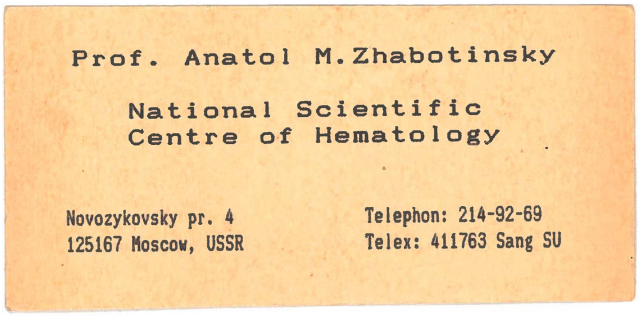

FIG. 7. Business card of ANATOL M. ZHABOTINSKY as a professor at the National Scientific Centre of Hematology (photograph courtesy and copyright by SATOSHI NAKATA).

In all Romanization tables for Russian Cyrillic, the letter [и] is always transliterated as [i]. However, the transliteration of [й] varies. For example, the Romanization adopted by the *United States Board on Geographic Names* (BGN) and the *Permanent Committee on Geographical Names for British Official Use* (PCGN), which is now called the BGN/PCGN 1947 system, uses [y]. This would result in ZHABOTINSK[IY], as used in many last names with Russian roots, but seemed not to have appeared in this context. For official Russian passports prior to 2010, the ending [iy] could also be changed to the simpler [y]. This might be the reason why ZHABOTINSKY chose this spelling, as he also used it on business cards prior to coming to the United States and joining Brandeis University as shown in Fig. 7.

Early on, scientists in the West were not sure which spelling version to use. DICK FIELD told me (N.M.) that he initially used "Zhabotinskii" because it was closer to the original Cyrillic spelling. However, according to DICK FIELD, change from *Zhabotinskii* to *Zhabotinsky* came from ANATOL ZHABOTINSKY himself,

> "It was Anatol himself who asked that we use [y] rather than [ii] in Zhabotinskii. I was surprised."

However, perhaps it should not be that surprising as shown in ANATOL ZHABOTINSKY's business card in Fig. 7. One of us (F.A.) also recollects that he used the [y]-ending in English publications and the [ii]-ending was used by the translators of Russian publications, which also appeared in English. One example is two of his articles in 1981: In the journal *European Journal of Biochemistry*, they used the name Zhabotinsk[y].[56] The English version of his article in Biochemistry (Moscow), translated by staff members from the original article in the journal *Биохимия*, appeared as Zhabotinsk[ii].[56]

The option, ZHABOTINSK[IJ], is based on the Soviet standard for Romanization, developed by the *USSR National Administration for Geodesy and Cartography* (GOST) and later adopted by the International Organization for Standardization (ISO). It is based on the scientific transliteration system used in linguistics. Those systems run under various names starting with either "GOST" or "ISO."

To illustrate the name finding of the Belousov–Zhabotinsky reaction, one can look at one of the early meetings, the Faraday Symposium 9 in London, UK in December 1974. In the first, introductory article *Introductory and Inorganic Oscillations* by NICOLIS and PRIGOGINE,[57] we find the term *Belousov–Zhabotinski reaction*. The next three articles chose other terms to refer to the reaction the authors became aware of about six years ago at the famous Prague meeting in 1968. FIELD and NOYES use *Belousov–Zhabotinskii reaction*,[58] KŐRÖS *et al.* name it Belousov-type oscillating reaction in the title and later in the text simply *Belousov oscillating reaction* (they are not even citing any of Zhabotinsky's publications),[59] and WINFREE does not specify a name and simply calls it *Z reagent* but cites BELOUSOV's 1959 article[4] and ZAIKIN and ZHABOTINSKY's 1970 *Nature* article (interestingly, he switched the order of the authors)[2] "In the chemical reagent of Belousov[6] and of Zhabotinsky and Zaikin[7]—called [Z] reagent henceforth—. . .."[60] As one can see, the ending with [y] did not appear, yet. However, WINFREE used the term "Z reagent" again in his 1978 book chapter[61] but using the [y] in ZHABOTINSKY's name now.

Another recurring issue in the example is the use of [Z] rather than [Zh]. The Russian letter [ж] does not correspond to any letter in the Greek alphabet and, therefore, has no connection to the Latin alphabet or any other non-Slavic alphabet (it is phonetically equivalent to letters in Slavic languages that use the Latin alphabet, such as the Polish [ż]). As a result, the transliterations into English were not always consistent.

It is represented in the LOC transliteration system as [zh]; though the English letters [z] or [s] can sometimes make this sound (e.g., a[z]ure, vi[s]ion, tea[s]ure), no single English letter is consistently pronounced equivalently (as heard in the surname of the main character of Pasternak's novel [Zh]ivago ([Ж]иваго), cf. surname of the 19th century botanist and agronomist Nikolai [Zh]ele[z]nov ([Ж]еле[з]нов), or [Zh]i[z]n' ([ж]и[з]нь), [life]. For this reason, the use of [Z] in the acronym for the reaction does not accord with the Russian grapheme, strict adherence to which would yield B-ZH or B-Zh reaction. However, even in Russian articles, authors would use the Latin abbreviation BZ, similar to Na when writing about sodium.

The abbreviation [Z] was also used for, what some authors called the ZHABOTINSKII–ZAIKIN–KORZUKHIN–KREITSER (ZZKK) kinetics, published by the four authors in 1971.[24] In this case, the last names of ZHABOTINSKY and ZAIKIN were abbreviated with the same Latin letter [Z], even if their first letter in their Cyrillic name is different. ANATOL ZHABOTINSKY himself did not question the use of the Latin letter [Z] as an abbreviation, as can be seen is Sec. IV A.

An example of various spelling of the name ZHABOTINSKY can be found in the 1972 article "A method for determining effects of diffusion on antocatalytic chemical reactions" by HLAVÁČEK, SINKULE, and KUBÍČEK.[62] In the Introduction, they are citing "Zhabotinski, 1964" and "Vavilin, Zabotinskij & Jagushinskij, 1967" but then used in the References "Zhabotinskii, 1964" and "Vavilin, Zhabotinskij & Jagushinskij, 1967," creating four different spellings. In Slavic languages with Roman alphabets, the letters [ij] are analogous to the Russian letters [ий]. In International Phonetic Alphabet (IPA), transcription [j] represents iotation ([й], a semi-palatalized "glide" sound preceding or following a vowel, like in English *boy* or the surname YELTSIN, also visible in transliterations of Belousov as B[ye]lousov).

It is also worth noting that because of the different names of the BZ reaction over time, one title, with exactly the same idea, can be created several times. Let us take a look at a title like "Chaos in the . . . reaction." This has been used three times:

1. "Chaos in the Zhabotinskii reaction" by RÖSSLER and WEGMAN in their 1978 Nature article.[63]
2. "Chaos in the Belousov–Zhabotinskii reaction" by HUDSON and MANKIN in their 1981 Journal of Chemical Physics article.[64]
3. "Chaos in the Belousov–Zhabotinsky reaction" by FIELD in a 2016 book chapter.[65]

II. **Transfer to other languages**

Language specific transliterations were sometimes used by authors when writing the eponymous name for the reaction in English articles. In this overview, we are focusing on the six languages for which we found evidence that they had an effect on the spelling of the name BELOUSOV–ZHABOTINSKY in English literature.

The first letter in ZHABOTINSKY's name is challenging in many languages. If someone never heard the name pronounced, they might opt to simply use the letter [Z] in their pronunciation. If they heard the name pronounced, they might come up with their own "interpretation" if no corresponding sound in their native language exists. Therefore, some scientists might have used [J] as the starting letter because many people would know how to pronounce the French name "Jacques" even if they do not speak French.

C) Czech:
Correct transliteration: BĚLOUSOVOVA–ŽABOTINSKÉHO reakce
In publications of the Institute of Mathematics of the Academy of Sciences (Aplikace matematiky) of the Czech Republic, scientists used the standard ending [ij] for ZHABOTINSKY's name.

F) French:
Correct transliteration: Réaction de BELOOUSSOV–JABOTINSKI
In French, the English pronounced letter [u] or the Russian letter [y] is spelled [ou]. As a result, the French spelling of [oou] with two distinct sounds for the Russian letters [oy] is actually closer/identical to the Russian pronunciation. The use of the double-s in BELOUSOV's name, to indicate a harder pronunciation, can be found in other languages as

well (e.g., German). Also, French is using the [J] at the beginning and a simple [i] at the end for ZHABOTINSKY's name. We did not find any evidence for the use of [J] by French authors but several used [Z] instead of [Zh].

In French publications

Using all translation differences, the full name BÉLOOUSSOV–JABOTINSKI is the correct French spelling of the reaction's name but does not appear in any English publication. VIDAL wrote in his 1992 French article[66]

> "Nous avons repris ici la transcription française des noms russes Белоусов et Жаботинский, qui permet une prononciation française correcte. Les publications de recherche utilisent la translittération Belousov et Zhabotinsky, compréhensible des seuls initiés (N.D.L.R.)."
>
> "We have used here the French transcription of the Russian names Белоусов and Жаботинский, which allows correct French pronunciation. Research publications use the Belousov and Zhabotinsky transliteration, understandable only to insiders (Editor's note)."

In the opposite translation, the famous museum in Paris, the *Louvre*, is spelled *Лувр* [Luvr] in Russian. In English, the two letters written as [ou] can be pronounced as a single [u]-sound, which most English speaking scientists do when they pronounce the Belousov–Zhabotinsky reaction.

In one of the earliest publications about the BZ reaction, HERSCHKOVITZ–KAUFMAN used in her 1970 article "Structures dissipatives dans une réaction chimique homogène"[67] ZHABOTINSK[I] in her descriptions and citations, without mentioning BELOUSOV. DE RIVERA *et al.* used BELOUSOV–ZABO[TH]INSKY in the Introduction of their French article "Microcalorimetrie: identification et deconvolution automatique a l'aide de modeles physiques,"[68] which is also just a typo.

G) German:

Correct transliteration: BELOUSSOW–SCHABOTINSKI-Reaktion

- Use of [w] instead of [v] for the Cyrillic letter [russiazz]. Beloussow is often found as the German translation of Белоусов. Therefore, some German authors used the letter [w].
- The use of [ss] in BELOUSOV's name has been found.
- We did not find any use of [Sch] instead of [Zh] in the English literature but the anglicized version [Sh].

In German publications

- **Belousov–Žabotinskij-Reaktion**
  This spelling has been used by some scientists and/or journals in the German Democratic Republic. For example, L. KUHNERT published two articles in the West-German journal "Die Naturwissenschaften"[69,70] but used Belousov–Zhabotinsky in his book in 1987.[71] T. PLESSER and S. C. MÜLLER had an article in the East-German journal "Wissenschaft und Fortschritt (Science and Progress)," published between 1951 and 1993.[72] H. WEIGT published many articles in the journal "Zeitschrift für Chemie" between 1983 and 1990, for example, Refs. 73 and 74, and in the journal "Zeitschrift für physikalische Chemie," Ref. 75.
- **Belousow–Zhabotinski-Reaktion**
  This spelling was used by MARKMAN in their 1984 article "*Zur Entstehung von stationären und oszillierenden dissipativen Strukturen im mathematischen Modell der Belousow–Zhabotinski-Reaktion.*"[76]
- **Beloussow–Schabotinski-Reaktion**
  This spelling appeared in the book chapter "Swarming, Entropy, Flow: Fließen, Schwärmen, Entropie" of the book *Verflüssigungen*.[77] This is the perfect Romanization of the Cyrillic names into German but it is interesting to note that this only appeared in a book chapter, written by B. TAYLOR, a Professor Emeritus of History of Art at the University of Southampton, UK and then translated into German by K. NAKAS, the editor of the book.
- **Beloussow–Shabotinski-Reaktion**
  This version appeared in an article in the magazine "Sowjetunion,"[78] which was actually the German translation of a Russian article.
- **Beloussow–Zhabotinsky-Reaktion**
  This spelling had been used as the title of Chapter 9 of Part II in the book "Beiträge zur Geschichte der Synergetik."[79] Interestingly, he writes in his final paragraph:

> "Die Reaktion der Cer-katalysierten Bromierung von Malonsäure trägt heute den Namen "Beloussow–Schabotinski-Reaktion" (engl. Belousov–Zhabotinsky reaction) und ist zu einem der bekanntesten chemischen Beispiele der Synergetik geworden."
>
> ("The reaction of the cerium-catalyzed bromination of malonic acid is known today as the "Beloussow–Schabotinski reaction" (engl. Belousov–Zhabotinsky reaction) and became one of the best known chemical examples of synergetics.")

- **Belusov–Zhabotinski-Reaktion**
  In addition to the eponymous names which are closer to the German transliteration, other misspellings can be found as well. One example is the name BELUSOV–ZHABOTINSKI, HERMAN HAKEN used in the description for the cover image (and in the caption of Fig. 7) of his 1985 article in the *Naturwissenschaftliche Rundschau*.[80]

H) Hungarian:

Correct transliteration: Belouszov–Zsabotyinszkij reakció

Hungarian authors could have applied various misspellings in English articles, but we could not find any. The only appearance of the name BELOU[SZ]OV was a typo in an English article by a non-Hungarian author. The misspelled beginning of ZHABOTINSKY's name with [Zs] was also a typo. The [Zs] beginning can be found in the "short title" created by the Hungarian typesetting staff, while the authors used the correct English spelling throughout the article.

According to "Rules of Hungarian Spelling" published by the Hungarian Academy of Sciences, proper names and common words taken from languages with non-Latin scripts are transcribed using the letters of the Hungarian alphabet, preferably from the source language (i.e., without the mediation of another language). When transliterating, the foreign

sound sequence or the foreign letter and sound sequence together are replaced with Hungarian sounds or the corresponding Hungarian letters in a regulated manner for each language.

In Hungarian publications

Examples of the Hungarian spelling can be found in BECK and VÁRADI's article *"Térben és időben periodikus homogén kémiai reakciók"* (*"Periodic homogeneous chemical reactions in space and time"*)[81] or in ZHABOTINSKY's own Hungarian article "Oszcilláló kémiai reakciók. A bromátos oxidáción alapuló periodusos reakciók mechanizmusa" ("Oscillating chemical reactions. Mechanism of periodic reactions based on bromate oxidation").[82]

I) Italian:

Correct transliteration: Reazione di BELOUSOV–ŽABOTINSKIJ

The Italian name offers two possibilities for "misspellings." Italian scientists might start ZHABOTINSKY's name just with a [Z] and they could have used the [ij] ending instead of any of the "usual" three endings [i], [ii], and [y]. We did not find any article using the latter case but several scientists starting ZHABOTINSKY's name with a [Z].

P) Polish:

Correct transliteration: Reakcja BIEŁOUSOWA-ŻABOTYŃSKIEGO

Use of [ieł] instead of [el] for the Cyrillic letter [c]. The Polish version of BELOUSOV is more a translation than a transliteration. As a native Polish name, it would be written as BIAŁOUSOW. Its literal meaning is "white-whiskered" or "white-mustached." The two semantic components share roots in Proto-Slavic; the first part is conformed to the modern Polish, but the second is not "translated" to the Polish wąsy (equivalent to Russian усы). Indeed, such "translation" would be highly unusual.

Even working from a Latin-based alphabet, some confusion might also result from Polish morphology. The Polish name literally means "reaction of Belousov–Zhabotinsky" (using the Polish genitive case, which grammatically implies "of"), unlike, for example, French "La réaction de BELOOUSSOV–JABOTINSKI." Names of the reaction in other Slavic languages generally parallel the Polish, e.g., Russian Рекация Белоусова-Жаботинского.

U) Ukrainian:

Correct transliteration: Реакція Бєлоусова –Жаботинського

Ukrainian also uses the Cyrillic alphabet but with slightly different transliterations. Therefore, authors might have used their common Romanization of [ий] to [yi].

III. **Pronunciations**

Some variations might be a result of the common pronunciation of BELOUSOV among English speakers. In Russian, the name has four syllables with three components: prefix [belo], root [us], and suffix [ov]. This might be explainable as eliding the two vowels in English (vowels do not form diphthongs in Russian as they can in English; as a general rule, every vowel is pronounced): Be-lo-u-sov. This is probably the reason for the name BEL[U]SOV in some articles, without the first [o].

III.a **Russian pronunciations**

In some cases, we can be reasonably certain that non-Russian-speaking scientists wrote one or another name according to how they heard a Russian speaker pronounce it. This entails spelling *as heard* rather than *as written* and, therefore, frequently incorporates rules of Russian pronunciation—final consonant devoicing, consonant assimilation, vowel reduction, etc.—into written form. Examples:

(i) BELOUSO[F] or BELOUSO[FF]: the Russian [в], when in end position in a word, is pronounced as [F]. This is sometimes referred to as the "STROGANOFF effect"; more generally, this is final consonant devoicing. At certain times and in certain places, it has been common to transliterate names with a single or double letter [F], e.g., TCHEKHO[FF], RACHMANINO[FF].

(ii) BEL[A]USOV, ZHAB[A]TINSKY: vowel reduction takes place in both cases for the same reason: the unstressed letter [o] in Russian is pronounced as [a] due to its position in the syllable preceding the stressed syllable.

III.b **Non-Russian pronunciations**

(i) BEL[OU]SOV and BEL[U]SOV:

The missing letter [o], which is probably due to the mispronunciation of the original Russian name in English, combining the two letter [o] and [u] into one [u].

(ii) BELOU[S]OV and BELOU[Z]OV:

In this spelling, the relevant Cyrillic letter in "Белоусов" has been translated into [z] instead of [s]. This might also be due to the mispronunciation of the voiceless consonant [s] as voiced consonant [z], as a non-native speaker of Russian might transfer the English [z] sound to the Russian word космос (cosmos).

IV. **Typos**

Typos, i.e., inadvertent misspellings as distinct from other conscious or unconscious deformations. Examples:

1. [ZH]ABOTINSKY and [Z]ABOTINSKY:
   In this variation, the letter [h] is missing in the transliteration of the Cyrillic letter [ж], which should be translated as [Zh]. This is difficult to determine if it is really a typo or a result of cases I–III.
2. ZHA[BH]OTINSKY and ZHABO[TH]INSKY:
   In these spellings, an extra [h] appears after the [b] or the [t] and is not based on any transliteration that we are aware of.
3. ZHA[B]OTINSKY and ZHA[V]OTINSKY:
   One could speculate that this typo is a result of the letters [v] and [b] next to each other on the keyboard.

V. **Miscellaneous**

V.a Optical Character Recognition (OCR) errors

Mistakes on journal websites when extracting the article title from the original work.

V.b Russian-speaking authors. Russian-speaking authors apply various conventions or *ad hoc* rules to transliteration of their own names into English or other languages or can also adopt transliterations from other sources (as had Zhabotinsky). Russian-speaking acquaintances of one of the authors (ZR) transliterate or transform their own names variously:

this variability: YELENA, ELENA, ELLEN, and HELEN, etc., correspond to Russian Елена. The standard LOC transliteration is Elena.

In Sec. III of the supplementary material, we list all eponymous names and the categories we think they are based upon.

IV. THE REACTION NAME IN ENGLISH LITERATURE

In addition to the plethora of one-, two-, and three-name variations used since the 1970s, two options have been mostly used in publication titles: "*Belousov–Zhabotinsky*" with 812 and "*Belousov–Zhabotinskii*" with 403 appearances. The other discussed option "*Belousov–Zhabotinski*" had only been used 13 times (Web of Science, March 23, 2025). In addition to the use of these eponyms in titles, about 15 000 articles can be found using "*Belousov–Zhabotinsky*," about 6000 using "*Belousov–Zhabotinskii*," and about 1200 using "*Belousov–Zhabotinski*" in the publication text (Google Scholar, March 23, 2025). Because of the importance of this reaction as a scientific research field, Web of Science created its own *microlevel citation topic* (9.143.1161 Belousov–Zhabotinsky Reaction). Articles included in this topic go slightly beyond the actual BZ reaction, including other oscillatory phenomena even before the 1960s, but lists now nearly 28 000 articles (Web of Science, March 23, 2025).

In this chapter, we present name variations we are aware of and start in Sec. IV B with the 13 legitimate, conscious eponyms we found, ignoring typos and other variation reasons. The numbered lists one-, two-, or three-name variations in Secs. IV C–IV E are simply alphabetically ordered and do not correspond to their appearance frequency. The chosen publications, especially for the more common variations are examples or if we found something else interesting to report. However, they highlight that many name variations appear simply as a single reference for a chemical pattern-forming reaction-diffusion system in other scientific fields.

Another great example of the diversity in naming the reaction and its chemical composition can be found in the book "Periodicities in chemistry and biology" from 1978, which is volume 4 in the series "Theoretical Chemistry" by the editors HENRY EYRING and DOUGLAS HENDERSON.[83] In two chapters, WINFREE and TROY used different naming versions to distinguish between different chemical compositions of the BZ system. WINFREE used the name *Belousov–Zhabotinsky reagent* and abbreviated it as *Z reagent*[61] ignoring the [B] completely (see Sec. III(I) in the article for Anglicizing the Russian letter [ж] [Zh] as a single letter [Z]). TROY used the name *Belousov–Zhabotinskii reaction* in his Introduction and in the Sec. III title, now with a [ii] instead of the [y]. However, he used three different names for reagents: (i) *Belousov–Zhabotinskii reagent* for the original solution with cerium and (ii) *Zaikin–Zhabotinskii reagent* or (iii) *Zaikin–Zhabotinskii–Winfree reagent*, to distinguish between systems only producing trigger waves or phase and trigger waves, respectively.[84]

A. The abbreviation BZ

The common abbreviation for BELOUSOV–ZHABOTINSKY is BZ, though one sometimes finds B-Z, especially in non-chemistry papers. For example, NATH used the abbreviation "B-Z" throughout their 2022 Physica D paper without spelling the full name once.[85]

Chemical Abstracts first reported the use of the term "BZ reaction" in the second sentence of "Observations of homogeneous bifurcation phenomena in oscillating chemical reactions" by JACK TURNER, MIELCZAEREK, and MUSHRUSH in 1977.[86] And DICK FIELD mentioned:

> "It might have appeared in the text of an earlier paper. However, I have a vague recollection that it was some time after the Oregonator paper that I first heard BZ. JACK TURNER was a PRIGOGINE Ph.D. student on the faculty of UT-Austin. It would be nice to see Jack get a piece of history."

1976 was also the "birth year" of the abbreviation BZ. Again, JOHN TYSON was the first to use the abbreviation in his 1976 book. He said,

> "I submitted the book manuscript in late 1975, just before I moved the family to Innsbruck, Austria, for a postdoc."

In that book, he also used "ZZKK model" in the appendix for the BZ model proposed by ZHABOTINSKY, ZAIKIN, KORZUKHIN, and KREITSER in 1971[24] and "FN model" based on publications by FIELD and NOYES (also called the Oregonator) to distinguish the model from the "FKN mechanism," in which KŐRÖS' name had been added.

However, it also appeared in at least three peer-reviewed articles around the same time, based on the submission dates. The first two used the abbreviation "B-Z": in the Chemical Engineering Journal article "The Belousov–Zhabotinskii reaction in a continuous flow reactor" by GRZIANI, HUDSON, and SCHMITZ[87] (submitted on August 14, 1975) and in the Journal of Physical Chemistry article "Analytic representation of oscillations, excitability, and traveling waves in a realistic model of the Belousov–Zhabotinskii reaction" by TYSON[88] (submitted on December 31, 1975). Interestingly, TYSON went back to "Belousov reaction" in his Journal of Mathematical Biology article "On the appearance of chaos in a model of the Belousov reaction,"[89] which he wrote during his time in Innstruck, Austria.

The first peer-reviewed article using the abbreviation "BZ" seems to be published in the Physics Letters A article "Chemical hysteresis, a new type of behavior in the Belousov–Zhabotinskii reaction" by TURNER[90] (submitted on January 19, 1976).

B. Legitimate name variations

In this section, we present all name variations for the *Belousov–Zhabotinsky* reaction, which seem to be conscious decisions by the authors. To shorten this list, we focus on the nowadays accepted spelling of ZHABOTINSKY. All other variations with, for example, ZHABOTINSKI or ZHABOTINSKII, can be found in the corresponding Secs. IV C–IV E.

One ongoing discussion is the question why/if the discoverer BELOUSOV was not initially acknowledged when naming the reaction. The rumor is that Western scientists "ignored" BELOUSOV's name because ZHABOTINSKY collaborated with scientists beyond the Iron Curtain, the influence region of the USSR and even that BELOUSOV worked for the USSR military and, therefore, should not be named. After reviewing all early publications regarding the BELOUSOV–ZHABOTINSKY reaction, these statements have been disproved. Table I in Sec. I of the supplementary material gives an

overview about the use of any eponym in an article or book chapter title until 1977. As one can see, initially, scientists chose to either use *Belousov reaction* or *Zhabotinsky reaction* but the decision was not based on the author's country. Starting in 1978, the number of publications increased significantly and scientists seemed to have settled on the name BELOUSOV–ZHABOTINSKY.

In 1973, both scientist's names have been used for the first time together as one eponymous name. NICOLIS and PORTNOW used the name BELOUSOV–ZHABOTINSKII reaction in their Chemical Reviews article "Chemical oscillations."[91] FIELD published an article the same year using both names, though in the German Journal "Chemie in unserer Zeit."[92] However, NICOLIS was not consistent in his naming as he used the name ZHABOTINSKI–BELUSOV (with this spelling) reaction in a book chapter the same year.[93] The following year, DICK FIELD and DICK NOYES used the name BELOUSOV–ZHABOTINSKII reaction in their Journal of the American Chemical Society (JACS) article "Oscillations in chemical systems. V. Quantitative explanation of band migration in the Belousov–Zhabotinskii reaction,"[94] and JAMES MURRAY can be named as the author using the nowadays used version *Belousov–Zhabotinsky reaction* for the first time in his Journal of Chemical Physics (JCP) article "On a model for the temporal oscillations in the Belousov–Zhabotinsky reaction."[95] However, in both cases, no abbreviation had been introduced.

Some scientists use different names for different types of reactions. For example, the name BELOUSOV system is used when describing the original reaction (often the temporal oscillations) with citric acid as the organic substrate and Ce^{3+}/Ce^{4+} as the catalyst, whereas the name ZHABOTINSKY reaction or BELOUSOV–ZHABOTINSKY reaction is used for a system with malonic acid as the organic substrate and ferroin as the catalyst.

1. **Belousov reaction**
   - 1972 FIELD and NOYES used this version in the title "Explanation of Spatial Band Propagation in the Belousov Reaction" of their June 1972 Nature article.[96] This is, to the best of our knowledge, the first time any scientist's name appeared in the title of an article about the BZ reaction. In the text, they cited the 1970 Nature paper by ZAIKIN and ZHABOTINSKY.[2]
   - 1972 FIELD, KŐRÖS, and NOYES used only BELOUSOV's name in their famous December 1972 paper "Oscillations in Chemical Systems. II. Thorough Analysis of Temporal Oscillation in the Bromate-Cerium-Malonic Acid System."[97] They continued using this name version in numbers III and IV of their "Oscillations in Chemical Systems" series.[94,96]
   - 1973 KOPELL and HOWARD followed the same idea in the title of their 1973 Science article "Horizontal Bands in the Belousov Reaction,"[98] while citing Belousov (1959)[4] but also Zhabotinsky (1964).[15]
   - 1974 KOPELL and HOWARD continued this naming with their article "Pattern Formation in the Belousov Reaction."[99] However, in the third paragraph, they write:

     > "The chemical system that was discovered by Belousov in 1958 is now generally known as the Zhabotinskii reaction."

     Interestingly, they did not cite any work by BELOUSOV or ZHABOTINSKY but three papers from the FKN sequence.
   - 1983 TABBUTT uses various terms in their book chapter "The Belousov–Zhabotinsky Reaction: Dynamical Surfaces as Models for an Oscillating System" (see below) but "Belousov Reaction" in all section headers.[100] On p. 131, he writes "... the oscillating reaction for this system has come to be known as Belousov–Zhabotinsky reaction. It will be referred to simply as the Belousov reaction in this paper."
   - 2017 More recently, TVERDISLOV *et al.* referred to a physicochemical system in their article "Active Media as a Physical Model of Spatiotemporal Self-Organization in the Stock Market" as a "Belousov active medium."[101]
   - 2017 In Chapter 1 "Images from the History of Synergetics" of the book "Imagery Synergetics," PLATH distinguishes between the BELOUSOV reaction for temporal Ce^{3+}/Ce^{4+} oscillations in a batch reactor and the BELOUSOV–ZHABOTINSKY reaction in general.[102]
     This is, from a historical point of view, a good way to distinguish between the purely temporal oscillation of BELOUSOV's system and the various BZ systems used today.
2. **Winfree reaction**
   - 1978 In a *Scientific American* article "Chemical systems that oscillate between one color and another" from 1978, J. WALKER named the reaction with cerium III and IV as the catalyst as the "Belousov reaction" and the reaction with the iron II and III couples as "Winfree reaction."[103]
3. **Zhabotinsky reaction**
   - 1972 GOLDBETER and LEFEVER used this version already in their 1972 article "*Dissipative Structures for an Allosteric Model.*"[104]
   - 1977 WINFREE using the spelling the first time in the title of his article "Spatial and Temporal Organization in the Zhabotinsky Reaction."[105]
4. **Belousov–Zhabotinsky reaction**
   - 1974 The title of J. MURRAY's JCP article "On a model for the temporal oscillations in the BELOUSOV–ZHABOTINSKY reaction" is the first publication to have the nowadays accepted spelling in the title.[95]
   - 1976 In 1976, the two-name eponym appeared for the first in a book title "*The Belousov–Zhabotinskii Reaction*" by JOHN TYSON.[106]
5. **Zhabotinsky–Belousov reaction**
   - 2009 The reverse order of these two names does not appear too often, but can be found in, for example, CHERUBINI's Physical Review E paper "Lagrangian field theory of reaction-diffusion."[107]
6. **Zaikin–Zhabotinsky reaction**
   - 2008 CARTWRIGHT uses this spelling throughout his book "Using artificial intelligence in chemistry and biology: A practical guide"[108] but cites only the 1972 paper by FIELD, KŐRÖS, and NOYES.[97]

2015 FIELD called the propagating fronts ZAIKIN–ZHABO TINSKY waves in his Mod. Phys. Lett. B article "Chaos in the Belousov–Zhabotinsky reaction."[109]

7. **Zhabotinsky–Zaikin reaction**
   1972 WINFREE used this option in the abstract of his famous Science article "Spiral waves of chemical activity."[5]
8. **Belousov–Zaikin–Zhabotinsky reaction**
   1980 SCHMIDT and ORTOLEVA used this combination in the introduction of their JCP article "Asymptotic solutions of the FKN chemical wave equation,"[110] though using the [ii] spelling in the bibliography.
   1984 FERNÁNDEZ and SINANOĞLU used this combination in their Z. Naturforsch. An article "A reactive system with diffusive transport displaying two different symmetry-breaking dissipative structures" and used the abbreviation B-Z-Z reaction,[111] while citing BELOUSOV's 1959 article and ZAIKIN and ZHABOTINSKY's 1970 Nature article,[2] though getting the year wrong.
   1984 In the book chapter "Cellular Clocks and Oscillators" by KLEVECZ, KAUFFMAN, and SHYMKO[112] (p. 102), while citing BELOUSOV's 1959 article[4] and ZAIKIN and ZHABOTINSKY's 1970 Nature article.[2]
9. **Belousov–Zhabotinsky–Winfree reaction**
   1974 RÖSSLER used this combination in his book chapter "A Synthetic Approach to Exotic Kinetics (With Examples),"[113] though also writing on p. 570 "...the excitable Belousov–Zhabotinsky reaction (Winfree, 1972)..." and "...the nonstirred two-dimensional Zhabotinsky reaction..." on p. 577.
10. **Belousov–Zhabotinsky–Zaikin reaction**
   1978 ORTOLEVA used this combination in his book chapter "Selected Topics from the Theory of Nonlinear Physico-Chemical Phenomena" including the abbreviation "BZZ reaction"[114] (p. 239).
11. **Zaikin–Zhabotinsky–Winfree reaction**
   1974 RÖSSLER used this spelling in his book chapter *A Synthetic Approach to Exotic Kinetics (With Examples)*.[113]
   2022 FIELD, MAZO, and MANZ used this spelling in their Chaos article "Science, serendipity, coincidence, and the Oregonator at the University of Oregon, 1969–1974"[10] with the argument "...to honor the discoverers of BZ-fronts and spirals."

C. One-name variations

- **Belousov reaction**
  See Sec. IV B 1.
- **Winfree reaction**
  See Sec. IV B 2.

12. **[Z]abotinsky reaction**
   1988 R. LESTIENNE used this name in their review article "From physical to biological time"[115] (p. 204).
13. **Zhabotinsk[i] reaction**
   1971 P. GLANSDORFF and I. PRIGOGINE used this version in their 1971 book "*Thermodynamic theory of structure, stability and fluctuations*" as part of the titles of Sec. XIV.9 (Example of oscillating systems—The Zhabotinski reaction) and Sec. XV.6 (Examples of a dissipative space structure. The Zhabotinski reaction) as well as in the text.[116]
   1971 I. PRIGOGINE and G. NICOLIS used this version also in their 1971 review article "*Biological order, structure and instabilities*."[117]
   1972 BECK and VÁRADI wrote

> "Two-dimensional spatial periodicity was found by Zhabotinski..."

   in their 1972 article,[118] while citing ZAIKIN and ZHABOTINSKY's 1970 Nature paper.[2]
   1986 BAIRD is using the spelling while introducing 3D patterns in Ref. 119 (p. 156).
14. **Zhabotinsk[ii] reaction**
   Some scientists continued to leave out BELOUSOV's name. In 1974, the Czech collaborators I. KOUMAR and M. MAREK published the article "A Mathematical Model for the Zhabotinskii Reaction,"[120] citing five of ZHABOTINSKY's article until 1971 and never mentioned BELOUSOV's name.
   1973 In his article "'Spatial Oscillations' in the Zhabotinskii Reaction," D. THOENES is citing the ZAIKIN and ZHABOTINKY Nature paper from 1970 but uses only the second author's name,[121] leaving out any reference to BELOUSOV's work. This is one of the few early articles arguing against the phenomena being a result of spatial dissipative structures. He argued that all patterns can be explained as purely geometrical phenomena.
   1978 RÖSSLER and WEGMANN used this name in the article title "Chaos in the Zhabotinskii reaction" but switched to "The Belousov–Zhabotinskii reaction is a chemical Bonhoeffer–van der Pol circuit, that is,..." in the first sentence of the abstract.[63] Because of this title choice, HUDSON and MANKIN could choose the title *Chaos in the Belousov–Zhabotinskii reaction* in their 1981 publication.[64]
   1979 REUSSER and FIELD used the same pattern of *Zhabotinskii reaction* in the title and *Belousov–Zhabotinskii reaction* in the text in their article "The transition from phase waves to trigger waves in a model of the Zhabotinskii reaction."[122]

- **Zhabotinsky reaction**
  See Sec. IV B 3.

D. Two-name variations

1. Two-name variations with BELOUSOV and ZHABOTINSKY

Two-name variations, including the names BELOUSOV and ZHABOTINSKY, are, not surprisingly, the most common. They are accountable for nearly 110 of the 140 variations we found in the scientific literature.

The next two tables present all variations separated by the initial spelling of ZHABOTINSKY's name. Table I lists all variations in which ZHABOTINSKY' name starts with [Zh], whereas Table II lists other variations (i.e., [J], [Sh], [Za], and [Zs]).

TABLE I. Two-name eponym variations in the order Belousov and Zhabotinsky (**starting** with [Zh]). Rows are for the first position, and columns for the second position. The numbers indicate the number in the detailed list in Sec. II A of the supplementary material.

	Zhab[a]tinsk[i]	Zhab[es]tinsk[ii]	Zhab[a]tinsky	Zha[bh]otinsk[ii]	Zhabo[s]tinsk[ii]	Zhabo[s]tinsky	Zhabo[th]insk[i]	Zhabo[th]insk[ii]	Zhabo[th]insky	Zhabotinsk[i]	Zhabotinsk[ii]	Zhabotinsk[ij]	Zhabotinsk[iy]	Zhabotinsky	Zhabotinsk[yi]	Zhabotinsk[yii]	Zhabot[y]nsky	Zhab[u]tinsky	Zha[v]otinsky
Belo[a]so[y]											15								
Be[ll]ousov														16					
Belo[lu]sov											17								
Belo[lu]so[w]														18					
Belo[o]sov														19					
Belo[ou]sov											20			21					
Bel[o]s[ou]v		23												24					
Bel[o]sov	25									26				27					
Belou[sh]ov										28	29			30					
Belouso[f]										32	33			34					
Belouso[ff]									35				36						
Belous[ou]v											37			38					
Belousov			53	54	56	57	58	59	60	62	63	64	65	**4**	66	67		71	72
Belousov[a]											75			76					
Belouso[w]										77				78					
Belou[ss]o[f]										79									
Belou[ss]ov										81	82			83					
Belous[v]											84								
Belou[sz]ov														85					
Belou[zh]ov														87					
Belou[z]ov									92	94	95			96					
Belou[z]o[w]														97					
Belo[v]sov		98									99			100					
Bel[uo]sov										101	102			103					
Bel[u]sov							107			109	110			111					
Bel[u][zh]ov										113				114					
Bel[u][zh]o[w]														115					
Bel[uz]ov										117				118					
Be[uj]usov											119								
B[ie]lousov													122				123		
B[ye]lousov														124					

The list with a detailed presentation of the nearly 110 entries can be found in Sec. II A of the supplementary material).

It is common practice to order the names in chronological order when combining the scientists' names. Therefore, BELOUSOV is usually the first name but there are exceptions from this rule when BELOUSOV's name has been used in the second position as shown in Table III. The list with a detailed description of these entries can be found in Sec. II B of the supplementary material.

2. Two-name variations with ZAIKIN and ZHABOTINSKY

The reaction has also sometimes been named after the two main authors of the initial publications as listed in Table IV. The list with a detailed description of these entries can be found in Sec. II C of the supplementary material.

WILLIAM TROY used probably the largest variety of name combinations in one publication in Chap. III (The Belousov–Zhabotinskii Reaction) in his 1978 book chapter "Mathematical Modeling of Excitable Media in Neurobiology and Chemistry."[84]

In Sec. III A (Introduction), he cites BELOUSOV's 1959 paper,[4] ZHABOTINSKY's 1964 paper,[15] and the ZAIKIN and ZHABOTINSKY Nature article from 1970[2] and names the overall reaction the BELOUSOV–ZHABOTINSKII reaction, as in the Chapter title and in Sec. III D. However, in Sec. III A 2. (Two Types of Traveling Waves), TROY mentions that the ZAIKIN–ZHABOTINSKII reagent can be spread out in a thin layer to create visible pacemaker centers, highlighting the key content of their 1970 Nature article. He continues

TABLE II. Two-name eponym variations in the order Belousov and Zhabotinsky (**not starting** with [Zh]). Rows are for the first position, and columns for the second position. The numbers indicate the number in the detailed list in Sec. II B of the supplementary material.

	[J]abotinsk[i]	[J]abotinsk[ii]	[J]abotinsky	[Sh]abotinsky	[Z]a[bh]otinsk[i]	[Z]a[bh]otinsky	[Z]abo[th]insk[i]	[Z]abo[th]insk[ii]	[Z]abo[th]insky	[Z]abotinsk[i]	[Z]abotinsk[ii]	[Z]abotinsky	[Z]abot[y]nsk[i]	[Zah]botinsky	[Zs]abotinsk[ii]
Bel[o]s[ou]v										22					
Belouso[f]														31	
Belousov	39	40	41	42	43	44	45	46	47	48	49	50	51	52	73
Belousov[a]														74	
Belou[ss]ov									80						
Belou[zh]ov												86			
Belou[z]ov									88	89	90	91			
Bel[u]sov						104				105		106			
Bel[u][zh]ov												112			
Bel[u][z]ov												116			
B[ieł]lousov										120			121		

citing four of WINFREE's publications from 1972 to 1974, including his two Science articles[5,123] and the appearance of phase waves and trigger waves while using a ZAIKIN–ZHABOTINSKII–WINFREE reagent, acknowledging WINFREE's contribution to the differentiation of these two wave types.

He also used the eponym FIELD–NOYES model in the header of Sec. III B to distinguish between the mathematical model and the chemical reaction scheme, the FIELD–KŐRÖS–NOYES mechanism.[94,97,124,125] FIELD and NOYES introduced themselves the name *Oregonator* model in their article.[124]

E. Three-name variations

In the three-name eponym, nearly no typos appeared in the last about 50 years. Variations are mainly based on the different spelling of *Zhabotinsky*. This is not surprising as scientists consciously choosing to honor three scientists are not simply citing the BZ reaction in a paper.

TABLE III. Two-name eponym variations in the order Zhabotinsky and Belousov. Rows are for the first position, and columns for the second position. The numbers indicate the number in the detailed list in Sec. II B of the supplementary material.

	Belousov	Bel[u]sov
[J]abotinsky	125	
[Z]abotinsk[ii]	126	
Zhabotinsk[i]	127	128
Zhabotinsk[ii]	129	
Zhabotinsky		130
[Zs]abotinsk[i]	131	

135. **Belousov–Zaikin–Zhabotinsk[i] reaction**
1977 DELLEDONNE and ORTOLEVA used this combination in the introduction of their JCP article "Oscillations and runaway states in a closed illuminated system."[126]

136. **Belousov–Zaikin–Zhabotinsk[ii] reaction**
1980 SCHMIDT and ORTOLEVA used this combination in the abstract of their JCP article "Asymptotic solutions of the FKN chemical wave equation" and abbreviated with "BZZ."[110] However, they switch to Belousov–Zaikin–Zhabotinsky in the introduction.

137. **Belousov–Zaikin–Zhabotinsk[iĭ]**
1976 HSÜ used these names in the title of their J. Diff. Equ. article "Existence of periodic solutions for the Belousov–Zaikin–Zhabotinskiĭ reaction by a theorem of Hopf."[127]

138. **Belousov–Zaikin–Zhabotinsk[ij]**
1989 HALUŠKA used this combination in their article "Stability of a model for the Belousov–Zhabotinskij reaction"[128] when citing HSÜ's 1976 article and changing [iĭ] to [ij].

TABLE IV. Two-name eponym variations with Zaikin and Zhabotinsky. Rows are for the first position, and columns for the second position. The numbers indicate the number in the detailed list in Sec. II C of the supplementary material.

	Zaikin	Zhabotinsk[i]	Zhabotinsk[ij]
Zaikin		132	133
Zhabotinsk[i]	134		

- **Belousov–Zaikin–Zhabotinsky**
  See Sec. IV B 8 in the article.

139. **Belousov–Zaikin–Zhab[ou]tinsky**
    1979 This typo appears in P. ORTOLEVA's article in the Annals of the New York Academy of Sciences "Discussion Paper: Bifurcations and Perturbed Attractors in Physicochemical Systems."[129]
140. **Belousov–Zhabotinsky–Noyes**
    1983 TABBUTT used "Belousov Reaction" in all section headers of his book chapter "*The Belousov–Zhabotinsky Reaction: Dynamical Surfaces as Models for an Oscillating System.*"[100]
    However, on p. 132, he writes "Many of the researchers in this field from all over the world have worked in his (Noyes') laboratory. It would seem fitting to call the reaction the "Belousov–Zhabotinsky–Noyes reaction," which he used on p. 178 again.

- **Belousov–Zhabotinsky–Winfree**
  See Sec. IV B 9 in the article.
- **Belousov–Zhabotinsky–Zaikin**
  See Sec. IV B 10 in the article.

141. **Belou[z]ov–Zhabotinsk[i]–Zaikin**
    1999 ALLOUCHE used this combination in his book chapter "Cellular Automata, Finite Automata, and Number Theory"[130] (p. 321).
142. **Bel[u]sov–Zaikin–Zhabotinsky**
    1977 The use of these three names, with another order but also a typo, appeared in SCHMIDT and ORTOLEVA's JCP article "A new chemical wave equation for ionic systems" and abbreviated it again as *BZZ system*.[131]
143. **Zaikin–Zhabotins[ii]–Winfree**
    1978 In TROY's book chapter in Sec. III A 2,[84] as outlined earlier.
    1979 FIELD and WINFREE used this spelling in the title "Travelling Waves of Chemical Activity in the Zaikin–Zhabotinskii–Winfree Reagent" in their 1979 J. Chem. Educ. article.[132]

- **Zaikin–Zhabotinsky–Winfree**
  See Sec. IV B 11 in the article.

V. CONCLUSION

The profusion of transliteration strategies and outcomes for the BELOUSOV–ZHABOTINSKY (BZ) reaction diminishes the findability of relevant research. This is a real hindrance to researchers familiar and unfamiliar with the Russian language and/or transliteration from Cyrillic alphabets alike. At the same time, the existence of so many variations derived from various languages highlights the international and interlingual character of BZ reaction research. This character is certainly broader than we indicate here, insofar as our examples only derive from transliteration strategies and pronunciations from a relatively small range of Indo-European languages (except Hungarian which is a Finno-Ugric language).

Standardization of terminology is an aid to researchers. The bibliography of this article perhaps may facilitate future research as a compendium not only of eponyms but also of the research using them. Still, the emergence of the single standard transliteration and eponym BELOUSOV–ZHABOTINSKY reaction was important. The findings here underscore the potential benefits of greater interlingual and intercultural education among and across scientific communities. While English may be the *lingua franca* of scientific communication currently, scientific progress will benefit from awareness of the diversity of linguistic and cultural backgrounds of scientists today and historically. This awareness, in turn, suggests the need for robust humanities programs in higher education, without which interdisciplinary connections become much more difficult. The present article evidences the benefits of such a connection.

In addition, the intentional use of spellings other than "BELOUSOV–ZHABOTINSKY" based on evolving transliteration rules or authors publishing in English who do not know Russian and/or whose native language is not English. Paying more attention while citing unfamiliar scientific concepts and creating a manuscript's bibliography is crucial. Most simple typos within the article text appeared in non-chemistry focused articles, when referring to a non-linear excitable, oscillatory, or pattern-forming chemical system. The other large group of typos can be found in the reference list, which highlights the need for authors to pay more attention when creating their bibliographies.

Determining the eponymous name for a scientific model, reaction, theory, etc. does not follow any rules and seems often to be arbitrary.[133] Some eponyms are simply based on (i) the author(s) of a single publication (e.g., TYSON–FIFE model[134] or the ZZKK model[24]), (ii) single one-author publications (e.g., RUNGE–KUTTA method[135,136]), or (iii) a series of single one-author publications (e.g., LOTKA–VOLTERRA method[137–139]). Many other eponyms can be traced back to publications with a mixture of one-author and several author publications (e.g., the BRAY–LIEBHAFSKY reaction[8,140]).

The BELOUSOV–ZHABOTINSKY reaction falls within the more complicated, not so straightforward case of eponym finding. One could argue that it is simple because BORIS BELOUSOV and ANATOL ZHABOTINSKY published the first two articles describing the reaction in 1959[4] and 1964.[1] However, in the following years, ZHABOTINSKY published many co-author articles with varying first authors with VASILY VAVILIN and ALBERT ZAIKIN (see Sec. II B). It is also important, especially for Western scientists at that time, that ZAIKIN and ZHABOTINSKY published a *Nature* article in 1970,[2] which was much more accessible than the Russian journals, even if *Biophysics (Moscow)* was available in English as well. However, the motion to add ZAIKIN's name to the eponym did not find many followers, though ZAIKIN–ZHABOTINSKY, ZHABOTINSKY–ZAIKIN, BELOUSOV–ZAIKIN–ZHABOTINSKY, and BELOUSOV–ZHABOTINSKY–ZAIKIN can be found in the literature. Interestingly, VAVILIN's name had never been used.

We conclude that the eponymous name is a result of honoring BORIS BELOUSOV for discovering the phenomena in the 1950s and ANATOL ZHABOTINSKY as the initial developer of the system in the 1960s who continued working on this system for more than 40 years. During his research career, he had 174 publications, which includes about 150 articles related to the BZ reaction. ALBERT ZAIKIN started working at the Institute of Biological Physics of the USSR Academy of Sciences in Pushchino in 1968 and worked mainly on other projects, publishing more than 80 scientific papers in the field of biophysics and chemical physics. VASILY VAVILIN also started his career at the Institute of Biological Physics of the USSR Academy of Sciences in Pushchino and is currently a scientist

at the Water Problems Institute of the Russian Academy of Sciences in Moscow.

SUPPLEMENTARY MATERIAL

The supplementary material file consists of three sections:

I. Table of eponyms in titles until 1977
The table contains publications until 1977, using any BZ-related eponymous name and is discussed in Sec. IV B.
II. Two-name variations with Belousov and Zhabotinsky
The section provides details for the about 110 spelling variations of the eponymous name BELOUSOV–ZHABOTINSKY reaction we found in the literature. It is related to Tables I and II in Sec. IV D 1.
III. Categories for all discovered eponyms
The section contains a short summary of the naming categories (possible reasons for the name variation) as discussed in Sec. III. Six tables list all eponymous names and assigns one or more to each entry.

ACKNOWLEDGMENTS

I (N. M.) thank DICK FIELD for many fruitful discussions on this topic and I am sad that he could not join me actively during the writing of this article. We thank MICHAEL BUKATIN, WERNER EBELING, MAXIM D. FRANK-KAMENETSKII, STEFAN C. MÜLLER, SIMON SHNOLL, VASILY VAVILIN, and ELENA ZAIKINA for various pictures, SATOSHI NAKATA for ZHABOTINSKY's business card, JOHN TYSON for information about the beginning of the abbreviation "BZ." We also thank OLGA KURICHEVA, NINA PAVLOVNA, and ELENA ZAIKINA for information about ALBERT ZAIKIN. This work was supported by the Hamburger Collaborative Project Fund at The College of Wooster.

AUTHOR DECLARATIONS

Conflict of Interest

The authors have no conflicts to disclose.

Author Contributions

Niklas Manz: Conceptualization (lead); Formal analysis (lead); Investigation (equal); Project administration (lead); Writing – original draft (lead); Writing – review & editing (lead). **Zachary Rewinski:** Formal analysis (equal); Investigation (equal); Writing – original draft (equal); Writing – review & editing (equal). **Fazly Ataullakhanov:** Formal analysis (supporting); Investigation (equal); Writing – original draft (supporting); Writing – review & editing (supporting). **Vilmos Gáspár:** Formal analysis (equal); Investigation (equal); Writing – original draft (equal); Writing – review & editing (equal).

DATA AVAILABILITY

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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