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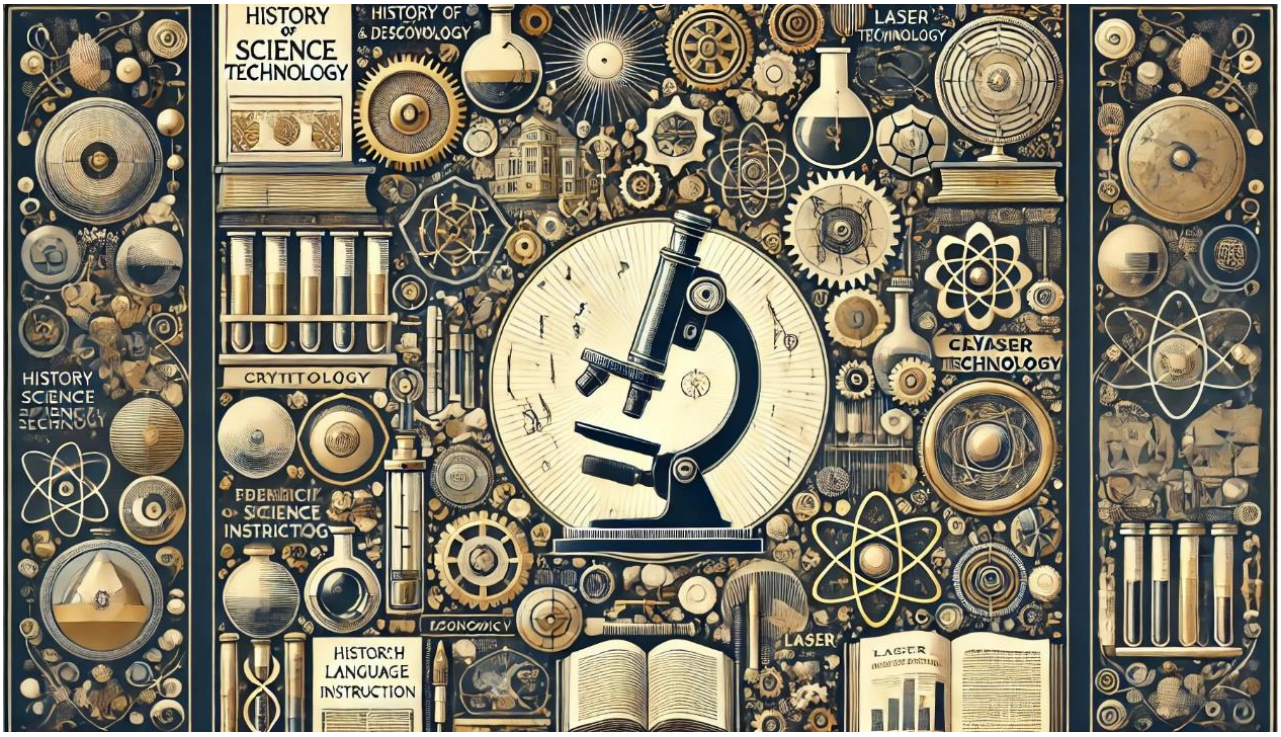

EDITORIAL

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PREFACE

This volume brings together a diverse collection of research studies, each reflecting critical inquiries into historical, scientific, cultural, and philosophical topics. The works presented here showcase the contributions of scholars who delve into the intersections of their disciplines, offering fresh perspectives and fostering a deeper understanding of the complexities of human endeavor and its implications for contemporary and future developments.

The issue begins with an article in which the author explores French language instruction in Galicia (1867–1939) and examines the pedagogical evolution from grammar-translation and text-based methods to the direct method. The study demonstrates that while the earlier period was dominated by translation-based approaches emphasizing grammar and textual analysis, the later adoption of the direct method marked a significant shift towards practical language use, particularly in speaking and writing. Through a historical-analytical approach, the authors illustrate how educational reform aligned with linguistic theories and psychological principles of the time. This transition marked a shift towards communicative competence and cultural integration, establishing a foundation for modern approaches to language teaching.

In economics, exploring planning paradigms provides an analytical framework for understanding the socio-economic processes that shaped historical and contemporary thought. The results of the next study showed the main driving force of the genesis is a change in the level of environmental stability, the degree of socio-economic processes predictability and the level of uncertainty in their future development. The study identifies three dominant paradigms – neoclassical, neo-institutional, and evolutionary – emphasizing their relevance in addressing uncertainty, environmental instability, and the interplay between theory and practice. These findings highlight the adaptability required for effective economic planning in an increasingly interconnected world.

The contributions of Ukrainian scientists to the development of the Tselinograd State Medical Institute during the 1960s offer an inspiring narrative of academic exchange and institutional growth. The authors focus on the pioneering work of Dr. Viktor Rafailovych Faitelberg-Blank and Dr. Mariia Vasilivna Kropelnitska, whose innovative approaches to medical education and research shaped scientific schools and advanced pedagogical methodologies. This study underscores the enduring impact of knowledge transfer across borders.

The investigation of natural and mathematical publications in the Dnipro region during the late 19th and early 20th centuries highlights their role in transforming teaching methodologies into a formalized science. By analyzing journals and publishing activities, the study traces the development of methodological schools and the integration of practical and experimental approaches into educational practices. This research reveals the foundations of educational technology as a distinct discipline.

The history of cryotechnology in reproductive medicine provides a compelling account of how advances in cryobiology revolutionized fertility preservation and assisted reproductive technologies. Tracing key milestones, the authors highlight how breakthroughs in cryopreservation – from sperm to oocytes and embryos – have transformed possibilities for family planning and fertility treatments. Given the critical role of cryotechnologies in modern reproductive medicine, this article delves into the historical context of these developments, exploring the key breakthroughs that have shaped this field. The authors conducted an in-depth analysis of existing literature, drawing on a wide range of scientific databases to highlight the global impact of cryobiology on the current successes in reproductive medicine. Furthermore, the article presents the results of the authors' research and practical experience in the field of reproductive cryobiology, with a particular focus on the application of these technologies in Ukraine. Ethical considerations, technological challenges, and future applications of cryotechnology are also addressed, offering a holistic view of its significance in modern healthcare.

The philosophical dimension of this volume is represented by an analysis of Karl Popper's critical rationalism. By tracing the development of Popper's ideas – from his principle of falsification in the philosophy of science to his critique of historicism and advocacy for open societies – the study demonstrates the continued relevance of his thought in addressing contemporary challenges of democracy and authoritarianism.

A historical examination of ophthalmology in the Dutch East Indies (1900–1942) focuses on the establishment of specialized medical facilities in response to prevalent eye health issues. Using archival materials and spatio-temporal analysis, the study highlights the regional expansion of ophthalmology services and their role in advancing public health. This work underscores the importance of institutional development in addressing medical challenges and promoting specialization.

Technological innovation is further explored in the development of electromagnetic torpedo tubes at the Kharkiv Electromechanical Plant (1936–1938). The provides a historical account of Soviet experimentation with electromagnetic systems for submarine torpedo launching, reflecting the challenges of integrating theoretical possibilities into practical solutions.

The next study of lasers for countering UAVs provides insight into the rapid technological evolution in defense systems. The development of unmanned aerial vehicles has prompted the need to develop alternative and innovative countermeasures. These methods may range from the usage of interceptor drones to the application of concentrated energy beams. This paper examines the progress and known uses of laser technology in the context of combating unmanned aerial vehicles. To deepen and systematize knowledge about the development of laser applications in the military field, a systematic bibliographic analysis of scientific papers and popular publications on the development of both laser technologies and unmanned aerial vehicles over the past century was conducted. The work offers a historical perspective and examines contemporary strategies for integrating laser technology into countermeasures against emerging threats.

Historiographic works on the history of cinema play an important role in preserving knowledge about the development of this art form. They not only document the key stages of the evolution of cinema but also provide an opportunity to analyze it as a cultural phenomenon that is closely intertwined with the history of mankind. Historiographic works on the history of cinema cover the study of the development of cinema as an art, a means of communication and industry. They reflect various aspects of its formation: socio-cultural influences, technological breakthroughs, genre transformations and the role of cinema in a historical context. However, a thorough analysis of historiographic sources on the study of the history of the evolution of cinema in the context of considering the stages of the development of science and technology has not been carried out before. The next study aims to investigate the state, completeness and reliability of the study of the history of the development of cinema in the context of considering the stages of the development of science and technology, based on the analysis of historiographic sources, the achievements of predecessors, and modern methodology. The objective of this article is to analyze historiographical sources that consider the magic lantern, the camera obscura, and the shadow play as key precursors to cinema.

The next article updates the most significant information about the outstanding scientist-mechanic and railwayman of the first third of the 20th century Academician of the All-Ukrainian Academy of Sciences Petro Mykhaylovych Suprunenko. It is proven that his activities in the field of railway development are a significant contribution to the development of world science and technology. The main scientific works of the scientist and engineer are devoted to important problems of transport mechanics. He paid special attention to locomotive and wagon construction (he was a wagon designer). Wagons were built on the basis of a large amount of experimental material, which at one time received significant public resonance and scientific and technical recognition. The scientist's achievements in the initial period of railway transport construction in Ukraine, especially on the South-Western Railways, are confirmed. The article shows that the role of P. M. Suprunenko was in his scientific work as an "idea generator" and a leading theorist in combination with engineering activities.

Together, these contributions reflect the richness of interdisciplinary inquiry, showcasing the interconnectedness of historical, scientific, and philosophical developments. They demonstrate how individual efforts and collective advancements contribute to shaping modern understanding across various fields.

This volume aims to inspire scholars and practitioners alike, providing a platform for dialogue and collaboration. As we face the challenges of the 21st century, the insights offered here serve as a reminder of the enduring value of inquiry, innovation, and reflection in driving progress and enriching our shared intellectual heritage.

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French language instruction in Galicia (1867–1939): Analysis of curricula, programs, and methodologies

Abstract. *This study investigates the evolution of French language teaching methodologies in Galicia from 1867 to 1939, with a particular focus on the transition from the grammar-translation and text-translation methods to the direct method. Utilizing a historical-analytical approach, the research draws upon a wide range of primary sources, including educational curricula, pedagogical reports, and theoretical works by contemporary educators. The study reveals that the early period of French language instruction in Galicia was dominated by methods that prioritized the systematic mastery of grammar through deductive learning, where reading and translating texts played a central role. Writing has been seen as the ultimate goal of language acquisition, while speaking was often relegated to a secondary position. However, a significant shift occurred by the end of the 19th century, influenced by contemporary linguistic theories such as Neogrammarianism and psychological principles like Gestalt psychology. These new approaches emphasized the importance of oral communication, the contextual understanding of language, and the integration of cultural knowledge into language instruction. The direct method, which emerged during this period, aimed to teach French in a more practical and communicative manner, encouraging students to speak the language from the outset and use it in everyday situations. Despite the shift towards the direct method, the study notes that some traditional practices, such as the use of the native language for explaining grammatical concepts, continued to persist. This research concludes that the evolution of French language teaching in Galicia was characterized by a gradual but profound transformation towards more communicative and student-centered approaches, which laid the groundwork for modern language pedagogy in the region. The findings contribute to a deeper understanding of the historical development of language*

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teaching methods and suggest areas for further research, particularly in the long-term impacts of these pedagogical shifts on contemporary language education practices.

Keywords: *French teaching methods; Galicia; grammar-translation method; direct method; history of foreign language teaching*

Introduction.

The teaching of the French language in the region of Galicia during the years 1867 to 1939 represents a dynamic interplay between educational policy, linguistic pedagogy, and broader socio-political changes. This period, framed by the complexities of Austro-Hungarian dominion followed by the resurgence of Polish sovereignty, provides a unique case study in the evolution of language education against a backdrop of significant historical upheavals.

French, as a language of diplomacy, culture, and international exchange, was strategically promoted within Galician educational institutions. Its teaching methodologies and curricular inclusion reflect shifting educational goals – from fostering a bureaucratic elite under the Austro-Hungarian Empire to promoting a broader cultural fluency as Galicia integrated into a reconstituted Poland. This study aims to dissect the curricular frameworks, pedagogical methods, and educational policies that shaped French language teaching in Galicia, seeking to understand how these elements were influenced by external political pressures and internal educational reforms.

Significantly, the period under review coincides with pivotal educational reforms across Europe, where language teaching began transitioning from classical methods focused on translation and grammar to more modern approaches that emphasized spoken language and cultural immersion. In Galicia, these changes were often at the mercy of political tides, reflecting broader nationalist and regional educational agendas.

The primary purpose of this study is to provide a detailed analysis of how French language education in Galicia evolved from 1867 to 1939, examining the curricular contents, teaching methodologies, and the socio-political contexts that influenced these educational practices. By exploring archival documents, contemporaneous literature, and educational reports from the period, this research not only contributes to our understanding of language education history in Eastern Europe but also illuminates the broader implications of language policy as a tool of cultural and political integration.

The history of foreign language teaching has been extensively researched by numerous scholars across Europe, reflecting the importance of understanding the evolution of language pedagogy within different cultural and educational contexts. For example, A. P. R. Howatt and Richard Smith's comprehensive work, "The History of Teaching English as a Foreign Language, from a British and European Perspective" (2014), offers an in-depth exploration of the pedagogical shifts and developments in English language teaching throughout Europe. Similarly, Marhabo Avazmatova's "Historical Overview of Foreign Language Teaching in Europe" (2021) provides a broad survey of the historical trends in language education, tracing the progression of various methodologies across different countries.

Richard Smith and Nicola McLelland's "Histories of Language Learning and Teaching in Europe" (2018) delves into the varied approaches and contexts in which foreign languages have been taught, offering valuable insights into the comparative aspects of language education. Ana Clara Santos' research, "A History and Historiography of Foreign Languages Teaching and Learning in Portugal" (2018), focuses on the specific historical trajectory of language education in Portugal, highlighting the unique challenges and strategies employed in this region.

Additionally, the cultural dimensions of language teaching are explored by Fanny Martín Quatremare, Irene Valdés Melguizo, and Ariane Ruyffelaert in their work "Cultural Representations through the Examples of French Language Textbooks for a Spanish-speaking Audience in the 20th Century (1970-1999)" (2023), which examines how cultural elements are portrayed in French language textbooks designed for Spanish-speaking learners. Marie-Madeleine Bertucci's study, "Proposals for a Study of the Notion of Mother Tongue in a Body of Research on the Didactics of French as a Foreign Language/Second Language from 1945 to 2015" (2022), further contributes to the understanding of language teaching by investigating the conceptualization of the mother tongue in French language education.

In Ukraine, the historical development of foreign language teaching has also attracted scholarly attention. Olga Homeniuk's work, "The development of methods for teaching Germanic languages in Bukovina (first half of the 20th century)" (2020), and Oksana Tumak's study, "The Formation and Development of the Methodology of Teaching English in Bukovina (Late 19th–Early 20th Century)" (2018), provide valuable insights into the regional specifics of language pedagogy. Bohdana Labinska's research, "Trends in the Development of Foreign Language Teaching Methodology in Western Ukraine (Second Half of the 19th–First Half of the 20th Century)" (2013), further explores the broader historical trends in language teaching in Western Ukraine.

Despite these contributions, there is a notable gap in the literature concerning the history of teaching French in Ukraine. While substantial research has been conducted on other languages and regions, no comprehensive study has yet addressed the evolution of French language education in Ukraine. This study aims to fill this gap, offering a focused investigation into the development of French language teaching in Galicia from 1867 to 1939. The relevance of this research lies in its potential to contribute to the broader understanding of language education in Ukraine, particularly in the context of its historical and cultural influences.

This exploration is significant for several reasons. First, it enhances our understanding of the historical dynamics of language education within a region subjected to multiple governance structures over a short span of time. Second, it provides insights into the role of language in nation-building and cultural identity formation in multicultural and multi-ethnic societies. Lastly, by examining the transition in pedagogical approaches, this study contributes to the broader historiography of educational practices and their evolution in response to changing political landscapes.

Research Methods.

The theoretical and methodological framework for the study of French language instruction in Galicia from 1867 to 1939 is interdisciplinary in nature. We employed a multi-level theoretical and methodological toolkit, encompassing four levels: philosophical (general principles of cognition and philosophical categories that define the overall epistemological direction of the research, including principles of objectivity, unity of historical and logical aspects, etc.), general scientific (based on systemic, synergetic, and paradigmatic approaches), specific scientific (including regional, chronological approaches, critical analysis of literary sources, study and generalization of positive teaching experiences in French language instruction, historical-comparative method, and terminological analysis method), and technological (methods of archival material selection, narrative and hermeneutic methods). These levels enabled us to obtain a scientific foundation for studying the selected phenomenon.

The analysis of the source base for this research has been conducted with reference to approaches to classifying historical materials. The entire source has been divided into three groups. The first group includes sources that directly highlight the process of the formation and development of the methodology of teaching French in schools and gymnasiums of Galicia from 1867 to 1939. The second group consists of scientific publications related to the methodological foundation of the research. The third group includes works related to the history of pedagogy, which at different times, mainly starting from the second half of the 19th century, reflected the development of pedagogical thought in Galicia.

Results and Discussion.

1. Evolution of School Curricula, Reports and Educational Programs

The characterization of the French language instruction in Galicia from 1867 to 1939 encompasses a scientific substantiation of the periodization of the stages of development of this methodology. Retrospective research on the formation and development of French teaching methodology in Galicia enabled us to develop criteria for transitioning from one stage of development to another during the second half of the 19th century to the first half of the 20th century. These criteria include: 1) historical-social and educational-organizational prerequisites for teaching French; 2) the influence of foreign methodologies of teaching foreign languages; and 3) changes in methodological science resulting from the emergence of new methodological ideas, goals, content, methods, and teaching tools. Based on these criteria, we identified the main stages in the formation and development of the methodology of teaching French in Galicia: the first stage (1867–1890) – the formation of the methodology of teaching French; and the second stage (1890–1939) – the development of the methodology of teaching French.

The primary educational documentation that has guided the instructional process across various types of educational institutions for centuries has been the curricula and teaching plans. Although the requirements for drafting and structuring such educational

documentation have evolved over time, their fundamental importance remains constant, regardless of the changing circumstances.

According to Władysław Seredyński (1880), the curriculum serves as a crucial tool for organizing information and reporting, which should be an indispensable component of the documentation of any educational institution. The curriculum outlines the school subjects taught to students, along with the scope of the material covered within these subjects. Additionally, it specifies the time allocated for mastering each discipline, and it articulates the educational objectives for each subject. Seredyński viewed the school curriculum as a guarantee of consistency and continuity in the study of school subjects, likening it to a geographical map of the scientific knowledge that a student is expected to acquire throughout their schooling. The time allocated for each subject was typically presented in terms of the number of hours per week (Seredyński, 1880, pp. 49–50).

When drafting curricula, educators of the time were careful to include only those subjects that were appropriate for the level of education and the intellectual development of the student. They also considered whether it was feasible to comprehensively cover a subject within the time allocated for school education. The distribution of educational material was structured to ensure that students could absorb and later reproduce the knowledge acquired. In other words, if a subject was included in the curriculum, the number of hours and the distribution of educational material needed to be in harmony with other school subjects, a factor deemed crucial for the quality of education (Seredyński, 1880, pp. 51–52). Thus, from the perspective of educators of that era, the curriculum needed to be aligned with the psychological and intellectual development of the student at each stage of their education. Several factors were considered in curriculum design, including the time available for schooling, the intellectual development of the student, and the coherence of school subjects.

Let us proceed to the analysis of curricula and school reports in which French is listed among the subjects. We have identified the curriculum of an eight-grade girls' school in Lviv, dated 1879, as well as school reports from Galician Real Schools (1875, 1888, 1889) and gymnasiums (1876, 1889).

First, we will analyze the reports of the Lviv Real School for the years 1875, 1888, and 1889. Although the reports do not specify the objectives of French language education, an examination of the described educational material suggests that the primary goals were to teach French grammar, engage with works of French literature, and familiarize students with the biographies of the authors studied. Among the tasks proposed was the translation of simple texts from the native language into French. The 1875 report shows that French was studied in two sections, with three hours allocated weekly. In the 1888 and 1889 reports, the period of study increased, while the number of hours decreased, with French being taught in three sections, two hours per week. It should be noted that in the terminology of the time, the words "section" and "class" were synonymous when referring to Real Schools and gymnasiums.

According to the 1888 report, the teaching of grammatical material in the first year began with the conjugation of the verbs *avoir* and *être*, an introduction to articles and nouns, the main rules for forming the plural of nouns and adjectives, as well as the

formation of the feminine gender. In the second section, students studied regular verbs, pronouns, and numerals. In the third section, they covered irregular verbs, the word order in French sentences, the agreement of past participles with nouns, and the rules for using tenses.

The instruction in reading was described in the third section, where students were expected to read small texts with translation into their native language, as well as works by well-known French writers and their biographies. The students used the textbook by A. Świtkowski and the anthology by J. Amborski. The 1889 report was identical.

Thus, the reports from the Lviv Real School for the years 1888 and 1889 placed significant emphasis on the teaching of grammatical material and included translation exercises, which were the main features of the translation methods prevalent in foreign language education at the time.

We now turn to the analysis of the reports from the Franz Joseph Real Gymnasium in Drohobych for the years 1876, 1889, and 1890, where French was also studied as an elective subject. In 1876, French was taught in three sections, with two hours allocated weekly. In the first section, instruction began with phonetic material, specifically the rules of French pronunciation. Additionally, students learned the pronunciation of French sounds and compared them with those of their native language, a distinctive feature considering the translation methods prevalent in the region at the time.

The teaching of grammar in the first section started with the rules for using nouns and verbs. In the second section, students continued to learn parts of speech and their usage rules, including the formation and use of tenses. The third section focused on the word order in French sentences and the subjunctive mood. Reading instruction in the first section involved small texts containing specific grammatical structures. In the second and third sections, students began reading literary texts in the original language, specifically literary excerpts from J. Amborski's anthology. Additionally, in the third section, students read Voltaire's novel *The History of Charles XII*.

The teaching of speaking skills has also been included in the report. In the first section, students recited memorized texts that contained necessary grammatical structures and vocabulary. In the second and third sections, students summarized the literary works they had read and memorized certain excerpts. Among the tasks in the third section was a summary of the novel by Voltaire. Writing instruction in all three sections was conducted through the completion of one written homework assignment after each lesson, with two assignments per month completed in class. The tasks included translation exercises from the native language into French and grammar exercises.

For the first section, the recommended textbook was W. Czechomski's grammar; in the second and third sections, A. Świtkowski's grammar and J. Amborski's reading anthology were used. The content of the 1889 report was identical. The 1890 report shows that the number of hours did not change. During the first year of study, students were introduced to the rules of French pronunciation and the forms of nouns and verbs, with homework assigned after each lesson. The second year was dedicated to studying all parts of speech and verb tense forms. During the third year, students reviewed the previously learned French grammar and read texts from the anthology (Sprawozdanie

dyrekcyi c.k. realnego Gimnazyum im. Franciszka Józefa w Drohobyczu za rok szkolny 1890, 1890, p. 12).

The proposal to introduce French as a mandatory subject appeared only in 1886. According to the proposal submitted to the Central School Council, it was suggested to begin teaching French in the third class with four hours per week. For the fourth through seventh classes, three hours per week were recommended. The specific educational content was not detailed (Czyński, 1887, p. 21).

Based on our analysis of French language education prior to 1890, we will now explore the significant changes that occurred once French was established as a compulsory subject in schools. The curricula and reports become more detailed; they more clearly outline the educational material according to the year of study, and an increasing number of textbooks recommended for French language teaching are published. Educational programs also emerge where "French Language" is a mandatory subject. Let us now analyze in detail the curricula, plans, and school reports used in Galicia during the specified chronological period. Among the documents we have identified are the plans of the Higher Real School from 1896, the reports of Gymnasium No. 5 in Lviv (1897, 1898, 1899), the reports of the Higher Real School (1895, 1896, 1898), the curriculum of the Higher Real Gymnasium from 1910, as well as the educational program (*Program nauki*) from 1937, all of which include "French Language" as one of the subjects studied by students.

Let us analyze the reports from the Higher Real School in Lviv for the years 1895, 1896, and 1898, where the study of French is documented. The reports provide a fairly detailed account of the educational material and list the textbooks used for teaching French. French was introduced as a second foreign language (following German) starting from the third class.

The reports do not include a specific description of the objectives for teaching French. However, after analyzing the provided material, it can be inferred that the primary goals were to teach grammar, develop the ability to express thoughts both orally and in writing, cultivate skills in summarization and recitation, familiarize students with examples of classic French literature, and, in the final class, also provide an overview of treatises on natural and technical subjects. It is important to note that the direct method of teaching foreign languages emphasized practical language acquisition, particularly spoken language. Teachers aimed to use exclusively monolingual methods, establishing direct associations between words and concepts. This method did not involve translation exercises.

The instruction followed a gradual progression, with material presented from simple to complex, building on previously acquired knowledge. Let us examine the documents found, focusing on their descriptions of phonetic, lexical, and grammatical material, as well as texts for reading, speaking (both dialogue and monologue), and writing.

Grammar instruction in the third class began with the study of nouns, articles, adjectives, and pronouns. Students learned the conjugation of regular verbs and the formation of key compound tenses. In the fourth class, the material was reviewed and expanded to include further study of parts of speech and grammatical structures,

focusing on adjectives, numerals, pronouns, adverbs, and prepositions, with particular attention given to the most important irregular verbs. In the fifth class, students deepened their knowledge of noun declensions and irregular verbs, as well as impersonal expressions and conjunctions. Grammar instruction in the sixth class concluded with the study of adjectival and adverbial phrases, while in the seventh class, the focus was on reviewing the grammatical material previously covered.

Information about reading material appears in the curriculum for the sixth class, where students began exploring descriptive and narrative French prose, epic and lyric poetry, and brief biographical information about the authors studied. In the seventh class, students continued to study French literature and also read treatises on natural and technical topics.

Speaking exercises for the third, fourth, and fifth classes were uniform: students summarized texts they had worked on by answering questions about their content. In the fourth and fifth classes, the tasks for developing speaking skills were more complex than in the previous class, with fifth-grade students summarizing the texts they had studied. For the sixth and seventh classes, speaking tasks were not specifically detailed. However, the development of both dialogic and monologic speaking skills was emphasized, a characteristic feature of the direct method of foreign language teaching.

Writing skills in the first half of the third class were developed through weekly short dictations composed of learned expressions. In the second half of the year, such dictations were written every four weeks. The material in the fourth class was identical, but it was noted that the requirements for writing dictations and assignments were more challenging. In the fifth class, short free compositions and translation exercises from the language of instruction into French were introduced. In the sixth class, students were tasked with reproducing texts they had read, condensing complex texts, rewriting descriptive prose passages, writing letters, and translating sentences into French using the grammar rules they had learned. Writing instruction in the seventh class followed the same pattern as in the previous year (Sprawozdanie dyrekcyi c.k. szkoły realnej we Lwowie za rok szkolny 1895, 1895/96/97/98). As we can see, despite the presence of translation exercises, they were not of primary importance. More emphasis was placed on forms of writing that exclusively used French, which was also a characteristic of the direct method.

For the third through sixth classes, the recommended textbook was J. Amborski's *Book for Learning the French Language* in four parts (each part corresponding to a specific class). There was no recommended textbook for the seventh class, which can be explained by the fact that students worked with original texts, and grammar work was solely focused on reviewing previously learned material. It should be noted that all three reports (for 1895, 1896, and 1898) are identical.

In the curriculum of the fifth-grade girls' school for 1896, we also find that French was a mandatory subject. The goal of French language instruction was the ability to express one's thoughts in both oral and written communication in everyday and social situations. The curriculum includes descriptions of materials for grammar, reading, speaking, and writing, as the plan was divided into sections: "Reading and

Conversation," "Grammar," and "Writing." The plan also contains a note for the teacher that lessons should be conducted exclusively in French.

Grammar instruction in the fourth class began with morphology – the study of nouns, adjectives, numerals, pronouns, adverbs, and prepositions. Students learned to conjugate regular verbs and form the most important compound tenses. They also studied the most important irregular verbs. In the fifth class, the material from the fourth class was reviewed, and students memorized irregular verbs, imperfective aspects, and impersonal expressions. Conjunctions were added to the parts of speech. It was noted that systematic review of the learned grammatical material was required throughout the year.

Reading instruction in the fourth class began with the reading of phrases and short texts. Later, students were expected to read the assigned texts expressively. The reading material in the fifth class was identical.

Speaking instruction in the fourth and fifth classes involved the expressive retelling of short texts, discussions about the content of the readings, and conversations about everyday life. Students memorized and recited prose excerpts and poetic works. It is important to emphasize that speaking instruction was practically oriented, with students being taught to communicate on topics related to everyday life situations, which was also a feature of the direct method of foreign language teaching.

Writing skills in the fourth class were developed through the completion of three assignments per month in class, including answering questions about the content of the texts read, short descriptions and stories, and dictations. In the fifth class, the number of assignments per month was reduced to two (one homework and one in-class), but the types of writing tasks were expanded to include letter writing, text condensation, descriptions, and short stories (Plany naukowe szkoły wydziałowej męskiej i szkol wydziałowych żeńskich 3-, 5- i 6-klasowych, 1896, p. 26).

The goal of French language instruction in the six-grade girls' school in 1896, as in the five-grade school, was the ability to express one's thoughts in oral and written communication within the context of everyday life and social relationships (Plany naukowe szkoły wydziałowej męskiej i szkol wydziałowych żeńskich 3-, 5- i 6-klasowych, 1896, p. 27). A new element in the curriculum was the introduction of independent reading of French literature and familiarization with the most important works. The educational material for the first three classes was similar in content to that of the five-grade school. The material for grammar, speaking, and writing instruction was identical to that of the five-grade girls' school. The only difference was the reading material. In the fourth class, students began reading prose and poetic works. In the fifth class, students were introduced to the biographies of the authors whose works were being studied. It was noted that home reading was mandatory. In the sixth class, a chronological overview of the most important French writers and their works was included (Plany naukowe szkoły wydziałowej męskiej i szkol wydziałowych żeńskich 3-, 5- i 6-klasowych, 1896, p. 33).

Let’s analyze the curriculum intended for Galician Real Gymnasiums, dated 1910. The curriculum indicates that students were offered a choice between French and English; however, German and Latin were mandatory subjects. The objective of

learning French was to develop proficiency in oral and written expression in everyday social communication, to facilitate independent reading of texts, and to familiarize students with some French authors (Sprawozdanie dyrekcyi c.k. szkoły realnej we Lwowie za rok szkolny 1910, 1910, p. 8).

French language instruction began in the fourth class and continued until the eighth, with three hours per week dedicated to the subject. The curriculum includes descriptions of the grammatical material, reading, speaking, writing, and translation.

Grammar instruction in the fourth class focused on the study of basic parts of speech (nouns, adjectives, pronouns), verb conjugations, and the formation of the most commonly used tenses in French. In the fifth class, students reviewed and deepened their understanding of verb conjugations and studied adverbs and prepositions. Compared to the previous year, more time was allocated to the study of irregular verbs. The grammar material for the sixth class introduced impersonal expressions and imperfect tenses. The seventh class was dedicated to completing grammar studies, including the imperative and subjunctive moods, as well as participial phrases. In the eighth class, the previously learned grammar material was reviewed.

For reading instruction in the fourth, fifth, and sixth classes, short, simple texts and dialogues were recommended. In the seventh and eighth classes, the reading material included narrative and descriptive prose, lyrical and epic poetry, and biographies of the authors whose works were studied.

Speaking instruction in the fourth, fifth, and sixth classes was based on reading – students summarized texts they had read, engaged in simple dialogues based on the readings, and composed and answered questions. In the seventh and eighth classes, students memorized and recited texts and poetry.

Writing skills in all classes were developed through the written summarization of texts and the completion of two dictations per month. Starting in the sixth class, translation exercises from the language of instruction into French were added to the writing tasks. Students in the seventh and eighth classes also wrote friendly letters.

Thus, in the Real Gymnasium, we also observe a practical focus in the teaching of French – students worked on developing skills in reading, dialogic and monologic speaking, and letter writing. Despite the presence of translation exercises, it is evident that the direct method of French language instruction was predominantly used.

We now turn to the analysis of the program for Galician gymnasiums with Polish as the language of instruction, dated 1937. According to this program, French was studied as both a first and a second foreign language. It is presumed that the choice of foreign languages in the gymnasiums was left to the students or their parents. Let us examine the schedule of hours for studying French as a first and second foreign language (Program nauki (tymczasowy) w państwowym gimnazjum ogólnokształcącym z polskim językiem nauczania, 1937, p. 16; p. 400).

The program states that the goal of teaching the first foreign language was to enable students to communicate orally and in writing in everyday and professional contexts, to understand simple texts, to work with more complex texts using a dictionary, and to learn and apply the basic norms of grammar. For the first time, the program specifies a method of language instruction, namely the direct method,

although it also mentions that this method does not necessarily exclude the use of the native language (Program nauki (tymczasowy) w państwowym gimnazjum ogólnokształcącym z polskim językiem nauczania, 1937, pp. 275–277). It is stated that the student should first perceive words aurally and infer their meaning from context. Later, the student should use the words independently in speech, and only afterward learn to recognize them in reading and reproduce them in writing. Let us examine the instructional material in more detail.

Phonetics instruction was integrated with vocabulary learning. Teachers of the time asserted that phonetic material did not require separate time for study and should be learned alongside other aspects of the language, although the importance of teaching correct pronunciation was repeatedly emphasized.

In the first class, grammar instruction included the study of definite and indefinite articles, with emphasis on their omission in cases involving the words *beaucoup* and *plein*. Nouns and their plural forms were also studied, including words ending in *-al*, *-eau*, and *-eu*. Irregular verbs studied in the first class included *avoir*, *être*, *aller*, *venir*, *tenir*, *sortir*, *faire*, *dire*, *lire*, *écrire*, *prendre*, *mettre*, *recevoir*, *voir*, *savoir*, *vouloir*, and *pouvoir*. Pronoun verbs and the most important tenses of the indicative mood were also taught. In the second class, students studied sentence structure (subject, predicate, object, adverbial), the formation of plural nouns and adjectives, and the formation of adverbs from adjectives. The study of articles continued, including indefinite, definite, and partitive articles. New tenses and moods introduced included the simple past tense, pluperfect, and the conditional mood. The use of the preposition *de* instead of an article was also specifically addressed.

The grammar material for the third class became significantly more complex. Students studied compound and complex sentences, infinitive constructions, and additional tenses and moods, including *passé antérieur*, *futur antérieur*, *conditionnel passé*, *subjonctif présent* and *passé*, *participe présent* and *passé*, and conditional sentences with *si*. In the fourth class, students learned the sequence of tenses. Other grammatical topics included *participe présent*, *adjectif verbal*, *gérondif*, *infinitif passé*, *imparfait*, and *plus-que-parfait* of the subjunctive mood.

Moreover, the program emphasized that all selected material should develop not only language knowledge but also general culture in the student. Teachers were encouraged to use materials about French life and culture to familiarize students with everyday life and culture in France. Reading literary works was also important. Vocabulary was to be learned through dialogues, anecdotes, songs, and texts that illustrated everyday life at home and in the city. The program indicated that texts should reflect family relationships, a love for nature, the student's responsibilities at home and school, and love for their city. Reading was to be expressive and with proper intonation. Teachers were expected to monitor pronunciation accuracy during reading and correct mistakes immediately if they occurred. Speaking was practiced through the creation and reproduction of dialogues about objects in the students' immediate surroundings, school, family, and nature. In higher classes, students discussed the works they had read and expressed their own opinions. In all classes, students practiced reciting short

poems and singing French songs, which, according to teachers, would not only improve speaking skills but also enrich the students' vocabulary (des Loges, 1934, p. 3).

After reviewing the 1937 French program, we conclude that it clearly defined the goals, content, and duration of French language instruction. Methodological recommendations for organizing the learning process were also provided. The outcomes of French language instruction met the requirements of the educational institution type, namely the gymnasium. The curriculum included the allocation of hours for learning French, with specific linguistic and communicative material outlined for each year of study. However, it should be noted that the grammatical material was the most fully described; other aspects of the language were presented quite briefly and generally. There were no recommendations for current and final assessments of French language learning achievements, nor was there a list of recommended textbooks.

After analyzing the aforementioned curricula, plans, and reports, we conclude that the content of French language instruction during the selected period aligned with the need for proficiency in oral and written expression in everyday communication. For instance, in the Higher Real School, attention was given not only to oral and written communication but also to the study of texts related to natural and technical fields, whereas in girls' schools, the primary focus was on communication in everyday situations. The curricula and reports specify the works of classical French literature and the authors studied by the students according to their year of study. We assume that the vocabulary material was described in the recommended textbooks for each type of school. However, methods of ongoing and final assessments were not mentioned. The recommended textbooks are only found in the reports; such information is absent in the curricula and plans.

It is important to emphasize that during the selected time period, grammar served as a tool for language instruction and was one component of French language education, alongside other aspects, but it was not the primary focus. Teachers of that time were more interested in teaching students to express themselves on everyday topics, both orally and in writing. The study of French literature also gained significant importance.

Having reviewed the French language curricula, plans, and reports from the investigated time period, we conclude that the primary goal of foreign language instruction was to develop students' ability to communicate in everyday situations, express basic facts, and share their own thoughts in French. Great emphasis was placed on reading literary works, particularly French classical prose and poetry, summarizing them, memorizing passages, and reciting them. Regarding written communication, students were taught to write letters, further demonstrating the practical focus of language learning. Based on a detailed analysis of the educational documents, it is reasonable to assert that the direct method of French language instruction was applied.

2. Practical Approaches and Teaching Methods in French Language Instruction

In the second half of the 19th century, theoretical works with a methodological-didactic focus began to emerge in the Galician lands, which were used by teachers in

the process of teaching foreign languages in the region. Upon searching for such literature, we observe a significant number of methodological works dedicated to the teaching of Latin and Ancient Greek, as these classical languages were an integral part of the school education of the time. Many publications also pertain to the teaching of the German language. In the 1880s, the first theoretical work describing the methodology of teaching French was published. A few studies also highlight the specific features of teaching foreign languages in general. Let us examine in more detail the pedagogical views of foreign language teachers in Galicia during this period.

The work of Marian Chyliński, titled *Thoughts on the study of foreign languages with the addition of a short method for practical learning* (1861), was published in Krakow and recommended for use by foreign language teachers in Galicia. Despite the prevailing trend at the time to teach classical and modern languages using nearly identical methodologies, the author argued that no nation in the world has naturally learned, nor learns, a language starting with grammar (Chyliński, 1861, p. 15). Throughout the work, the author provides numerous arguments in favor of the idea that modern foreign languages should be learned through exposure to authentic language examples, such as literary works or periodicals. Czilinski believed that the first thing a teacher should instill in a student when teaching any living foreign language is a sense of the language. Language learning, he argued, should be based on cultivating a feeling for the language, which later aids in selecting the correct grammatical structures and linguistic forms (Chyliński, 1861, p. 141).

The educator believed that a student should acquire language gradually, taking small steps. By progressing from the simplest linguistic forms and phenomena, the student can eventually master more complex modes of expression. Czilinski was convinced that this approach would guarantee the acquisition of solid foreign language skills (Chyliński, 1861, p. 148).

Analyzing this theoretical work, we conclude that its author was a proponent of the text-translation method of foreign language teaching. Reading was given significant attention, with the recommended practice being to thoroughly analyze and translate texts into the native language to aid in the semantic understanding of unfamiliar vocabulary. Grammar instruction was primarily contextual: students analyzed the texts they read and learned new grammatical phenomena and structures accordingly. Pronunciation instruction was conducted through reading texts aloud.

A notable work published in 1887 is *A few remarks on the teaching of the French language in secondary and private schools* by Czesław Czyński, a French language teacher at a gymnasium and real school in Krakow. This book is the first theoretical work specifically dedicated to the methodology of teaching French (whereas the previous work we analyzed pertained to the teaching of all foreign languages taught in various types of schools in Galicia). According to the author, the teaching of French in schools and gymnasiums has either a pedagogical or practical objective. The study of both classical and modern languages was considered a means of developing logical thinking, a sense of logic, and cultivating the inner culture of the student (Czyński, 1887, p. 3).

As with the previous methodological work, Czyński was inclined to believe that French could not be taught using the same method as Latin and Ancient Greek in schools, as the study of French requires the student to learn to express themselves in the language, not just to understand and interpret literary works. A similar feature of both works is that Czyński asserted that the study of French should not be grammar-centric, as grammar is merely a means to an end, not the end itself (Czyński, 1887, p. 4). Grammar rules should not serve as a tool for illustrating language material; instead, they should be explained contextually and only as commentary on the texts read.

Thus, the author emphasized the importance of teaching French in schools and gymnasiums not exclusively through memorization of grammar rules, meaning that the educational objective was not solely the explanation and study of grammar.

The educator identified four key components of successful French language learning: gradual progression, proportionality, equivalence, and balance. By gradual progression, he referred to the consideration of the student's age characteristics in the process of learning French. It was deemed inadvisable to start learning before the child reached seven years of age, as this is when a child begins to develop thinking abilities, and the physiological development of the body creates favorable conditions for the start of school education (Czyński, 1887, p. 5). The term "proportionality" was used by the author to describe the alignment of educational material with the student's age characteristics. All words, phenomena, and concepts that the student learns in the process of mastering French should be comprehensible and relevant to their everyday life. The importance of ensuring that all lexical items studied in French should be familiar to the student in their native language was also emphasized.

For the author, equivalence meant that equal attention should be given to the harmonious development of the child, instilling moral and spiritual qualities, fostering imagination, humanity, wit, consciousness, and more. The study of French should be one of the components of the harmonious upbringing of the individual, but not the main one. In the process of learning French, it was advisable to refer to objects in the student's surroundings, their feelings, emotions, life situations, descriptions of nature, and their homeland, so that French could serve as one of the means of cultivating a well-rounded and conscious individual (Czyński, 1887, p. 7).

By balance, the author meant a balanced study of French and the native language. A student can only learn to read and write in a foreign language if they have already achieved this in their native language. The author asserted that the balance between learning French and the native language could be achieved by the tenth year of the student's life (Czyński, 1887, p. 8).

The methodological work reveals that French language instruction during the selected chronological period was closely linked with the native language. All grammar and pronunciation rules were explained to the student exclusively in the native language. After working on a short text or phrase, the student was asked to translate words or expressions from the native language into French.

Czyński emphasized the importance of students' homework in French. He pointed out that the number of hours allocated for learning French in school or gymnasium was

insufficient, and therefore daily practice at home, reviewing the material covered in class, was necessary. The educator recommended increasing the number of hours for French instruction in schools to six per week, as he believed that with six hours of instruction at school and daily review at home, students could achieve the ability to independently express themselves on simple, everyday topics in French by the end of the first year of study. In addition to reviewing material, students were required to memorize texts and poetry in French. However, in class, it was essential to ensure that every lexical item and grammatical phenomenon was thoroughly reviewed and understood by the student. One of the homework assignments was also to describe familiar objects and impressions (e.g., descriptions of a home, room, garden, street, etc.) (Czyński, 1887, p. 12).

The outcome of French language instruction at the end of a two-year period was expected to be the student's fluent command of the language within familiar topics. The educator stressed the importance of not only developing reading and speaking skills in French but also proficient writing. He recommended lessons with native speakers or teachers for further improvement of knowledge and acquisition of better proficiency in pronunciation and speaking. It was emphasized that the native speaker should necessarily be examined by a French language teacher, as a native speaker who lacks teaching skills cannot effectively explain the rules of their language. Additionally, it was considered unnecessary to cover too much material in class, as "a good teacher is not one who teaches a lot, but one who teaches well" (Czyński, 1887, p. 15). The ultimate goal of language instruction, namely confident language proficiency, was expected by the end of the third year of study, with the optimal age for this three-year period being between 10 and 13 years old (Czyński, 1887, pp. 12–13).

At the time of the publication of this methodological work, the choice of method for teaching French was still a significant issue. The author believed that each teacher tended to use their own method of French language instruction, which significantly complicated the learning process. As students transitioned from one teacher to another, they sometimes could not progress because the teaching methods differed from one teacher to another, leading to uneven progress (Czyński, 1887, p. 16).

Thus, after reviewing another theoretical work, we conclude that grammar was not considered the primary focus of French language instruction in Galician schools and gymnasiums. Grammar was not intended to serve as a means of illustrating French language material. We also note the significant attention given to the connection between French and the native language: the teaching of lexical items, grammatical phenomena, pronunciation rules, and the reading of French literature were to be presented to students in close connection with their simultaneous acquisition of knowledge in their native language and literature.

French language instruction in Galicia during the period of 1867–1890 was based on the grammar-translation and text-translation methods of foreign language teaching, where primary attention was given to the systematic mastery of grammatical material, which was illustrated through a deductive approach. Within the framework of translation methods, the acquisition of a foreign language was grounded in students'

conscious understanding and comprehension of its rules and patterns, the study of grammar rules, and the performance of translations. Reading and the study of grammar rules were of paramount importance in the process of learning French. Writing was considered the ultimate outcome of successful French language study, while speaking was given a secondary role.

In the context of the grammar-translation method, instruction began with the study of grammar rules. In contrast, the text-translation method started with reading a text or literary excerpt, based on which grammatical phenomena were then studied. Translation was used as a means of semanticizing vocabulary.

It is important to note that the comparison of French grammatical constructions with those of the Polish language, rather than with classical languages, was particularly significant. Grammar study was based on conscious understanding rather than mechanical memorization and reproduction of grammatical rules. The primary source of vocabulary was reading texts.

Distinctive features of the implementation of translation methods in French language instruction in Galicia include the teaching of pronunciation at the initial stage and the explanation of the difference between sounds and letters. Additionally, some textbooks included keys to exercises, which at that time was an innovative component of the materials offered for foreign language instruction.

Thus, French language instruction during the second half of the 19th century was grounded in didactic and methodological principles. Students were introduced to the finest examples of literary works. The comparison of French grammatical phenomena with those of the native language is considered a positive aspect. Among the main shortcomings of the methodology of that time, we note that the goal of French language instruction was not the development of speaking skills. The educators of that period were more interested in mastering French from a theoretical perspective.

Certain techniques of translation methods are still employed in French language instruction today: familiarization with the language system and certain aspects of grammar presentation continue to have a place in foreign language teaching. Despite the drawbacks associated with translation methods, it is important to research these methods to enable the application of some of their successful techniques in modern foreign language teaching practices.

Having explored the methods employed before 1890, we now turn our attention to the period following this pivotal year to analyze the evolution of French language teaching methods and their subsequent developments.

Educators of the time insisted that the teaching of modern languages could not follow the same methodology as the teaching of classical languages such as Latin and Ancient Greek. Stefan Kwiatkowski (1932), in his work *Methodology of Teaching Living Languages*, writes, "…modern language structures are formed under different conditions than those of Latin and Ancient Greek, and the psychological element plays a significant role in the formation of living languages. As a result, the logic of teaching living languages must differ from that of teaching classical languages" (Kwiatkowski, 1932, p. 13). According to the author, the differences in teaching classical and modern languages were as follows:

- The study of classical languages does not consider the possibility of communication in them. The perception of classical languages is much narrower – passive, as they are used exclusively for understanding literary works.
- The study of classical languages relies on a certain immutable logic since the structure of classical languages has crystallized and remains unchanged over centuries.
- In the case of modern languages, we strive not only to perceive them passively but also to communicate in them.
- When learning modern languages, we aim to express our thoughts in the same way as our contemporaries, the native speakers of the language. The structure and logic of their expressions are less "fixed" than in the case of Latin or Ancient Greek.

This need for the practical use of foreign languages prompted the shift from translation methods to the direct method of foreign language teaching. Bohdana Labinska (2013) believes that the direct method of language teaching prioritized the practical goal of teaching oral communication, which allowed students to achieve quick, albeit not entirely accurate and somewhat limited, proficiency in a foreign language, particularly enabling them to engage in brief dialogues with foreigners (p. 115).

The new linguistic trend called "Neogrammarianism," which emerged in the 1870s in Germany (Leipzig), significantly influenced the contemporary methodology of foreign language teaching. The main achievement of the Neogrammarians was the rejection of verbal-scholastic methods of research and old views on language in favor of studying the living, spoken language and recognizing the priority of oral speech over written language (Labinska, 2013, p. 116). Neogrammarian scholars reduced the study of language to identifying the relationships between linguistic usage and the speech activity of individuals, asserting that the description of usage itself was the goal of grammar research. The importance of oral speech was emphasized because language cannot exist independently of people; it exists only within individuals. Therefore, any changes in language occur exclusively through the involvement of individuals engaged in the speech process.

Neogrammarians considered it a significant shortcoming of past linguistics that language was studied separately from the people and the real society in which it was used. They viewed language as a part of culture, as both culture in general and language in particular reflect the mental activity of humans (Udovychenko, 1980, p. 64). Previous linguistics was characterized by a lack of attention to the study of speech in general and its technical aspects in particular.

It should be noted that Galician educators only partially supported the Neogrammarian convictions. For example, they did not consider oral speech to be superior to written speech. Analyzing the curricula, plans, and reports, we find that both oral and written speech were equally important in the teaching of French. The idea of completely discarding the native language in the process of foreign language learning was also not fully supported, as the native language was still used by educators to explain theoretical grammar rules, and some translation exercises were employed. On the other hand, during the described period, a significant amount of cultural material was incorporated into French language teaching, with students being

introduced to French customs and culture, literature, and art. Another contribution of Neogrammarianism to foreign language teaching methodology was the recognition of the importance of phonetics, distinguishing sounds from letters, and the introduction of phonetic transcription.

In addition to linguistics, contemporary foreign language teaching methodology was influenced by developments in psychology, including Gestalt psychology, one of the leading trends in Western European psychology, which emerged in the first third of the 20th century in Germany. According to the principles of Gestalt psychology, in the process of perception, the whole cannot be reduced to the sum of its parts, and over this sum of sensory elements, certain higher processes are superimposed (Shynkaruk, 2002, p. 119). From this, it follows that the unit of language learning should not be the word, but the sentence, which represents something whole (a gestalt). It is evident that the concept of Gestalt psychology was utilized in French language teaching in Galicia, as speaking instruction was conducted using whole sentences within the context of conversational topics.

The textbooks of the period under study reflect the uniqueness of the time, which mirrored the transition from translation methods to the implementation and blending of the direct method of language teaching. According to scholar O. Homeniuk (2020), the main goal of the direct method was "to teach speaking, which allowed students to communicate at an early stage of language learning. They would then begin to learn reading and writing. According to the pioneers of this method, students should begin learning a foreign language as children do, that is, by speaking first" (Homeniuk, 2020. p. 125).

A significant theoretical work of the time is Stefan Kwiatkowski's *Dydaktyka i metodyka nauczania języków nowożytnych* (*Didactics and Methodology of Teaching Modern Languages*) (1932), which states that educators in the 1920s used a method for teaching foreign languages known as the "direct," "intuitive," or "natural" method – synonyms for the term "direct method." Furthermore, the educator expressed the view that foreign language instruction in schools should consider the comprehensive and harmonious development of the student, with the primary goal of foreign language education being the ability to express thoughts in oral and written forms and to read literary and scientific works in the language being studied (Kwiatkowski, 1932, p. 21). The author noted that foreign language instruction in secondary schools should be closely linked with the teaching of other subjects to promote the student's overall development (Kwiatkowski, 1932, p. 16).

According to the contemporary educator S. Ciesielska-Borkowska (1930), the direct method should use only the foreign language, without comparing it to another language. The starting point of language instruction should be the word and the grammatical rule. From the very first lessons, linguistic units of the foreign language should be used. Thus, the direct method is initially based on imitation (Ciesielska-Borkowska, 1930, p. 21).

As we can see, educators who taught French during the period under study asserted that the direct method of language teaching posed greater challenges than translation methods (Kwiatkowski, 1932, p. 30). In their view, the use of the native

language ensured that phenomena studied in the foreign language would be explained and understood correctly. In contrast, with the direct method, there was a risk of incorrect interpretation of words and phenomena, leading to the formation of incorrect associations. Students began learning a foreign language at an age when native language skills were already established. Therefore, according to contemporary scholars, the process of creating similar cognitive processes in the foreign language was significantly more complicated. Learning a foreign language should rightly begin when the concepts surrounding the student have already been established in the native language, making acquaintance with the same concepts in the foreign language more conscious. However, this formation will inevitably occur unnaturally, at a faster pace than in the case of the native language, and situations of using the foreign language will be artificially constructed. Therefore, it is necessary to select linguistic material in such a way that incorrect associations between foreign words and concepts in the student's mind are excluded. In other words, the material should be chosen considering the student's level of psychological development and range of interests, as well as the complexity level of the linguistic material. These points are the postulates of the direct method of foreign language teaching. Such an approach to foreign language acquisition at an early age provides a solid foundation for further mastery of abstract concepts and ideas that the student will encounter at a more mature age (Kwiatkowski, 1932, pp. 35–37).

Thus, foreign language instruction using the direct method takes place at four levels:

1. Learning the names of objects, phenomena, and activities that can be observed directly;
2. Mastering linguistic material related to objects and phenomena that are part of everyday life but not in the student's immediate surroundings;
3. Expanding and enriching language based on previously acquired linguistic material;
4. Mastering linguistic material related to distant things and abstract concepts (Kwiatkowski, 1932, p. 28).

Objects, phenomena, and activities constitute the lowest level of educational material learned through the direct method. The names of objects and activities with which the student interacts in daily life should serve as material that motivates the student to study the foreign language. According to Galician scholars, in the initial stages of foreign language learning, emphasis should be placed on two main parts of speech – nouns and verbs (Kwiatkowski, 1932, p. 30). The things within the student's observation and activity radius are the primary material for foreign language study, which will later be expanded and supplemented.

At the same time, the formation of associations is of great importance. Muscle memory plays a significant role in this process. For example, in the act of writing on the board in the classroom, the teacher should simultaneously comment on the actions in the foreign language. Students should imitate the teacher's actions, repeating after them the material – names of objects (nouns) and types of activities (verbs).

Simultaneously, students imitate the teacher's movements, which helps fix the meaning of words and expressions in their memory (Kwiatkowski, 1932, p. 32).

Only after mastering material related to surrounding objects and actions did the instruction move to pictures, scenes, and situations from life that were not directly observable. For this purpose, it was recommended to use drawings depicting scenes from the students' everyday life. Great importance was placed on the cultural aspect of foreign language study, particularly the use of material for description that reflected concepts and realities unique to the people of the country whose language was being studied. It was recommended that the drawings or paintings illustrating the seasons, villages or cities, landscapes, or even train stations be created by artists well-versed in the culture of the nation, who deeply understood the characteristic features of the people. These images were seen as an essential part of the foreign language study material, providing students with an opportunity to familiarize themselves not only with the language but also with the culture of the country.

Contemporary scholars believed that linguistic material initially mastered through direct observation of objects and later through the description of pictures was comprehensive and universal. At the next stage, it could serve as a starting point for further vocabulary enrichment.

Avoiding the native language should become a habit for the student, requiring constant attention and mental effort, which will eventually facilitate communication in the foreign language. During foreign language instruction, the teacher should refrain from using the native language from the very first lessons, replacing it with gestures, facial expressions, and images. Subsequently, it was allowed to use synonyms and antonyms for already known words, and so on.

However, the complete rejection of the native language was not entirely endorsed. For example, contemporary scholars Kwiatkowski (1932, p. 23), Ciesielska-Borkowska (1930, pp. 33–34), and des Loges (1934, p. 2) did not object to the use of the native language in foreign language lessons. This was due to the educators' conviction that the direct method in school education posed far more questions and challenges than translation methods. By using the native language, even as a starting point, one could be sure that foreign language material would be explained and understood correctly. Specifically, S. Kwiatkowski believed that at the higher levels of foreign language instruction, it was appropriate to resort to translating sentences from the native language into the foreign language (Kwiatkowski, 1932, p. 40).

The direct method of foreign language teaching, according to S. Ciesielska-Borkowska (1930), should be based on the following psychological principles:

5. The importance of visualizing words and concepts (in the initial stages of learning, each new expression should be visualized using an object or phenomenon from the student's immediate environment);
6. The effective method of associations (linguistic material is better learned through the creation of associations, with the understanding that the association of the word with the object should be direct, i.e., without using the student's native language);

7. The importance of repetition of previously covered material (previously acquired knowledge serves as a solid foundation for acquiring new knowledge);
8. The complexity of texts and tasks should gradually increase, with each new stage of learning logically continuing the previous one;
9. Consideration of different types of memory and mental abilities of the student (attention should be paid to the type of memory that helps the student best memorize new expressions – auditory, visual, or motor) (Ciesielska-Borkowska, 1930, pp. 40–41).

It is noteworthy that S. Kwiatkowski and S. Ciesielska-Borkovska, educators who published significant theoretical works directly related to the methodology of teaching French in Galicia during the studied period, adhered to the same ideas. For both scholars, the method of associations, through which students mastered the linguistic material of French, and the minimal use of the students' native language in the learning process were important. Additionally, both educators emphasized the importance of gradually increasing the complexity of the material presented to students in the process of learning French.

Analyzing French language instruction, we can assert that during the period of 1890–1939, the main principles of the direct method of foreign language teaching were applied in Galicia. The primary focus was on developing reading, speaking, and writing skills.

Reading practice held a special place in foreign language teaching as it served not only as a goal of instruction but also as an effective means. Reading helped students master grammatical material, which was taught inductively, that is, through reading texts. Through reading, students became familiar with the culture, history, and customs of France, explored samples of French literature, learned about the biographies of the most famous writers and poets, and discovered advancements in science and technology. Based on the texts they read, students practiced self-dictation, retelling the texts, and reciting poetic works. The goal of French language teaching in Galicia during this period was to achieve proficiency in French for everyday communication, enabling students to express their thoughts on various topics. Students were also taught to discuss and analyze literary works, journalistic texts, treatises related to science and technology, and more. Writing skills were developed according to the same principles, with students learning to write summaries of texts, essays, friendly and official letters.

It is important to note that the implementation of the direct method of French language teaching in Galicia had its own characteristics. Primarily, this concerned the reluctance of educators to completely abandon certain theoretical aspects of French language study, particularly the study of language theory. The French language textbooks of the studied period included printed supplements with grammar theory and exercises. There were also instances of using translations of foreign words into the native language. In textbooks from the 1890s to the 1910s, we see that the initial stages of instruction involved mastering pronunciation and grammar rules. However, starting from the 1920s, instruction increasingly focused on learning linguistic material without translation or explanation of certain linguistic phenomena. Vocabulary was often visualized in textbooks through illustrations. Lexical and grammatical material was

learned through creating contexts from which students inferred the meaning of a word or grammatical structure.

The techniques of the direct method of French language teaching were widely used in the process of learning French in Galicia during the years 1890–1939. It is important to emphasize that certain aspects of this method are debatable. For instance, the complete rejection of the native language significantly complicates the explanation of certain concepts and phenomena. The complete abandonment of grammar theory or the exclusive use of the inductive method to learn grammatical phenomena is also questionable. We agree on the undeniable importance of speaking and writing as the primary goals of learning any foreign language. However, it is clearly inappropriate to dismiss the study of theoretical material, which could further contribute to the correct formation of speech.

Conclusions.

In conclusion, the research successfully analyzed the evolution of French language teaching methodologies in Galicia from 1867 to 1939, focusing on the transition from grammar-translation to direct methods. The study demonstrates that while the earlier period was dominated by translation-based approaches emphasizing grammar and textual analysis, the later adoption of the direct method marked a significant shift towards practical language use, particularly in speaking and writing. This methodological evolution was influenced by contemporary linguistic and psychological theories, which emphasized the importance of oral communication and the contextual understanding of language. The research objectives outlined in the introduction were met through a detailed examination of historical curricula, pedagogical works, and educational reports, which collectively illustrate the gradual shift in teaching practices. Ultimately, this study highlights the complex interplay between traditional and innovative methods in shaping the pedagogy of French language instruction in Galicia, thereby contributing to a deeper understanding of historical language teaching practices.

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Викладання французької мови у Галичині (1867–1939): Аналіз навчальних планів, програм та методик

Анотація. *У дослідженні розглянуто еволюцію методик викладання французької мови у Галичині з 1867 по 1939 рік, з особливим акцентом на перехід від граматико-перекладного та текстово-перекладного методів до прямого методу. Використовуючи історико-аналітичний підхід, дослідження ґрунтується на широкому спектрі первинних джерел, включаючи навчальні програми, педагогічні звіти та теоретичні праці сучасних педагогів. Дослідження показує, що на початковому етапі викладання французької мови в Галичині домінували методи, які надавали перевагу систематичному оволодінню граматикою через дедуктивне навчання, де основну роль відігравали читання та переклад текстів. Письмо розглядалося як кінцева мета оволодіння мовою, тоді як усному мовленню часто відводилося другорядне місце. Однак наприкінці XIX століття відбувся значний зсув, під впливом тогочасних лінгвістичних теорій, таких як неограматизм, та психологічних принципів, як-от гештальт-психологія. Ці нові підходи наголошували на важливості усного спілкування, контекстуального розуміння мови та інтеграції культурних знань у викладання мови. Прямий метод, що виник у цей період, мав на меті навчати французької мови у більш практичний та комунікативний спосіб, заохочуючи учнів говорити*

мовою з самого початку та використовувати її в повсякденних ситуаціях. Незважаючи на перехід до прямого методу, дослідження відзначає, що деякі традиційні практики, такі як використання рідної мови для пояснення граматичних понять, продовжували зберігатися. У дослідженні доходимо висновку, що еволюція викладання французької мови в Галичині характеризувалася поступовою, але глибокою трансформацією у напрямі до більш комунікативних і орієнтованих на учня підходів, що заклало основу сучасної методики викладання французької мови в регіоні. Отримані результати сприяють глибшому розумінню історичного розвитку методів викладання мов і вказують на напрямки для подальших досліджень, особливо щодо довгострокових наслідків цих педагогічних змін на сучасні практики викладання мов.

Ключові слова: *методи навчання французької мови; Галичина; граматико-перекладний метод; прямий метод; історія викладання іноземних мов*

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Planning paradigms throughout economic history

Abstract. *Planning has always been an essential part of scientific and practical activities, driven by the need for purposeful development in science, technology and society. The paper focuses on the study of the development of planning in the context of the history of economics and economic thought. The purpose of the paper is to study the formation of planning paradigms throughout economic history as a reflection of the features of the socio-economic processes that dominated from the late 19th century to the early 21st century. To achieve this purpose, general scientific (analysis, synthesis, induction and deduction, generalization of literary sources) and special*

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(historical-retrospective, chronological, historical-typological, historical-systemic) methods were used. The results of the study showed the main driving force of the genesis is a change in the level of environmental stability, the degree of socio-economic processes predictability and the level of uncertainty in their future development. The historical process of the formation of planning paradigms divided into three periods of dominance: I. The dominance of the neoclassical paradigm (from the late 19th century to the 1970s); II. The dominance of the neo-institutional paradigm (from the late 1970s to the late 1980s); III. The dominance of the evolutionary paradigm (from the late 1980s to the early 21st century). The formation of the neoclassical paradigm was due to the development of capitalism in Europe and was based on the assumption of socio-economic processes dynamics predictability. It allowed the use of optimization planning by continuing established trends into the future. The need to consider the current and future conditions of institutions and their impact on the activities of the economic agents (entrepreneurs, companies, states) led to the formation of a neo-institutional planning paradigm. Recognition of the environmental instability led to the formation of an evolutionary planning paradigm based on considering the trends in the changing world and their dynamics, as well as the ability of economic agents to adequately respond (adapt) to them. One of the main factors in the formation of new planning paradigms was the deepening of the gap between planning theory and practice. As a result, it was impossible to obtain reliable long-term forecasts. One of the features of the genesis of planning paradigms is the parallel use, which allows ensuring their development considering the socio-economic processes that have developed.

Keywords: *history of economics; planning; instability; development; socio-economic processes; environment*

Introduction.

Planning arose at the dawn of humanity, as soon as people began to understand their place in the surrounding world. The well-known aphorism "to plan or to be planned for" was relevant at all stages of human development. The need to define and describe future trends in various spheres of human activity determined its importance. So, the planning of transport routes, on the one hand, considered the placement of settlements (cities), and, on the other hand, influenced the prospects for their development (Yang, Han, Zhang, Han & Long, 2023; Berisha, Cotella, Janin Rivolin & Solly, 2021). One of the most important aspects of techniques and technology development was to ensure global sustainable development, which also involved the use of strategic planning technologies (Yadav, A., Pal, Patra, & Yadav, M., 2020; Prokhorova et al., 2024). Technological changes required revising the methodological principles of planning various aspects of the socio-economic development, namely the "digitization of the planning culture" and the introduction of artificial intelligence (Nummi, Staffans & Helenius, 2023). The technical development in society and the emergence of new technologies were impossible without investment and innovation planning (Kravchenko & Kychygin, 2023; Trischler & Li-Ying, 2023).

As P. Healey (2020) noted, the development and tradition of planning remained a "curious case". It required constant efforts to identify and study the interaction of dominant social concepts and the needs of social development and its influence on the conceptual foundations of the planning paradigm to ensure its advantages over disadvantages (Rydin, 2021). Therefore, one of the directions of modern research became a rethinking of the theoretical and practical aspects of planning to meet the modern needs of society and ensure an effective transition to the sixth technological order (Avar & Cive, 2024; Glushchenko, 2021).

Although planning was an essential aspect of social, technical, and technological development, it was most often associated with the economy, and its evolution took place in the context of changing economic concepts. Therefore, the study of planning through economic history made it possible to determine the driving forces of the paradigm changes, the main reasons for their changes, and contributed to increasing the effectiveness of planning as a tool for ensuring purposeful development of both the economy and technology.

Methodology.

The study of the formation of planning paradigms through economic history involved the analysis of various aspects, from the study of the dynamics of the development of socio-economic processes and their predictability to the analysis of the conceptual foundations of planning and the prerequisites of forecasting tools. This determined the complex use of general scientific and special research methods. To study the historical periods of the development of society in the context of its predictability, a historical-retrospective and chronological analysis was conducted. Historical-typological and historical-systemic methods were used to characterize the ideas that dominated in European countries in different historical periods, to analyze their impact on the formation of prerequisites and basic planning hypotheses. To generalize the research of the founders of various economic schools and their critics, general methods of scientific research were used, namely analysis, synthesis, and generalization of literary sources. The methods of induction and deduction were used to study the trend of changing planning paradigms that dominated from the late 19th to the early 21st century. The use of systemic and interdisciplinary approaches made it possible to form a certain idea about the conceptual foundations of planning and forecasting in various historical periods.

Results and Discussion.

The rapidity and radical nature of the changes that have occurred in the social structure of European countries were reflected in the initial assumptions and hypotheses of the established planning paradigms.

Neoclassical planning paradigm. In modern economics, the influence of the neoclassical paradigm (mainstream) was largely preserved. Its foundations were laid out in the late 19th century by W. S. Jevons, K. Menger, M-É-L. Walras. The emergence of neoclassical economic theory was due to the development of capitalism in Europe and the United States. Its main provisions reflected the current conditions of

economic activity of enterprises and a fairly high level of stability in the socio-political life of states in Europe.

This determined the expediency of considering the economy as a system (mechanism) that is in dynamic equilibrium. To maintain such equilibrium, no additional intervention is required. At the same time, each economic agent (entrepreneur, enterprise, state) had the opportunity to use available production factors with the greatest efficiency.

In this case, any economic agent was an integral object, considered as a "black box" in which the transformation of attracted resources into the final product was carried out in accordance with the nature of the production function and the external environment that determined the method of profit maximization as the target function of the existence of the economic system (Hodgson, 1988). The behavior of economic agents was guided by rational preferences, with actions always aimed at maximizing profits based on complete and reliable information, regardless of other economic agents.

The neoclassical approach was based on the assumption that information about the environment (societal development trends, economic system dynamics, achievements of scientific and technological progress) was complete ("perfect"). R. M. Cyert and C. L. Hedrick (1972) noted that the environment determined available resources, manufactured products, the economic agents' behavior and, thus, contributes to the maximization of profits.

Neoclassicists viewed processes in society and the economy as completely deterministic, which allowed them to be viewed as mechanistic. That contributed to the formation of the idea among economic agents that current socio-economic processes would change insignificantly and could be "mechanically" transferred (extended) into the future. That was also associated with the "natural scientific ideal of research, historically inherent in the late 19th century – early 20th century" (Blaug, 1987, p. 13).

The formation of the neoclassical planning paradigm was significantly influenced by the hypothetico-deductive model, which dominated during that period. According to this model, forecasting and planning can only be done effectively if strictly defined "hypotheses" about current and future socio-economic processes in the environment were formed. For such a study, it was also necessary to adopt sufficiently strict restrictive assumptions about the nature of the economic agent and the features of its functioning.

The postulated predetermination of the economic agents' activities and the environment in which they were carried out influenced the approaches used in forecasting and planning. Namely, the possibility of extending already known trends in the development of socio-economic processes into the future enabled to use extrapolation methods. In this case, deviations of actual values from those calculated on the basis of constructed models were considered "obstacles", the size and impact of which could be reduced by taking into account accumulated experience and knowledge about the surrounding world.

The basis of most of the constructions of neoclassical theory, including in planning, was the theory of choice, which allowed an economic agent to choose the

best of all possible outcomes, namely, (i) the criterion for making all decisions was the only one; (ii) the possibilities of receiving and processing information coming from the external environment were unlimited (Cyert & Hedrick, 1972). In this case, when planning, the distribution of available resources could be an optimization task under constraints, which involved finding a conditional extremum (maximum or minimum value) for a certain criterion of the economic agent's efficiency. This enabled the development of an optimization approach to planning.

The implementation of the optimization approach to planning involved solving one of the following problems: (1) minimizing the required volume of financial resources needed to achieve the set goal; (2) maximizing the efficiency of operation with a given volume of own and attracted resources; (3) obtaining an optimal balance between available resources and the expected effect. The emergence of optimization planning and its implementation in the economic agents' activities was the result of a more intensive implementation of mathematical constructions (methods, models) for managing socio-economic processes. During that period, the idea emerged that the level of scientific development was, to some extent, determined by the amount of mathematics used. Then the problem of planning consisted of determining a set of parameters that allowed optimizing the results of the economic agent's activities, taking into account the known limitations of the surrounding world. In the conditions of a stable environment, the development trends of which were understandable to economic agents, the use of the optimization approach allowed for calculating realistic forecasts and making feasible plans.

However, since the early 1950s, increasing instability of the external environment led to the need to apply forecasting as a mandatory component of planning. At the same time, long-term planning and forecasting were based on the assumption of constant and uniform change in the external environment. The consequence of the dominance of the postulate regarding possibility of extrapolating existing trends to the medium and long term was the use of time series analysis and correlation-regression analysis as the main forecasting methods. In conditions of relative stability, the mathematical accuracy of these methods was high enough, which made it possible to develop realistically feasible plans, even in the long term.

In the 1970s, the era of relative stability in the economy ended, which led to a shift in emphasis to the development of alternative forecasting methods. One of the most promising approaches to improve the forecasting of future states was considered to be attempts to apply game theory, which was considered as a generalization of optimization theory for two or more participants in an economic process, provided that their preferences regarding outcomes and restrictions on the set of possible alternatives for each of them were given (Weintraub, 2002). The fundamental difference between game theory and traditional optimization theory was the consideration of existing and possible interaction between participants in the economic process, as well as the possible conflict between them. This difference was reflected in the objective function, which determined the size of the payoff of each player depending on the chosen solution: the payoff of a participant in the economic process depended on the alternatives chosen by both him and others.

The experience of the 1970s and 1980s showed that unpredictable changes in the external environment could seriously disorient the activities of economic agents, since these changes, as a rule, were not trends, but turning points that largely determined the long-term future of corporations. These changes had to be considered as much as possible (Nelson & Winter, 1982).

Based on the above, the following characteristic features of the planning process could be identified from the standpoint of the neoclassical paradigm: (i) the absence of systemic information about the external conditions of the functioning of economic agents; (ii) forecasting was carried out on the basis of the principle that the future was a continuation of the past; (iii) planning was aimed at achieving a state of equilibrium by the economic agent; (iv) the main attention was paid to planning the volumes and structure of resources necessary to maximize profits; (v) the assignment of a strict system of restrictions constructing an optimization planning model.

However, the optimization approach to planning had significant shortcomings: ignoring tasks that could not be described quantitatively; the effectiveness of planning and forecasting largely depended on the completeness, accuracy and degree of correspondence of the constructed model to the actually existing system; the impossibility of constructing an optimization model in which it was possible to describe all aspects of functioning and existing relationships in a complex system. The consequence of this was the planning of only those "rational" parts of the system for which it was possible to build optimization models; the degree of plan fulfillment depended on the desire or unwillingness of workers to act in accordance with the planned goals; the system of control over the fulfillment of the plan was aimed exclusively at detecting and correcting errors, the possibility of which was foreseen in advance.

The optimization approach to planning did not allow for the constant and progressive increase in the rate of change in the environment. In most cases, it was impossible to carry out truly optimal calculations of planned indicators, since it was very difficult, and in some cases impossible, to identify and formalize objective criteria for planning and management. In addition, planning process based on a rational approach "has neither subject nor object; it ignores the nature of the agents implementing the planning and is indifferent to the object of their efforts" (Beauregard, 1987, p. 367). This approach to planning was only acceptable for short-term planning, since developing an optimal comprehensive strategic plan was currently impossible (Ackoff, 1969).

In addition to the identified shortcomings of the optimization approach to planning, it should be noted that changes in the conditions of economic agents' functioning had led to the neoclassical model becoming incapable of adequately describing real processes. This was due to the fact that it was based on unreasonable and unrealistic hypotheses, which negatively affected the quality of model descriptions of economic agents and their relationships with the surrounding world (Nelson & Winter, 1982).

The main criticism stemmed from the assumption of economic agents' rational behavior capable of collecting and processing all available information without any

costs. Even if the models included parameters characterizing the uncertainty of the surrounding world and the expectations of economic agents, the assumption remained that all of them could accurately calculate possible states and, as a result, all expectations would be fulfilled automatically. At the same time, the possibility of the influence of factors that might force them to make an irrational choice was not considered. The result of this was that large corporations that were monopolists in industry markets for the sale of products (services) gradually moved away from the principle of profit maximization as a criterion for the efficiency of functioning (Williamson, 1985).

Thus, the standard assumptions of conditional maximization were no longer sufficient to produce most forecasts (Samuelson, 1991), and therefore plans developed on their basis were not realistic. At the same time, it remained true that in planning, forecasting should not be treated as "some kind of technical exercise". Naive extrapolation or adjusting trends to past facts and data is worthless. This is due to the fact that the future does not necessarily recreate past pictures, which would be very convenient for planning (Brealey, Myers, & Allen, 2019).

The equilibrium hypothesis of the market system also caused fair criticism. R. R. Nelson and S. G. Winter (1982) noted that economic systems were not in a normal state of equilibrium, and economic agents did not act as perfect optimizers. All levels of the economic system were characterized by diversity and heterogeneity, which meant that analysis should focus on the study of changes and dynamics of socio-economic processes, and not on the study of equilibrium points.

R. H. Coase (1990) identified key points in the functioning of corporations that did not fit into the framework of the neoclassical paradigm: (i) the devaluation of the experience of managers, caused by the emergence of fundamentally new tasks; (ii) the complication of management problems caused by the increase in the multiplicity of tasks in connection with the expansion of the geographical boundaries of markets; (iii) the emergence and widening of the gap between the complexity and novelty of tasks, on one side, and the existing management skills gained in the past, on the other side; (iv) the increase in the likelihood of strategic surprises, caused by the increase in the frequency of the emergence of new tasks.

Since the early 1960s, the discrepancy between theoretical models and the practice of forecasting and planning had continued to increase. Thus, well-structured theories of forecasting and planning had been developed, allowing one to obtain supposedly real forecast estimates and planned indicators, which in fact had no relation to reality. This led to economic planning being viewed as an eclectic field associated with neoclassical theory (Friedmann, 1987, p. 39). As F. Archibugi (2007) noted, "the planning process must become more consistent and plans more consistent with the external environment, that is, more rational, at the same time more feasible and become a more sophisticated management tool. Rationality must be identified with reality" (p. 4). At the same time, plans had not only to reflect the existing reality, but also influence it through management and modification. This led to the transition to a new planning paradigm.

Neo-institutional planning paradigm. The formation and development of the neo-institutional paradigm was determined by a set of problems that were maturing in science, namely (i) insufficient attention of neoclassical theory to the environment in which economic agents exist and operate; (ii) a decrease in the predictability of changes in the surrounding world; (iii) an understanding that the rules and traditions developed in society (social institutions) have a significant influence and must be considered in planning. Its foundations were set out in R. Coase's paper "The Nature of the Firm", published in 1937. However, interest in this theory appeared only towards the end of the 1970s. Since this school belongs to the neoclassical direction, its development was conditioned by the increasing gap between the methodology and practice of managing the economic agents' activities in general and planning in particular.

Neo-institutionalism included an analysis of the role of institutions and their influence on the economic agents' activities based on the principles of rationality and methodological individualism. The object of institutional theory is institutions, not human interactions in a space with restrictions set by institutions.

The neo-institutional paradigm is based on the following assumptions:

1) institutions (fixed, interconnected norms that were based on collectively shared values inherent in a particular society or social group, and were generalized as ways of acting, thinking, and feeling) influence the performance of economic agents and the dynamics of the economy as a whole. D. C. North (2003) noted that "institutional change can result from change in the formal rules, the informal norms, or the enforcement of either of these" (p. 12). He classified "constitutions and laws" as formal rules, and "norms of behavior, conventions, and codes of conduct" as informal rules (p. 11);

2) recognition of the limited rationality of economic agents. The most important characteristics of economic agents, as noted by O. E. Williamson (1985), were limited rationality and opportunism, while the pursuit for rationality meant an orientation toward the economical use of limited resources;

3) denial of the principle of maximization as a criterion for the effectiveness of activity: economic agents in their activities were guided to a greater extent not by maximization of the target function, but by acquired rules of behavior and social norms – institutions that determined specific methods for achieving these individual goals;

4) the doctrine of transaction costs – the implementation of any market transactions, including the acquisition of information, was associated with certain costs, that was, the expenditure of resources (money, time, labor, etc.) for planning, adaptation and control over the fulfillment of obligations assumed by individuals in the process of alienation and appropriation of property rights and freedoms accepted in society.

In the early 1990s, the first attempts were made to develop planning theory considering the basic provisions of neo-institutional theory. However, they proved unsuccessful. This was explained by the fact that institutions and their impact on the economic agents' activities were most often described by qualitative parameters, which were very difficult to transform into quantitative ones to be considered in forecasting and planning. Additional difficulties arose from the subjectivity of the perception of the surrounding world by economic agents and the incorrect understanding of ongoing socio-

economic processes, as well as the influence of formal and informal rules and restrictions on them. That significantly complicated economic-mathematical modeling and reduced the quality of forecast and planning models. As N. Verma (2007) noted, "for planning this task is more than incomprehensible" (p. 33).

Neo-institutionalism was manifested in satisfaction planning. In this approach, the main criterion for planning efficiency was the satisfaction of the economic agents' needs. At the same time, efficiency was no longer understood as maximizing profit from the use of limited resources.

The characteristic features of planning from the standpoint of the satisfaction approach were:

1) the development of plans should begin with the definition of goals and objectives that are considered both feasible and desirable. This allows the planning process to find a compromise between the capabilities of the economic agent and the restrictive conditions that existing institutions impose on its activities;

2) the revision of planning goals and objectives is carried out only if they were not feasible;

3) only one feasible and acceptable plan was developed, even if it was not the optimal one;

4) the main requirement for the plans being developed was their feasibility, which was interpreted as minimizing the number and extent of possible deviations from the existing policy and practice of the functioning of the economic agent;

5) the focus of planning was more on recognizing past shortcomings caused by existing policies than on analyzing the exploitation of future opportunities. Identified shortcomings were considered an unaccounted-for institutional influence. This orientation could be explained by the desire of economic agents to minimize transaction costs in the future.

One of the significant disadvantages of satisfaction planning was the attempt to transfer into the future knowledge about existing institutions and their influence on the activities of economic agents through forecasts and plans. D. C. North (2003) correctly noted that "the institutional constraints accumulate through time, and the culture of a society is a cumulative structure of rules, norms, and beliefs that we inherit from the past, that shape our present, and that influence our future" (p. 9). However, they were not predetermined, which increased the complexity of forecasting and planning. Changes in institutions could also be perceived by economic agents either as potential threats to their activities or as new development opportunities. That significantly reduced the feasibility of using the satisfaction approach for long-term planning in conditions of a highly dynamic external environment. Nevertheless, in the context of a transformational economy, taking into account possible changes in forecasting and planning was a necessary condition for obtaining reliable estimates of the future states of the research object.

Furthermore, a significant disadvantage of satisfaction planning was the use of point (single) forecasts, which was justified only in conditions of a deterministic environment. In conditions of unpredictable changes in the surrounding world, that might lead to the

development of unrealistic plans and reduce the manageability of the economic agents' activities.

Evolutionary planning paradigm. The emergence and development of the evolutionary approach was a consequence of the desire of modern scientists to study "poorly organized" (diffuse) systems (Nalimov, 1971). It developed within the framework of the economic mainstream and was called the theory of evolutionary changes in systems.

The evolutionary approach was a relatively new direction in economic science, the origins of which was laid by the works of J. A. Schumpeter. However, the allocation of evolutionary ideas into a separate direction of economic science was associated with the appearance of the publication of R. R. Nelson and S. G. Winter "Evolutionary Theory of Economic Change" in 1982.

Evolutionary economics viewed all processes in the surrounding world as open, spontaneous, and irreversible, undergoing constant development and resulting in quantitative and qualitative changes. They had a constant impact on the activities of economic agents, who had to respond to the changes that occur by adapting to them.

The fundamental assumptions that form the basis of the evolutionary paradigm were the following:

1) heterogeneity of economic agents: evolutionary economics accepted their differences within the accepted framework of established thinking and rejects the "unification" underlying neoclassical theory. It was accepted that the behavioral differences between economic agents were so significant that the use of the statistical average method did not allow not only to conduct a correct analysis of functioning, but also to understand the mechanism of occurrence of changes;

2) variability, selection and conservation: most evolutionary models were based on the Darwinian theory of variability and natural selection. The possibility of constant and varied changes in the economy determined the selection of economic agents, taking into account the limited scarce resources. Based on the existing diversity, a "viable population" of economic agents was determined and, consequently, their average characteristics;

3) uncertainty: "true" changes in the external environment were always accompanied by uncertainty, which could not be described in probabilistic terms. This uncertainty meant that the future was "open" to qualitative changes and could not be predicted through the past and current states of economic agents;

4) entrepreneurship: economic agents were motivated to act creatively. When faced with uncertainty, they had to seek new ways to solve emerging problems. Economic activity was viewed as an open learning process that involved a sequence of entrepreneurial hypotheses, experiments, and refutations of ineffective solutions to emerging "problems" of the external environment;

5) nonequilibrium dynamics: evolutionary models rejected equilibrium as a desired state and explored the behavior of systems far from equilibrium, particularly with respect to self-organization.

In evolutionary theory, an economic agent was considered as one of many similar objects that could be considered ("likened") as a biological population. In that case, the

behavior of a specific economic agent was determined by two aspects (Kleyner, Tambovtsev, & Kachalov, 1997): (i) relationships between members of a given population; (ii) internal characteristics of the economic agent, which included routines, that was, "normal and predictable patterns of behavior" in response to internal or external influences. According to "evolutionists", it was routines that influenced the decision-making of an economic agent, and not the desire to maximize profit under any conditions. At the same time, routines were not established once and for all, but were changed in accordance with the external environment.

Recognition of the variability of the surrounding world and the economic agents operating in it necessitated the formation of a new approach to planning, namely, an evolutionary paradigm, which was based on:

(1) a systemic representation of an economic agent as a dual object: on the one hand, it is a member of a "population" and its activities reflected all the consequences of the evolution of this community, and, on the other hand, it had its own routines, which were reflected in the features of functioning, decision-making algorithms and features of reaction to changes in the surrounding world (external environment);

(2) recognition of the "instability" of the conditions for implementing the plans of economic agents, the consequence of which was the need to take into account both in production plans and in plans the possibility of maneuvering to achieve the set goals of existence (development).

According to the evolutionary theory, the activity of an economic agent in a changing environment is effective (successful) if it has the ability to adjust (adapt) to the changes that arise (Ackoff, 1969). Despite the fact that changes in the surrounding world were spontaneous, the adaptation of economic agents to them had to be purposeful and controlled (Innes & Booher, 1999). That contributed to the formation of the evolutionary planning paradigm or, in other words, adaptive planning.

Adaptive planning was based on three main principles: (i) the main benefit lay in the planning process itself, not in having plans already made; (ii) the modern need for planning was generated mainly by the lack of effective management and control, so the goal of planning should be to create a system that could minimize the need for retrospective planning and preserve forward planning aimed at creating the desired future; (iii) each type of knowledge about the future (certainty, uncertainty and ignorance) required its own way of planning: by commitments, options or reactions.

Adaptive planning was based on these assumptions was the definition of the development goals of an economic agent in a surrounding world, the justification of ways to achieve them considering the available volumes of necessary resources. In this case, the possibility of (1) the emergence of factors that destabilized the economic agent’s activity, as well as (2) the reduction of their negative impact should be taken into account. When planning, a comprehensive assessment of an economic agent’s resources, directions for their most effective use, as well as available sources of their replenishment should be carried out. Then, as a result of adaptive planning, a planned development trajectory of an economic agent might be formed with an assessment of its sustainability in the surrounding world, with the identification of "narrow" and "wide" places of its implementation to control the effectiveness of adaptation to the current conditions.

As noted by R. L. Ackoff (1969), the use of adaptive planning allowed economic agents to respond flexibly and promptly to changes in the external environment and to adapt to them effectively by taking these changes into account in operational and strategic planning, as well as in budgeting.

At that time, adaptive forecasting methods were actively used. They were based on maintaining the inertia of the economic agent's development, but taking into account the factor of "obsolescence" of data. The advantage of adaptive forecasting models was the ability to quickly change (adapt) its structure and parameters when trends changed, as well as any fluctuations in which a pattern could be traced. That allowed us to consider only those trends that had not yet become outdated and still had an impact on the economic agent's activities, which was achieved by assigning different weighting coefficients depending on the distance of the indicators from the moment of forecasting.

Within the evolutionary paradigm, the most widely used models were those based on the exponential smoothing procedure, since they allowed for constructing adaptive forecast models in conditions where there was no reliable information about the nature of changes in the dynamic characteristics of processes. The lack of information led to the use of the "only reasonable" assumption in such a situation about the slow drift of these characteristics. However, G. Midgley (2000) noted that the limitations of using adaptive forecasting methods had not yet been studied.

By means of an adaptive planning system it was possible to carry out passive (changes in the behavior of the economic agent) and, if possible, active (the economic agent itself changes the external environment) adaptation to ensure its more efficient functioning and development in the present or future.

When implementing the adaptive approach, the following initial planning principles were adopted:

1) economic agents did not have a single criterion for the optimality of decisions made. That criterion was strictly individual and reflected not only individual preferences, but also the historical experience of functioning;

2) optimality of planning did not necessarily correspond to the principle of maximizing the efficiency of activities. In addition, efficiency was not always synonymous with adaptability to changes in the external environment;

3) economic agents were considered as dynamically stable complex systems, subject to strength tests by random impacts of environmental factors, therefore the efficiency criterion was dynamic, changing from period to period;

4) uncertainty was an uncontrolled variable;

5) planning considered future scenarios while being informed by past and present conditions;

6) in forecast models of the economic agents' activities, the potential for variability of all forecast parameters had to be taken into account: goals, indicators, criteria, principles, etc.

However, adaptive planning had significant shortcomings that negatively affect its effectiveness. Firstly, the evolutionary planning paradigm could be applied only if changes in the surrounding world and the economic agents' activities were predictable. Otherwise, forecasts and plans were unrealistic. Secondly, to date there is no developed

methodology that allow for effective planning (really implemented plans) in current conditions. Thirdly, adaptive planning does not take into account the structural components of the surrounding world, their dynamics nor their impact on the economic agents' activities.

The conducted research showed that during the analyzed period there was no fundamental change in planning paradigms, and the driving force behind their development was the increasing discrepancy between theoretical provisions and the needs of planning practice (Fig. 1). Thus, at the first stage of a new planning paradigm's formation, there was maximum correspondence between theory and practice in terms of the main idea, the orientation of planning work, and the results.

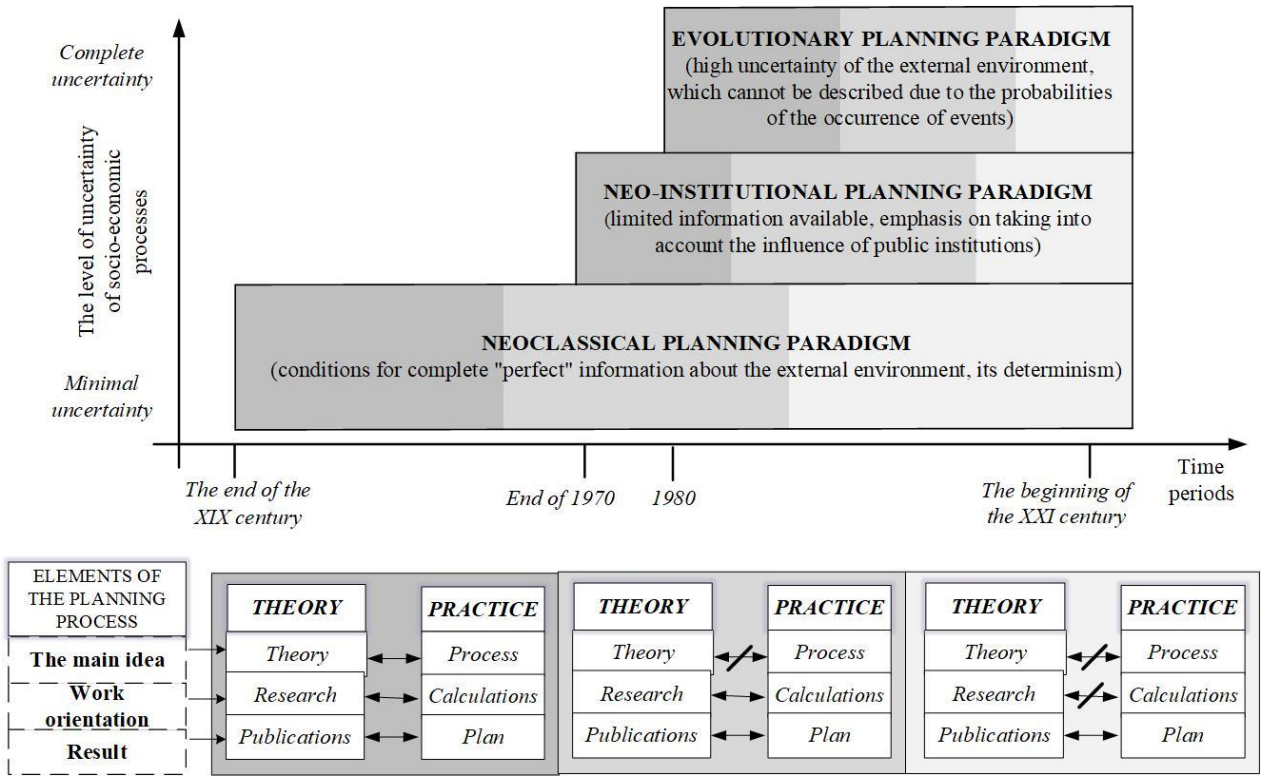

Figure 1. Change of planning paradigms from the late 19th century to the early 21st century (Own elaboration).

Changes in the surrounding world, a decrease in the predictability of the socio-economic processes' development, and an increase in the complexity of their influence on the economic agents' activities primarily led to a gradual increase in the discrepancy between the basic idea of the paradigm, the orientation of planning work and, as a consequence, the results of planning.

Conclusions.

As a result of the research, new information about the formation of planning paradigms through the economic history of the end of the 19th – the early 21st centuries obtained. It allowed us to characterize the planning paradigms' genesis as a reflection of the socio-economic processes' features that dominated during the analyzed period.

1. The analysis of the initial prerequisites and conditions for the formation of planning paradigms allowed to identify the main driving force behind their change in the degree of stability and predictability of socio-economic processes. The growing uncertainty in the surrounding world formed a significant gap between the theory and practice of planning, which reduced its effectiveness.

2. Summarizing the formation of planning paradigms throughout economic history from the end of the 19th century to the early of the 21st century, three periods distinguished: I. Dominance of the neoclassical paradigm (from the late 19th century to the 1970s); II. Dominance of the neo-institutional paradigm (from the late 1970s to the late 1980s); III. Dominance of the evolutionary paradigm (from the late the 1980s to the early 21st century). The neoclassical planning paradigm was based on the assumptions of high stability and predictability of socio-economic processes, which allowed economic agents to act rationally and carry out optimization planning by extending past trends into the future. The neo-institutional planning paradigm was based on considering the influence of societal institutions and their impact on activities, which allowed for the development of plans aimed at achieving efficiency that met the needs of economic agents. The evolutionary planning paradigm was based on considering the variability of the surrounding world, understanding the impossibility of predicting and describing quantitative and qualitative changes through past events and the ability of an economic agent to adapt to these changes.

3. The change of paradigms did not involve abandoning the previous one; instead, it became the basis for the next, taking into account changes in socio-economic processes and their predictability. The feature of the planning paradigms' genesis was its parallel use.

The issue of the economic paradigms' development is complex and multifaceted, which requires further thorough research. Thus, the growing unpredictability of the external environment dynamics, the formation of new trends (shifting the emphasis on client-oriented activities, the growing importance of external collaboration, etc.) actualized the need for research into its impact on the conceptual foundations and tools of planning and forecasting. Separate research can also be devoted to the study of the impact of technological progress's, in particular information technologies, on the development of planning theories and forecasting tools.

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Парадигми планування через економічну історію

Анотація. *Планування було, є і буде найважливішою складовою наукової та практичної діяльності людей, що пов'язано з необхідністю здійснення цілеспрямованого розвитку науки, техніки, суспільства. Стаття присвячена дослідженню розвитку планування в контексті історії економіки та економічної думки. Метою статті є дослідження формування парадигм планування протягом економічної історії як відображення особливостей соціально-економічних процесів, що домінували з кінця XIX століття та до початку XXI століття. Для досягнення поставленої мети використовувалися загально наукові (аналіз, синтез, індукція та дедукція, узагальнення літературних) і спеціальні (історико-ретроспективний, хронологічний, історико-типологічний, історико-системний методи) методи. Результати дослідження показали, що основною рушійною силою генезису є зміна ступеня передбачуваності соціально-економічних процесів та рівня невизначеності їх майбутнього розвитку. Історичний процес формування парадигм планування поділяється на три періоди домінування: I. Неокласичної парадигми (з кінця XIX ст. до 1970-х років); II. Неінституційна парадигма ((з кінця 1970-х до кінця 1980-х років); III. Еволюційної парадигми (з кінця 1980-х років до початку XXI ст.). Формування неокласичної парадигми було обумовлено розвитком капіталізму в Європі та засноване на припущенні про передбачуваність динаміки соціально-економічних процесів. Це дозволяло здійснювати оптимізаційне планування шляхом продовження у майбутнє тенденцій, які склалися у минулому. Необхідність розгляду поточного та майбутнього стану інституцій та їх впливу на діяльність економічних агентів (підприємців, компаній, держави) обумовила формування неоінституційної парадигми планування. Визнання нестабільності середовища привело до формування еволюційної парадигми планування, заснованої на врахуванні тенденцій у навколишньому середовищі, що змінюється, та їх динаміки, а також можливості економічних агентів адекватно реагувати (адаптуватися) на них. Одним з основних факторів формування нових парадигм планування стало*

поглиблення розриву між теорією і практикою планування, наслідком чого була неможливість отримання достовірних перспективних прогнозів при використанні загально вживаного інструментарію прогнозування. Однією з особливостей формування парадигм планування є паралельне використання, що дозволяє забезпечити їх розвиток з урахуванням соціально-економічних процесів, що склалися.

Ключові слова: *історія економіки; планування; нестабільність; розвиток; соціально-економічні процеси; середовище*

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Ukrainian scientists at the Tselinograd State Medical Institute: Contribution to education and science (1960s)

Abstract. *The article examines the work, scientific achievements, and contribution of Doctor of Medical Sciences, Professor Viktor Rafailovich Faitelberg-Blank and Candidate of Medical Sciences, Associate Professor Maria Vasilievna Kropelnitskaya to the development of the Tselinograd State Medical Institute in the 1960s. Authors used the methods of microhistory and comparative historical analysis to achieve the goal of the study, which made it possible to comprehensively reveal the activities of scientists and organizers of medical education V. R. Faitelberg-Blank and M. V. Kropelnitskaya in the Virgin Land. The authors used archival funds and documents, and brief historiographical reviews during the research. For the first time, a set of sources have been introduced into scientific circulation that allow a new look and an objective assessment of the activities of Ukrainian scientists at the Tselinograd Medical Institute. Based on documentary materials from the State Archives of Astana, information from the surviving personal files of V. R. Faitelberg-Blank and M. V. Kropelnitskaya, the main stages of their formation as scientists and teachers in the territory of Ukraine, as well as the reasons for their appearance in Kazakhstan to*

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work at the medical institute have been specified. The activities of V. R. Faitelberg-Blank as the founder of the Department of Pathological Physiology contributed to forming a scientific school that received recognition in Kazakhstan. Also he was engaged in the general development of the problems of "physiology and pathology of digestion". Despite the short time of V. R. Faitelberg-Blank's work at the institute (1965–1967), he was one of the first scientists at the university who contributed to instilling in his colleagues' scientific skills of experimental work with animals. The article focuses on the fact that the scientist's many years of experience led to the development of long-term scientific interests of the department in the study of functional and somatic muscles and the gastrointestinal tract under static load and exposure to high-frequency physical agents. V. R. Faitelberg-Blank laid the traditions of teaching students, which has become the foundation for the training of qualified medical personnel in Kazakhstan. The authors have proved the enormous role of M. V. Kropelnitskaya in the formation of the Department of Internal Diseases Propaedeutics, which received recognition as a scientific school engaged in the study of specific methods of treating patients with pathologies of internal organs. M. V. Kropelnitskaya paid students great attention to the study of many physiological processes in norm and pathology. For the first time at the university, she accompanied theoretical material with a demonstration of patients during classes and gave relevant clinical examples. In conclusion, a resume has been made about the enormous contribution of the scientific and pedagogical heritage of V. R. Faitelberg-Blank and M. V. Kropelnitskaya to the development of medical education in virgin Kazakhstan.

Keywords: *virgin Kazakhstan; Ukraine; scientists; V. R. Faitelberg-Blank; M. V. Kropelnitskaya; medical education*

Introduction.

In the 1950s and 1960s, northern Kazakhstan became a place for the development of virgin and fallow lands. Future virgin land pioneers began to come to the region from all the republics of the former Soviet Union. The concentration of a great number of people on virgin lands gave rise to many problems, among which the most important were environmental, socio-economic, and, of course, problems related to the health of the population (Balykova et al., 2023; Kozina et al., 2023). The country's leaders saw the fastest solution to these problems in opening a higher medical educational institution that trained general practitioners.

Speaking about the emergence and development of medical education in the Virgin Lands Territory in Kazakhstan (since 1960 it included the North Kazakhstan Region, Kokchetav Region, Kostanay Region, Pavlodar Region; since 1961 – Tselinograd Region), first of all, it is worth noting that in the 1960s there were no medical educational centers in the region. In the remaining regions of the Kazakh Soviet Socialist Republic (KazSSR), by that time, four large scientific and educational institutions in the medical field were already successfully operating: in 1931, the Medical Institute was founded in Alma-Ata, in 1950 – the Karaganda Institute, in 1953 – the Semipalatinsk Institute, and in 1957 – the Aktobe Institute. In the Virgin Islands, medical education began to emerge only in the 1960s.

In 1964, as part of the implementation of the resolution of the Central Committee of the Communist Party of Kazakhstan and the Council of Ministers of the Kazakh SSR dated October 26, No. 729 (by the protocol decision of the Presidium of the Council of Ministers of the USSR dated July 31, 1964, protocol No. 28) and to expand the training of medical personnel, the Tselinograd State Medical Institute (TSMI, now "Astana Medical University") was organized with a plan to admit 300 students in the first year and 100 in the second year in the specialty "General Medicine" in the 1964/1965 academic year, subordinated to the Ministry of Health of the Kazakh SSR (State Archive of Astana city. Fund 215, Inventory 1, Case 7, Sheet 1). In the order of the Minister of Health of the Kazakh SSR N. Senkov, the Department of Personnel and Educational Institutions was charged with the responsibility of "staffing the Tselinograd Medical Institute with qualified professors and teaching staff of the 1st year department and ensuring the start of academic classes at the institute by November 20, 1964" (State Archive of Astana city. Fund 215, Inventory 1, Case 7, Sheet 62).

A notable feature of this important historical event was that in the first year of the institute's work, specialists from other universities of the republic were invited to fill the positions of almost the entire faculty of the opening university. Thus, in the order of the Minister of Health of the Kazakh SSR No. 1452 of October 28, 1964, the rectors of the Alma-Ata and Karaganda Medical Institutes were obliged to provide practical assistance to the Tselinograd State Medical Institute in staffing with professors and teachers (State Archive of Astana city. Fund 215, Inventory 1, Case 7, Sheet 92). Already on November 4, 1964, the first group of teachers and employees arrived from Alma-Ata: S. D. Poletaev (rector, associate professor), I. P. Serdyuk (dean, head of the foreign language department), P. A. Pak, G. S. Morenko, S. S. Likhodiy, E. Tursunov, Rakhmatullina, V. V. Tuzovskaya (head of the physics department), V. A. Vdovtseva (State Archive of Astana city. Fund 215, Inventory 1, Case 2, Sheet 57). An admissions committee was organized to accept applicants to the institute. As planned, in the year of its opening, the institute accepted 300 students for the first year (State Archive of Astana city. Fund 215, Inventory 1, Case 7, Sheets 1–10).

The first departments to start functioning at the institute were the departments of foreign language, Latin, physics, history of the CPSU, and anatomy (Balykova et al., 2023). At the same time, they began accepting applications from students who transferred from other medical universities to the second year of the institute. On February 8, the second year, consisting of 130 people, began their studies (State Archive of Astana city. Fund 215, Inventory 1, Case 2, Sheet 58). If the first year, according to the curriculum, studied mainly general education disciplines, then second-year students had already begun to master medical subjects. In connection with the start of classes in the second year, the following departments were organized: histology (Associate Professor F.S. Balakin), normal physiology (Associate Professor R. D. Kolesinskaya), philosophy (Candidate of Law N. S. Gagarin), microbiology (Candidate of Medical Sciences V. A. Fainshmidt), biochemistry (Associate Professor V. K. Zakharova) (State Archive of Astana city. Fund 215, Inventory 1, Case 15, Sheet 6). By September 1, 1965, to ensure a full-fledged educational process, it was

planned to expand the work of the third-year departments: pathological physiology, pathological anatomy, topographic anatomy and operative surgery, pharmacology, general surgery, and propaedeutics of internal diseases (State Archive of Astana city. Fund 215, Inventory 1, Case 1, Sheet 17).

The first classes began not on November 15, as prescribed in the Resolution of the Central Committee of the CPC and the CM of the Kazakh SSR, but on December 25, 1964. The postponement of the start of classes was influenced by several reasons: a shortage of classrooms, medical equipment, inventory, reagents, and much more, but most importantly – a shortage of teaching staff with an academic degree.

Since the Virgin Lands Campaign was one of the areas of the "general line of the party", its practical implementation was of great importance for the country. The experience of the first year of the institute's work showed that it was difficult to resolve the personnel "hunger" and other current issues by the efforts of the Kazakh Republic. Therefore, "to improve the quality of training doctors, expand exchange and communication between the republics in the field of training health care personnel ..., by the order of the Minister of Health of the USSR No. 744 dated December 20, 1965, the Tselinograd State Medical Institute was transferred from the health care of the Kazakh SSR to the direct subordination of the Ministry of Health of the USSR" (State Archive of Astana city. Fund 215, Inventory 1, Case 1, Sheet 1). The subordination of the Tselinograd State Medical Institute to the USSR Ministry of Health led to the expansion of the geography of the search for candidates for the positions of teachers at the institute.

In this regard, the rector of the institute, S. D. Poletaev launched an energetic effort to attract scientists from the country's central universities to the institute. It should be noted that the problem of finding highly qualified personnel in the first years of the university's work was permanent and required a constant search for a solution to the problem. As we wrote above, the departments organized in the first year of the institute's work were not fully staffed with professors and teachers. Thus, in the explanatory note to the annual accounting report for 1964, it was noted that "the estimate provided for staffing the teaching staff by 37 units only 26 were staffed. The positions of heads of departments were mainly understaffed due to the lack of specialists" (State Archive of Astana city. Fund 215, Inventory 1, Case 9, Sheet 12). Thus, the personnel problem, despite the actions taken by the rector of the university, was not resolved. It is no coincidence that in the summer of 1965, the university administration announced a competition to fill vacant positions of heads of departments, inviting leading specialists from Ukraine, Russia, and Belarus, who were to provide the educational process for the third year.

After the competition in the summer of 1965, the following third-year departments were organized: pathological anatomy (Associate Professor B. M. Shapiro), pharmacology (Associate Professor L. S. Grebneva), pathological physiology (Candidate of Medical Sciences V. R. Faitelberg-Blank), propaedeutics of internal diseases (Candidate of Medical Sciences M. V. Kropelnitskaya), general surgery (Candidate of Medical Sciences V. M. Udod), operative surgery (Associate

Professor V. M. Klebanov) (State Archive of Astana city. Fund 215, Inventory 1, Case 15, Sheet 9).

Among the galaxy of famous teachers of the Tselinograd State Medical Institute who arrived in those years from Ukraine are highly qualified medical personnel who made an enormous contribution to the formation and development of this institute, Kazakhstani science, and education: Head of the Department of Pathological Physiology V. R. Faitelberg-Blank, Head of the Department of Propaedeutics of Internal Diseases M. V. Kropelnitskaya, Vice-Rector for Research N. M. Khomenko, head of the forensic medicine department E. I. Zaitseva and others. In 1965, 15 teachers with academic degrees arrived from Ukraine alone (State Archive of Astana city. Fund 215, Inventory 1, Case 2, Sheet 117).

The importance and role of the Tselinograd State Medical Institute in the current state of medical education in Kazakhstan is challenging to overestimate. It is enough to note that along with the training of professional medical staff for healthcare entities of the republic, the medical institute has become a place not only for the concentration of high-level specialists but also a forge of highly qualified scientific and pedagogical personnel who have made a significant contribution to the creation and development of Kazakhstan's healthcare and education.

Through the efforts of the teaching staff of the institute and its management, the Tselinograd State Medical Institute eventually turned into the largest medical higher educational institution in Kazakhstan, where the training of medical personnel in the 1960s was carried out in the specialty of “General Medicine”, which was in demand not only in the Virgin Land of the republic but also in all sectors of healthcare in the Kazakh SSR.

In this regard, we believe it is necessary to dwell in more detail in the article on the period associated with the organization of the first departments of the clinical and therapeutic profile – pathological physiology and the department of propaedeutics of internal diseases, the first heads of which were Ukrainian scientists and teachers Viktor Rafailovich Faitelberg-Blank and Maria Vasilievna Kropelnitskaya, respectively. Thus, the purpose of the article is to study the contribution of Ukrainian scientists to the establishment of the Tselinograd State Medical Institute in the 1960s based on documentary materials from the state archive of the city of Astana.

Discussion.

The historiography of the history of the formation and development of medical education is quite extensive and covers a wide range of issues, covering both the subject matter of the medical school itself and the problems of medicine and health care organizations. In their works, researchers undertake conceptual attempts to analyze not only the problems of the history of medicine and health care in different geographic regions, but also general and specific factors that influenced the emergence and development of medical educational organizations (Kamyshnikov, 2022; Sokolova & Tkach, 2022; Gubergrits et al., 2023; Isaeva et al., 2023; Kamyshnikov, 2023; Kharitonova & Grigoriev, 2023; Rakhimkulov et al., 2023; Nikolaeva & Murtazina, 2024; Stochik, 2024).

The first historical and journalistic works about the Tselinograd State Medical Institute appeared in the pages of periodicals in the 1960s and 1970s (Dobrov, 1969; Lempel, 1972; Shendrik, 1972). At the same time during these years, interest began to grow in Kazakhstani historiography in the scientific and pedagogical activities of scientists and teachers who stood at the origins of medical education not only in the Virgin Lands, but also in other regions of the republic, and who made a significant contribution to the development of higher medical education (Shitikov, 1969; Rozhitsyn, 1972).

In Soviet historiography, it is necessary to highlight the works that revealed the systemic achievements and prospects for the development of Kazakhstan's healthcare, including medical educational institutions (Sharmanov, 1980; Aliyev, 1982). In particular, in an article by the Minister of Health of the Kazakh SSR, Professor T. Sh. Sharmanov, it was noted that "the truly golden fund of the republic is the trained medical personnel" (Sharmanov, p. 11).

In recent years, studies have appeared in domestic historiography that reflect the activities of scientists and teachers of medical universities in Kazakhstan, who have had a significant impact on the formation and development of medical science and education (Ermukhanova et al., 2018; Baizoldauly, 2022; Tusupbekova, 2022). At the same time, it is worth noting that the history of the Tselinograd State Medical Institute – "Astana Medical University", the activities of its teachers in the medical, socio-political and cultural spheres is still studied fragmentarily, within the framework of general and reference-bibliographic studies. Unfortunately, the history of the Tselinograd State Medical Institute and the activities of its teachers in the medical, socio-political, and cultural spheres were studied fragmentarily, within the framework of general reference and bibliographic studies (Lust et al., 1981; Tsoi, 1984; Dalenov, 1995; Omarova et al., 2019). As the authors of the biographical collection "With Love to Alma Mater (1964–2019)" write: "The biographical collection presents materials dedicated to the biographies of rectors, vice-rectors, deans, heads of departments, professors, and doctors of science of the NAO MUA" (Omarova et al., p. 1). The same biographical information is available in collections dedicated to the university's anniversaries, the history of individual departments, etc. A brief comparative analysis of the activities of the heads of the departments of pathological physiology of the Tselinograd State Medical Institute is proposed by the authors in a special article (Udartseva & Kabdualieva, 2015). However, these materials did not reflect the full activities of the heads of departments, Viktor Rafailovich Faitelberg-Blank and Maria Vasilievna Kropelnitskaya, who arrived in the city of Tselinograd in the first years of the university's formation and made a huge contribution to its development.

Only recently, the history of the formation and development of the Tselinograd Medical Institute has become the subject of research by Kazakh scientists, whose works fragmentarily cover the activities of Ukrainian teachers and scientists who came to work at this institute (Balykova et al., 2023; Mazhitova & Kurbanova, 2023).

Thus, a brief historiographical review allows us to summarize that, despite the relatively long period of its existence, there are still no special research works devoted

to the analysis of the contribution of Ukrainian organizers of medical education and science in the Virgin Land. Our article is a modest attempt to fill this gap.

Methods and Materials.

The methodology of the article is based on the use by the authors of the methods of microhistory and comparative historical analysis, which allowed for verify the sources used about the work activities of scientists, teachers, and organizers of medical education in the Virgin Lands Region Viktor Rafailovich Faitelberg-Blank and Maria Vasilievna Kropelnitskaya at the institute, to link little-known/unknown biographical data in their internal relationship. In addition, the article uses biographical and historical-typological methods, which contributed to the systematization of archival materials of the Virgin Lands Fund, allowing us to identify the contribution and importance of scientists in the formation and development of medical education in the city of Tselinograd.

This article is based on materials from the State Archives of Astana. In this archive, in fund 215 – "Tselinograd State Medical Institute" there are materials related to the activities of the institute from the moment of its creation (1964) to 1990. The files used in this study present materials on the history of the first departments of the institute, personal files of the faculty, reports of the departments, and materials of the Academic Council of the institute. Also used from this fund (inventory 3) are files that are directly related to the educational and scientific activities of V. R. Faitelberg-Blank and M. V. Kropelnitskaya at the Tselinograd State Medical Institute.

Mr. Faitelberg-Blank's Viktor Rafailovich contribution to the formation and development of the Department of Pathological Physiology.

Viktor Rafailovich Faitelberg-Blank was born on July 3, 1934, in Odessa in the family of an employee. In 1952, after finishing high school, he entered the medical faculty of one of the best Ukrainian institutes of that time – Odesa Medical Institute named after N. I. Pirogov, from which he graduated in 1957. While still in his 2nd year at the institute, he began working at the Department of Pathological Physiology, performing several experimental works and studying the processes of absorption in the pleural cavity under normal and pathological conditions. During his studies at the institute and later, during the years of scientific and pedagogical activity, Professor N. N. Zaiko (State Archive of Astana city. Fund 215, Inventory 3, Case 6, Sheet 10) had a huge influence on the formation of V. R. Faitelberg-Blank's professional views and his choice of scientific direction.

After graduating from the institute, having received the qualification of a doctor, V. R. Faitelberg-Blank went to work in Donbas, where he worked as a neuropathologist at the Kirov Makiivka Physiotherapy Hospital. At the same time, V. R. Faitelberg-Blank continued his scientific work at the Department of Biochemistry of the Donetsk Medical Institute. In this place, he gradually determined a specific scientific direction, an interest in independent research appeared, and the contours of scientific interests were established, around which plans personal ideas, and interests were born. Based on the results of his work at the department, in 1960 he

defended his dissertation for the degree of candidate of medical sciences, dedicated to the problems of the absorption capacity of the pleura in various states of the body using therapeutic atoms (State Archive of Astana city. Fund 215, Inventory 3, Case 6, Sheet 7).

In addition, V. R. Faitelberg-Blank organized an isotope laboratory at the hospital, where several clinical and experimental works were carried out, and in this laboratory, under his supervision, candidate dissertations of practicing doctors were prepared (M. I. Yatsenko, G. B. Isaeva) (State Archive of Astana city. Fund 215, Inventory 3, Case 6, Sheet 25).

In 1960, V. R. Faitelberg-Blank moved to work at the Ukrainian Research Institute of Balneology and Physiotherapy, where from 1961 he worked as a senior research fellow, whose subject area of scientific interest became issues of studying the influence of physical agents on the body under normal and pathological conditions. During this period, he published a lot in well-known scientific journals, lectured at advanced training courses for doctors, on behalf of the Ministry of Health of the Ukrainian SSR, provided advisory assistance to specialists working in various regions of Ukraine, became close to outstanding scientists and figures of Ukraine, Academician V. N. Chernigovsky, Professor A. O. Voynar et al. (State Archive of Astana city. Fund 215, Inventory 3, Case 6, Sheet 26).

In 1964, based on the results of many years of research, V. R. Faitelberg-Blank completed and in June 1965 submitted for defense at the Pavlov Institute of Physiology of the USSR Academy of Sciences his doctoral dissertation, in which the physiological mechanisms of action of high-frequency physical agents on absorption processes in the gastrointestinal tract were investigated (State Archive of Astana city. Fund 215, Inventory 3, Case 6, Sheet 9). By the decision of the Higher Attestation Commission under the Ministry of Higher and Secondary Specialized Education of the USSR on April 23, 1966, he was awarded the degree of Doctor of Medical Sciences (State Archive of Astana city. Fund 215, Inventory 3, Case 6, Sheet 68).

As we noted above, in those years the development of virgin and fallow lands continued in the Kazakh SSR, and the construction of a network of medical institutions was underway, in connection with the need for training highly qualified medical specialists and increasing the share of professional national medical personnel in the republic increased sharply. For the Virgin Lands region, this problem was of primary importance.

In the summer of 1965, the management of the Tselinograd State Medical Institute invited V. R. Faitelberg-Blank to participate in the competition for the position of head of the department of pathological physiology (pathophysiology). On July 2, 1965, he wrote an application to the rector of the Tselinograd Medical Institute S. D. Poletayev with a request to allow him to participate in the competition for the vacant position of head of the department of pathological physiology (State Archive of Astana city. Fund 215, Inventory 3, Case 6, Sheet 4) (see Figure 1).

Figure 1. V. R. Faitelberg-Blank, 1965 (from a personal file). (State Archive of Astana city. Fund 215, Inventory 3, Case 6, Sheet 1).

Together with the application of V. R. Faitelberg-Blank sends a package of necessary documents (a copy of the diploma of a senior research fellow, a list of works, an autobiography, a reference from a previous place of work) (State Archive of Astana city. Fund 215, Inventory 3, Case 6, Sheet 51). As the director of the Ukrainian Institute of Balneology and Physiotherapy F. E. Kurkudym wrote in his reference: "V. R. Faitelberg-Blank has a good command of various physiological, pathophysiological, the latest biochemical and biophysical research methods, as well as surgical techniques. As a clinical physiotherapist, V. R. Faitelberg-Blank is a trained and erudite specialist" (State Archive of Astana city. Fund 215, Inventory 3, Case 6, Sheet 10).

On July 13, 1965, the first meeting of the Academic Council of the Tselinograd State Medical Institute was held, at which the issue of electing heads of departments, including pathological physiology, was considered. Professor P. I. Lomanos, Doctor of Medical Sciences, who was elected to this position, refused several days later (State Archive of Astana city. Fund 215, Inventory 1, Case 22, Sheet 1). Therefore, already at the next meeting of the Academic Council on July 20, the agenda again included consideration of candidates for the position of head of the pathological physiology department. Now, Candidate of Medical Sciences P. Ya. Novorassova and Doctor of Medical Sciences V. R. Faitelberg-Blank are applying for this position. The opinion of the selection committee was as follows: "Comrade Novorassova is denied participation in the competition due to her advanced age" (State Archive of Astana city. Fund 215,

Inventory 1, Case 22, Sheet 1). Thus, having passed the competitive selection, by the decision of the Academic Council of the Tselinograd State Medical Institute dated July 20, 1965 (minutes No. 2), V. R. Faitelberg-Blank was elected to the post of head of the Department of Pathophysiology and began to perform his duties on August 20 (State Archive of Astana city. Fund 215, Inventory 3, Case 6, Sheet 5). From that day on, V. R. Faitelberg-Blank's scientific, pedagogical, and organizational activities in Kazakhstan until the day of his dismissal from the post (due to family circumstances) – September 4, 1967, were associated with the Tselinograd Medical Institute.

Appointed to the post of head of the department, V. R. Faitelberg-Blank actively formed the teaching staff of the department and negotiated with many famous scientists located both in the republic and abroad (in Alma-Ata, Odessa, Moscow, Leningrad, etc.).

After being appointed head, V. R. Faitelberg-Blank intensified the scientific work of the department. It should be noted that thanks to his efforts, the department acquired an operating room with a preoperative room, rooms for scientific research of microelements, blood electrolytes, enzymes of parietal digestion, biopotentials of the brain and nerves, physicochemical analysis of proteins, “animal housing for the temporary maintenance of experimental animals”, etc. (State Archive of Astana city. Fund 215, Inventory 1, Case 135, Sheet 153). Considering that in the first years of the institute's work, there was not enough money even for the acquisition of educational and methodological equipment, the energetic position of the head of the department in creating favorable opportunities in scientific work positively influenced the scientific potential of the team.

Under the scientific supervision of V. R. Faitelberg-Blank, a regional scientific school of pathological physiology was formed and recognized at the department, which was engaged in the general development of the problems of “physiology and pathology of digestion” (State Archive of Astana city. Fund 215, Inventory 1, Case 44, Sheet 140). Professor V. R. Faitelberg-Blank regularly reported on the scientific achievements of the department at all Union and Republican scientific conferences in the cities of Kyiv, Odesa, Rostov-on-Don, Moscow, Leningrad, Alma-Ata, Tselinograd and other cities of the country (State Archive of Astana city. Fund 215, Inventory 3, Case 6, Sheet 60).

The acquisition of animals for scientific experiments by a medical institute is always associated with certain difficulties. However, V. R. Faitelberg-Blank, repeatedly appealing to the university management about the need to purchase animals for scientific experiments, to a certain extent solves the department's problem. Thus, in the 1966/67 academic year alone, Associate Professor of the Department P. A. Pak conducted a study on the absorption activity of the pleura using the radioactive indication method in experimental obstruction on 51 cats and 14 dogs, which allowed him to successfully defend his dissertation for the degree of Doctor of Medical Sciences in the future. The research team of the department studied “functional and somatic muscles of the gastrointestinal tract under statistical load and exposure to high-frequency physical agents as a result of experiments on dogs and mice (State Archive of Astana city. Fund 215, Inventory 1, Case 44, Sheet 140). In addition, it was found

that under the conditions of serous and purulent pleurisy, there was a change in the absorption of organic and inorganic substances in the intestine. These areas of scientific research in the republic were just gaining momentum, and therefore the contribution of the department to the study of these problems was undeniable.

In general, the obtained scientific results allowed the teachers of the department to prepare and defend one doctoral and five candidate dissertations.

The department had a well-organized student scientific circle. For example, students of the department took part in the All-Union Student Conference in Leningrad, and the regional conference in Tselinograd, where they reported on the results of their research.

The undoubted successes of the department staff in the scientific plan became the methodological foundation, allowing to organization of the educational process of training specialists with higher medical education at a qualitatively new level. It should be said that the short organizational, scientific, and teaching activities of V. R. Faitelberg-Blank during these years took place in extremely difficult conditions. The newly-established university was provided with four not-the-best educational buildings in the city, so it occupied only one building (the former boarding school at 51A Mira Street). During the work of the department, there was a lack of premises, an incomplete adaptation to the educational process, and a shortage of medical equipment, which negatively affected the organization of the educational process. The department's arsenal included "2 classrooms, …and 1 room for experimental research" (State Archive of Astana city. Fund 215, Inventory 1, Case 44, Sheet 135. Therefore, it is no coincidence that on September 3, V. R. Faitelberg-Blank wrote a statement to the rector with a request to send him on a business trip to Moscow "to purchase equipment necessary for the educational process and scientific work" (State Archive of Astana city. Fund 215, Inventory 3, Case 6, Sheet 53).

In a short period, the educational process was well-established using the latest teaching methods for that time. For example, biophysical devices were demonstrated during biophysics lectures, with an analysis of their operating principles, and two scientific films were shown ("Biopotentials of the Brain" and "Cybernetics in Diagnostics"). During practical classes, students were introduced to the methods of working with many devices in the clinic (electrocardiographs, VEKS, electroencephalographs, physiotherapy equipment, etc.) (State Archive of Astana city. Fund 215, Inventory 1, Case 44, Sheet 156). At that time, the use of the latest equipment significantly distinguished the regional medical university from similar ones in the republic.

On April 18, 1966, V. R. Faitelberg-Blank left for Moscow to the first and second medical institutes to get acquainted with the educational process and master new experimental methods (State Archive of Astana city. Fund 215, Inventory 3, Case 6, Sheet 58). The information he received allowed him to develop and implement in the educational process, in addition to the programs on pathological physiology approved by the USSR Ministry of Health, methodological developments for a new practical course "The Influence of Physical Agents on the Body" (State Archive of Astana city. Fund 215, Inventory 1, Case 22, Sheet 9). He was also the author of the curriculum for

the discipline “Pathological Physiology” (State Archive of Astana city. Fund 215, Inventory 3, Case 6, Sheet 47). In total, Professor V. R. Faitelberg-Blank, during his short time at the institute, prepared over 20 educational and methodological developments and scientific works that were of great importance in practical health care (Faitelberg-Blank, 1965a; Faitelberg-Blank, 1965b; Faitelberg-Blank & Matveeva, 1966).

By the order of the Minister of Higher and Secondary Specialized Education of the USSR No. 396 from December 31, 1964, to November 1, 1965, the Republican Educational and Methodological Directorate “was charged with the responsibility of summarizing the reports and proposals of the ministries... on the development and application of programmed learning... in educational institutions of higher and secondary education” (State Archive of Astana city. Fund 215, Inventory 3, Case 6, Sheets 8–11). Taking into account the order of the Minister of Education, the Institute planned to prepare programmed teaching aids for 1965–1967. To solve this difficult scientific and technical problem, on October 19, 1965, the Rector of the Institute S. D. Poletaev sent V. R. Faitelberg-Blank to Alma-Ata for a republican conference on issues of programming learning. The information received by V. R. Faitelberg-Blank at this conference allowed the Department of Pathological Physiology, one of the first departments of the Institute, to introduce programmed learning in practical classes (State Archive of Astana city. Fund 215, Inventory 3, Case 6, Sheet 54). Undoubtedly, this innovation made it possible to ensure the educational process at a higher educational and methodological level.

Professor V. R. Faitelberg-Blank carried out a great deal of organizational and methodological work: having arrived in the region, he organized and was the chairman of the Tselinograd Society of Physiologists and Pathophysiologists, which initially united 32 people; he was a lecturer for the Znanie Society, and provided all possible assistance to healthcare organizations (State Archive of Astana city. Fund 215, Inventory 3, Case 6, Sheet 35).

On September 4, 1967, V. R. Faitelberg-Blank wrote a statement about his release from the position of head of the Department of Pathological Physiology “due to family circumstances” (State Archive of Astana city. Fund 215, Inventory 3, Case 6, Sheet 86).

Professor V. R. Faitelberg-Blank had worked within the walls of the institute for a short period. But his contribution to the establishment and development of the Tselinograd Medical Institute, as a whole, science, and education of the Kazakh Republic, is undeniable. Thanks to his active scientific position, the team was able to determine the vector of scientific research from the moment the department was organized, which it adheres to at the present stage. The foundations of educational and methodological work and organization of the educational process laid by Professor V. R. Faitelberg-Blank showed a multiplier effect, allowing to ensure high-quality implementation of the educational and methodological process at a high theoretical and practical level.

Mrs. Kropelnitskaya Maria Vasilievna is a founder of the Department of Propaedeutics of Internal Medicine at the Tselinograd State Medical Institute.

One of the outstanding heads of departments who stood at the origins of the development of medical education in the Virgin Lands region was Maria Vasilievna Kropelnitskaya.

M. V. Kropelnitskaya was born on December 27, 1917, in the village of Sasha, Teplikovsky district, Vinnytsia region, in the family of a people's teacher. Due to work circumstances, in 1930 her parents moved to the village of Krutye, Kodymsky district, Odessa region, where she completed seven years of school. In 1936, M. V. Kropelnitskaya entered the Odessa paramedic-obstetric school, graduating in 1939. Before entering the Chernivtsi Medical Institute in 1947, she worked as a nurse in the district hospital in the city of Kotovsk, Odesa region, and as a paramedic in the city of Akkerman, Izmail region. From that time on, the fate of M. V. Kropelnitskaya was determined – the following years of her life were devoted to her favorite work – treating people (State Archive of Astana city. Fund 215, Inventory 3, Case 23, Sheets 3–5).

It is no coincidence that in 1947 M. V. Kropelnitskaya entered the Chernivtsi Medical Institute and in 1952 graduated with honors from the full course of the said institute in the specialty of "physician" (State Archive of Astana city. Fund 215, Inventory 3, Case 23, Sheet 8). After graduating from the institute, she was enrolled in a clinical residency at the Department of Propaedeutic and then Hospital Therapy, and in 1954 she was transferred to the position of assistant at the Department of Hospital Therapy, where she worked until arriving in Tselinograd (State Archive of Astana city. Fund 215, Inventory 3, Case 23, Sheet 7).

On December 11, 1958, M. V. Kropelnitskaya defended her candidate's dissertation on the topic of "Functional state of the liver in circulatory failure", which she published in the form of abstract and numerous articles in conference proceedings and the journal "Medical Affairs" (State Archive of Astana city. Fund 215, Inventory 3, Case 23, Sheet 7).

As we noted above, in 1965 the management of the Tselinograd State Medical Institute invited several teachers with academic degrees to work in the then-open departments of the therapeutic profile. Among those who expressed a desire to take part in the competition for the position of associate professor of the Department of internal diseases propaedeutics with a course in radiology was M. V. Kropelnitskaya. At that time, the organized Department of internal diseases propaedeutics was one of the first therapeutic departments of the Tselinograd Medical Institute.

On June 16, 1965, M. V. Kropelnitskaya wrote a statement to the rector asking for permission to participate in the competition for the position of associate professor in the Department of Propaedeutics of Internal Diseases (State Archive of Astana city. Fund 215, Inventory 3, Case 23, Sheet 4). A submission to the rector of the Tselinograd State Medical Institute, Associate Professor S. D. Poletaev, about the competition participant M. V. Kropelnitskaya, signed by the rector of the Chernivtsi Medical Institute A. Yukhimets, has been preserved: "During her work at the Chernivtsi Medical Institute, M. V. Kropelnitskaya has proven herself to be a good clinician. She

has good experience in teaching, taught a course on the history of the clinic of internal diseases, and gave separate lectures on the course of military field therapy and a trial lecture on the course of the hospital clinic, which she handled well. She is currently working on her doctorate" (State Archive of Astana city. Fund 215, Inventory 3, Case 23, Sheet 10).

As a result of a secret vote at a meeting of the Institute's Academic Council, a decision was made to elect Maria Vasilievna Kropelnitskaya to the position of associate professor of the Department of Internal Medicine Propaedeutics and simultaneously entrust her with the duties of head of the department (minutes No. 1 of July 13, 1965) (State Archive of Astana city. Fund 215, Inventory 3, Case 23, Sheet 4).

On October the 1-st, 1965, by order of the rector S. D. Poletaev, M. V. Kropelnitskaya was transferred from the position of associate professor to the position of acting head of the department of internal diseases propaedeutics, and on June 16, 1966, after passing the competition, she was confirmed in the position of head of the department (State Archive of Astana city. Fund 215, Inventory 3, Case 23, Sheet 16). Thus, M. V. Kropelnitskaya became the first head of the Department of Internal diseases propaedeutics.

The Department of Internal Diseases Propaedeutics of the Tselinograd State Medical Institute was opened based on the therapeutic department of the regional clinical hospital (bed capacity – of 50 beds) and the basis of the therapeutic department of the 2nd Road hospital (bed capacity – of 100 beds) and was in an extremely cramped situation. At that time, the department had only one small room for classes at its disposal (State Archive of Astana city. Fund 215, Inventory 1, Case 1, Sheet 16). The location of the department on two bases was inconvenient since it made it difficult to normally provide the educational process. In addition, there was no room for a functional diagnostics room and a laboratory where laboratory classes with students would be held. Therefore, it was necessary to place both the equipment and the laboratory in the classroom. The lack of an auditorium for lecturing in the premises of clinical hospitals was a great inconvenience. Cold auditoriums in the morphological buildings and frequent bad weather conditions (Tselinograd was located in a zone of sharply continental climate) in the autumn and winter made it difficult to demonstrate patience at lectures. In the year of the department's establishment, in addition to M. V. Kropelnitskaya, 2 assistants worked at the department – candidates of medical sciences A. V. Shulgin and Yu. G. Zhenderkina (State Archive of Astana city. Fund 215, Inventory 1, Case 44, Sheet 62).

The lack of sufficient space remained the main reason causing great difficulties in the development of full-fledged classes. In organizing the work of the department, the outstanding organizational skills of M. V. Kropelnitskaya were fully demonstrated. Despite the insufficient space of not only classrooms but also laboratory premises, the shortage of equipment at first, as well as the lack of visual teaching aids – M. V. Kropelnitskaya managed to subordinate everything to solving a complex task – to make the department a place for effective student training and a platform for conducting research work.

M. V. Kropelnitskaya was forced to devote her main attention to the issues of organizing the work of the department, finding funds, and monitoring the expansion of the educational and hospital beds of the department. M. V. Kropelnitskaya's repeated appeals to the management of the institute yielded positive results for the department – already the following year it became stronger and more authoritative, setting the tone for the entire institute in educational, methodological, and scientific work. This was because, firstly, the staff of the department was increased – the number of teachers increased to 5 people (the staff included candidates of sciences V. I. Neklyudova and I. D. Rachinsky), secondly, the base of the department was expanded due to the therapeutic department of the 2nd road hospital of the Tselinograd station. At the same time, the department began to have 300 beds. Thanks to the efforts of M. V. Kropelnitskaya, practical classes on the methodology of examining a patient and studying the symptoms of individual diseases were held directly at the patient's bedside, and laboratory classes were held in a specially equipped room. New equipment necessary for biochemical research and functional diagnostics of patients was purchased. A five-channel electrocardiograph with attachments (phono-cardiographic, rheographic, ballistocardiography, hagiographical, and electromanometer), as well as a spirometer, pneumotachometer, and echocardiograph were used in laboratory research (State Archive of Astana city. Fund 215, Inventory 1, Case 44, Sheet 63). Since there were not enough visual aids (tables) at the department, students independently made original educational tables and dummies, which were included in the unique table fund, which has not lost its relevance today (State Archive of Astana city. Fund 215, Inventory 1, Case 44, Sheet 65). Conditions were created for students not only to study the theoretical part of the taught disciplines of the therapeutic profile but also to independently conduct patient appointments for educational and scientific purposes.

M. V. Kropelnitskaya was an excellent lecturer. She gave most of the lectures herself, and since at first the department was poorly equipped with educational and methodological literature, Maria Vasilievna tried to present the material in such a way that students almost did not need to refer to textbooks when studying the material. In her classes, lecture material and practical classes were linked to material on normal physiology, pathological anatomy, and pathological physiology, and the development of many processes in norm and pathology was covered – in healthy and sick people. When giving lectures, she accompanied them, whenever possible, with demonstrations of patients, and gave relevant clinical examples (State Archive of Astana city. Fund 215, Inventory 1, Case 44, Sheet 64). When conducting practical classes, she paid attention to providing students with independence, developing research skills in them, and practicing methods for correctly presenting a disease. Under her supervision, students constantly worked at the patient's bedside: they collected anamnesis, conducted an objective examination of patients, and carefully practiced methods for physical examination of patients (State Archive of Astana city. Fund 215, Inventory 1, Case 44, Sheet 65).

Figure 2. Department of Propaedeutics at the Regional Hospital Head of Department Maria Vasilievna Kropelnitskaya. 3rd year. 1966 (Far left) (National Museum of the Republic of Kazakhstan. Fund 1, Inventory 1, Case 14896, Sheet 6).

Worked as the head, and since 1966, the scientific secretary of the Academic Council of the Institute left little time for scientific research. But M. V. Kropelnitskaya found it and involved the teachers of the department in the circle of her scientific interests. On December 14, 1966, by the decision of the Higher Attestation Commission of the USSR, M. V. Kropelnitskaya was awarded the title of associate professor in the department of "internal diseases" (State Archive of Astana city. Fund 215, Inventory 3, Case 23, Sheet 17). The optics of the scientific interests of the department included the following scientific problems: the clinical features and course of myocardial infarction and rheumatism in adolescents in the city of Tselinograd, changes in some enzyme systems in rheumatism, the functional state of the liver in atherosclerosis, rheumatism, peptic ulcer disease, cholelithiasis. Using instrumental methods (ballistocardiography, phonocardiography, polycardiography, rheography, and others), the department studied the functional state of the cardiovascular system in atherosclerosis, rheumatism, and chronic lung diseases. Using the liver rheography method, the department staff under the direction of M. V. Kropelnitskaya studied intrahepatic blood circulation in ulcers and cholelithiasis.

The breadth of scientific interests of the founder of the Department of Internal Medicine Propaedeutics largely determined the target settings of scientific research of her colleagues. In a short time, the department was formed as a center for the study of special methods of treating patients with pathologies of internal organs. In the 1966/67 academic year alone, the department held 23 scientific conferences, one candidate's dissertation was defended (assistant V. I. Neklyudov) and a candidate's dissertation was submitted for defense (A. V. Shulgina). Under her supervision, the teachers of the department completed 22 scientific works, of which 10 were published in journals and

collections, and 12 were accepted for publication (State Archive of Astana city. Fund 215, Inventory 1, Case 44, Sheet 69). M. V. Kropelnitskaya is the author of 22 scientific works (Kropelnitskaya, 1966a; Kropelnitskaya, 1966b; Kropelnitskaya, 1966c), participated in the work of the 1st Republican Congress of Therapists, in the All-Union Conference of Physiologists (in Tselinograd), completed an internship at the 1st Moscow Medical Institute to familiarize herself with the work of the Academic Council and the Academic Secretary (State Archive of Astana city. Fund 215, Inventory 3, Case 23, Sheet 28).

M. V. Kropelnitskaya paid special attention to the work of the student scientific circle (she took responsibility for its work herself). The members of the circle not only listened to reports and abstracts at their meetings but also once every two weeks, under her leadership, conducted evening rounds of patients in the department with a detailed analysis of case histories and the development of methods for examining patients (State Archive of Astana city. Fund 215, Inventory 1, Case 44, Sheet 75).

In addition to educational and scientific work, M. V. Kropelnitskaya paid great attention to helping healthcare authorities. Regularly, she conducted clinical rounds of patients in the therapeutic department of the regional and railway hospitals. To assist in practical health care, the employees of the department repeatedly traveled to the Derzhavinsky, Kurgaldzhinsky, Atbasarsky, and Alekseevsky districts of the Tselinograd region, where they regularly held consultations in various departments of hospitals and clinics (State Archive of Astana city. Fund 215, Inventory 1, Case 2, Sheet 20). Moreover, the department's teachers traveled to distant pastures, where they assisted shepherds and their families.

Despite the short period of work at the institute, it can be safely said that her name is associated with the traditions of organizing teaching and research work at the department. During her two-year tenure as head of the department, M. V. Kropelnitskaya carried out significant organizational and methodological work, and also equipped the department with modern equipment. Being an experienced clinician, she carried out extensive medical work in the regional hospital, on the basis of which the department was located. She conducted advanced training for general practitioners. She also had extensive experience in teaching and conducting scientific work.

Her husband's health problems became the basis for M. V. Kropelnitskaya's appeal to the rector of the institute with a request to dismiss her at her request. In the statement, written on July 17, 1967, it was noted that "due to health reasons, her husband cannot be in the conditions of the Tselinograd climate and left for Ukraine to his previous place of work" (State Archive of Astana city. Fund 215, Inventory 3, Case 23, Sheet 41). Family circumstances developed in such a way that she was forced to look for work within the western regions of Ukraine. M. V. Kropelnitskaya left for the city of Ternopil, where she got a job at the Ternopil State Medical Institute (State Archive of Astana city. Fund 215, Inventory 3, Case 23, Sheet 40).

Thus, having analyzed the key aspects of the subject of our research, it can be noted that the Tselinograd l State Medical Institute, created in 1964, thanks to the support of state health authorities and the efforts of the faculty, eventually became the

regional center of medical education. While inferior in many respects (educational infrastructure, treatment facilities, materials, medical devices, etc.) to leading foreign and domestic medical educational centers, the Tselinograd State Medical Institute eventually began to transform into a large scientific and educational institution, becoming the flagship in the republic for the training of medical personnel. Undoubtedly, scientists and teachers of Ukraine played an important role in this process, whose experience and qualifications provided invaluable assistance to the young university.

Conclusions.

In the article, the authors have attempted to analyze the contribution of Professor V. R. Faitelberg-Blank and Associate Professor M. V. Kropelnitskaya in developing the Tselinograd State Medical Institute in the 1960s. Considering the main aspects of the problem of "the contribution of Ukrainian scientists to the development of the Tselinograd Medical Institute", it is possible to formulate several conclusions. Firstly, the topic of "Ukrainian scientists in virgin Kazakhstan" is poorly studied, and only recently has it become an object of research in domestic historiography. Secondly, the analysis of archival materials made it possible to determine the leading role of Ukrainian scientists in setting off the third-year departments of pathological physiology and propaedeutics of internal diseases (the first therapeutic department of the institute). Thirdly, the results of this study allow us to objectively state that V. R. Faitelberg-Blank and M. V. Kropelnitskaya were not only the founders of the Chairs, but also managed to determine the vector of directions of scientific and pedagogical searches of teachers for many years, created educational and methodological traditions that became a solid foundation for the comprehensive development of departments in the training of highly qualified medical personnel in the region.

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Conflicts of interest.

The authors declare no conflict of interest.

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Українські вчені в Цілиноградському Державному Медичному Інституті: Внесок в освіту і науку (1960-ті роки)

Анотація. *У статті об'єктом вивчення стали питання трудової діяльності, наукових досягнень та вкладу доктора медичних наук, професора Віктора Рафаїловича Файтельберг-Бланк та кандидата медичних наук, доцента Марії Василівни Кропельницької у становленні Цілиноградського державного медичного інституту у 1960-ті роки. Для досягнення мети дослідження було використано методи мікроісторії та порівняльно-історичного аналізу, що дозволили всебічно розкрити діяльність вчених та організаторів медичної освіти В. Р. Файтельберг-Бланк та М. В. Кропельницької у Цілинному краї. Дано характеристику архівних фондів та документів, на основі яких було написано статтю, короткий історіографічний огляд дослідженої теми. Вперше в науковий обіг було запроваджено комплекс джерел, які дозволяють по-новому поглянути та дати об'єктивну оцінку діяльності українських вчених у Цілиноградському медичному інституті. На основі документальних матеріалів Державного архіву міста Астани, відомостей із особистих справ В. Р. Файтельберг-Бланк та М. В. Кропельницькій, уточнено основні етапи їх становлення як науковців та педагогів на території України, а також причини появи у Казахстані для роботи в медичному інституті. Діяльність В. Р. Файтельберг-Бланк як засновника кафедри патологічної фізіології сприяла формуванню наукової школи, що здобула визнання в Казахстані та займалася спільною розробкою проблем «фізіологія та патологія травлення». Незважаючи на нетривалий час роботи В. Р. Файтельберг-Бланк в інституті (1965–1967), він одним із перших вчених вишу сприяв прищепленню колегам наукових навичок експериментальної роботи з тваринами. У статті акцентується увага на тому, що багаторічний досвід вченого призвів до розробки довгострокових наукових інтересів кафедри з вивчення функціональних та соматичних м'язів та шлунково-кишкового тракту під час статистичного навантаження та дії високочастотними*

фізичними агентами. Показано, що В. Р. Файтельберг-Бланк вдалося закласти традиції навчання студентів, які стали фундаментом підготовки кваліфікованих медичних кадрів у Казахстані. Автори довели величезну роль М. В. Кропельницької у формуванні кафедри пропедевтики внутрішніх хвороб, що здобула визнання як наукової школи, яка займалася вивченням спеціальних методів лікування хворих із патологіями внутрішніх органів. М. В. Кропельницька приділяла велику увагу вивченню студентами багатьох фізіологічних процесів у нормі та патології. Вперше у виші на заняттях вона супроводжувала теоретичний матеріал демонстрацією хворих, наводила відповідні клінічні приклади. Наприкінці зроблено висновки про величезний внесок науково-педагогічної спадщини В. Р. Файтельберг-Бланк та М. В. Кропельницької у становленні медичної освіти у цілинному Казахстані.

Ключові слова: *цілинний Казахстан; Україна; вчені; В. Р. Файтельберг-Бланк; М. В. Кропельницька; медична освіта*

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Natural and mathematical publications of the Dnipro region at the end of the 19th–beginning of the 20th century: Establishment of educational technology as a science

Abstract. *The article defines the role of the Journal of Elementary Mathematics, the Bulletin of Experimental Physics and Elementary Mathematics, and the “Mathesis” Publishing House in transforming the total knowledge about the technology of teaching natural and scientific disciplines into Science. When organizing the research, for a meaningful analysis of its subject, the analysis of information from publications the generalization of the elements of natural and mathematical knowledge presented in the publications, and the systematization of descriptions of the technology of teaching natural and mathematical disciplines were used. Quantification of text, collection of empirical data, their generalization, and mathematical and statistical processing were used in the process of quantitative analysis. As a result of the research of the materials of both magazines and the products of the “Mathesis” Publishing House during the entire period of their operation, the authors came to the following conclusions. Firstly, from 1886–1925, the ideas of technologies were actively*

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developed in the pages of authoritative publications of the Russian Empire at the time, which functioned in the territory of the Dnipro region – "Journal of Elementary Mathematics", "Bulletin of Experimental Physics and Elementary Mathematics" and book editions of the "Mathesis" Publishing House teaching of natural and mathematical disciplines, the contents of textbooks and methodical manuals in Mathematics and Natural Sciences were published and discussed, the peculiarities of teacher training were analyzed, methodical schools of outstanding scientists and methodologists were started and fixed, educational programs were reviewed. This shows that thanks to the activities of both magazines and publishing houses, real conditions were created for the meaningful and technological provision of the transitional period from the stage of formation of methodological approaches to the stage of scientific substantiation of the technology of teaching natural and mathematical disciplines in high school in the global context of its formation as a Science. The total volumes of publications, the number of their articles and books, the quality of execution, and the breadth of coverage of the content of natural and mathematical disciplines testify to the ability of editorial offices to carry out the planned measures for the production of substantive and methodical support for teaching and distribution of popular science publications to motivate a wide range of young people (and older members of the population) to study Mathematics, Physics, Astronomy, Biology, Chemistry, and Geography. Both journal editors and the management of the publishing house were aware of the important role of practice in the study of natural and mathematical disciplines – for all analyzed institutions, more than a fourth of the volume of all publications was allocated for problem material and laboratory workshops. Articles and books of a methodological nature became an important component of the publications, in which the peculiarities of the teaching technology were revealed, the subject terminology was clarified, discussions were organized about teaching models, the peculiarities of the speeches of famous mathematicians and natural scientists at various level congresses and congresses were highlighted, and the pedagogical and scientific heritage was disseminated, famous scientists.

Keywords: *educational and scientific periodicals; publishing house; teaching technology; natural and mathematical disciplines; science*

Introduction.

The problem of researching the process of transformation of a set of scientific information, a set of knowledge, and methods of activity into a scientific unit requires for its solution the study and analysis of certain conditions that ensure systematicity, objectivity, and methodological validity. The body of knowledge must be tested and repeatable, systematized and have a theoretical basis, amenable to generalization and classification, capable of self-correction and adaptation. An important condition for such a transformation is the institutionalization of the totality of knowledge, in particular, its provision with professional and methodical sources. It was at the turn of the 19th and 20th centuries that the technology of teaching natural and mathematical disciplines as a Science took place in Europe. That is why the best forces of

mathematicians and nature researchers of the Dnipro region were actively concerned with the need to participate in the processes of reforming the educational sector of the then Russian Empire. Such activity was manifested in the publishing movement – first in Kyiv, later in Odesa, authoritative centers for the publication of popular science, natural, and mathematical periodicals appeared, which existed for almost 40 years. The study of the role of these centers of literature publication in the process of transformation of the technology of teaching natural and mathematical disciplines into science appears to us to be an urgent problem.

Literature Review.

Research on the development of popular scientific publications from the cycle of natural science and mathematics disciplines for the formation of natural and mathematical knowledge in young people, for teacher training, as well as to meet the educational needs of science and mathematics lovers was carried out by various scientists. Among the different works, we can single out the voluminous meaningful analysis of the mathematical part of the "Journal of Elementary Mathematics" and the "Bulletin of Experimental Physics and Elementary Mathematics", which was carried out by *S. A. Dakhiya* (Dakhiya, 1956). A detailed biography of the Odesa scientist *V. M. Kagan*, who was directly related to most of the publications analyzed in the article, can be found in *A. M. Lopshytsia, P. K. Rashevsky* (Lopshits, 1969). A brief description of the activity of popular scientific publications of that time in the context of the activity of natural and scientific societies of Ukraine was made by *I. O. Demuz* (Demuz, 2014) and *V. S. Savchuk* (Savchuk, 1994). A general description of the operation of the Odesa "Mathesis" Publishing House was created by *Yu. D. Katsenelson* (Katsenelson, 1960). Finally, the authors of this article revealed the peculiarities of coverage in the "Bulletin of Experimental Physics and Elementary Mathematics" of biographical materials about famous scientists and teachers (Pasichnyk, Rizhniak, & Deforzh, 2022) and about the organization, conduct and results of domestic and foreign congresses and congresses of mathematicians and natural scientists (Pasichnyk, Rizhniak, & Deforzh, 2023).

In this research, we will determine the role of the Journal of Elementary Mathematics, the Bulletin of Experimental Physics and Elementary Mathematics, and the "Mathesis" Publishing House in transforming the body of knowledge about the technologies of teaching natural and scientific disciplines into science.

Methodology.

When organizing the research, for a meaningful analysis of its subject, an analysis of information from publications and a synthesis of logical references and conclusions were used, as well as a generalization of the elements of natural and mathematical knowledge presented in the publications and a systematization of descriptions of the technology of teaching natural and mathematical disciplines. Quantification of text, collection of empirical data, their generalization, and mathematical and statistical processing were used in quantitative analysis (Atteslander, 2003; Früh, 2003). At the stage of quantification of the text as a unit of content, issues of magazines were used,

which were combined according to the years of publication, as well as individual books of the publishing house. All the analyzed texts were classified – Mathematics and the main components of Natural Science: Physics, Biology, Chemistry, Geography. Publications on Philosophy and interdisciplinary areas were also highlighted separately. The number of pages in a specific issue of magazines and a specific edition was used as a unit of account (parts of the volume of pages were determined from the ratio of the occupied area on the page).

Main Research Results.

"Journal of Elementary Mathematics" was published during 1884–1886 in Kyiv. Its founder and editor was Kyiv University professor *Vasyl Petrovych Yermakov*. Since 1886, the editing of the magazine was handed over to *Erasm Korneliyovych Shpachynskyi*, who had also previously taken an active part in the editorial and publishing work of this publication. At the same time, the magazine changed its name to "Bulletin of Experimental Physics and Elementary Mathematics" (hereinafter referred to as "Bulletin"), and at the request of *E. K. Shpachynskyi V. P. Yermakov* remained the ideological leader of its mathematical department. Both magazines were considered the best editions of popular science periodicals of the Russian Empire of the late 19th and early 20th centuries. In 1891, the editorial office of Bulletin moved to Odesa, and the editing of the magazine from 1898 (after a short stay in the role of editor-in-chief of Professor *V. Y. Zimmerman*) until the end of its publication was transferred to private docent *V. F. Kagan*. The fate of Bulletin is connected in the future with the mathematical department of the Novorossiysk Society of Naturalists and with the teachers of the Novorossiysk (Odesa) University. The publisher of the magazine during 1897–1917 (from No. 259) was *V. O. Gernet*.

In 1904, the "Mathesis" Publishing House (Greek: mathesis – knowledge) was founded in Odesa. The first mention of this project appeared on the pages of Bulletin on January 15, 1904. Further, announcements about books being prepared for publication and catalogs of published literature appeared regularly in the magazine until 1914. The founders of the publishing house were private docents of Odesa (Novorosiysk) University, famous mathematicians *V. F. Kagan*, *S. O. Shatunovskyi*, astronomer *A. R. Orbinskyi*, and the owner of the printing house *M. F. Shpencer*. The central figure of "Mathesis" was *Veniamin Fedorovych Kagan*. During the first 10 years of its activity, the publishing house became one of the largest in the Russian Empire and the largest among publishing houses that specialized in publishing educational and popular scientific literature in the natural and mathematical direction. The books on Mathematics, Physics, Astronomy, Chemistry, Biology, History, and Philosophy of Natural Science, published thanks to the "Mathesis" Publishing House, have become outstanding examples of literature on the history of science, education, and book publishing.

Based on this, it is possible to consider the results of the content analysis of the contents of the "Journal of Elementary Mathematics", Bulletin and publications of "Mathesis" as representative for formulating conclusions regarding the peculiarities of

the formation of the technology of teaching natural and mathematical disciplines as a science at the turn of the 19th and 20th centuries.

It is known that total knowledge goes through several important stages for its registration into science (see, for example, Lane, Flagg (2010) or N. Lederman, J. Lederman (2019)). In the first stage, the accumulation of empirical data takes place: a large number of observations, facts, and empirical data are collected; observations are replicated to confirm their reliability. This is followed by the stage of forming hypotheses: based on the accumulated data, hypotheses are put forward that explain the observed phenomena or regularities. The next step is experimental testing of hypotheses: hypotheses are tested through controlled experiments and research. The fourth stage is a theoretical generalization: after the successful testing of hypotheses, theories are formed that unify individual hypotheses and explain broader patterns and principles. The fifth stage is the systematization of knowledge: knowledge is systematized, classified, and structured into a complete system; scientific concepts, categories, classifications, and terminology are developed. The next stage is methodological substantiation: research methods are developed and improved, which allows for obtaining reliable and objective data; standards and protocols for conducting research are created. The seventh stage is the institutionalization of science: specialized scientific institutions and research centers are created, where systematic research and training of new generations of scientists are carried out; scientific societies, journals, and conferences for the exchange of knowledge and research results are emerging. In the eighth stage, the dissemination and implementation of knowledge is implemented: research results are published in scientific journals, monographs, textbooks, and scientific knowledge is implemented in practice, technology, education and other areas of life. At the next stage, critical analysis and self-correction are carried out: adaptation and correction of knowledge in response to new data, discoveries and achievements. Finally, at the tenth stage, the evolution and development of science is realized: new knowledge and approaches are integrated, and new scientific disciplines and interdisciplinary areas emerge, which contributes to the further development and complication of science.

The formation of the technology of natural and mathematical disciplines as a Science is related to the development of Pedagogy in the context of specific Sciences, such as Mathematics, Geography, Biology, Chemistry and Physics (Arnold, 2012; Pollet, 2023). This issue is closely related to the content of these sciences, education reforms and changes in school curricula.

The substantive and quantitative analysis of the contents of the “Journal of Elementary Mathematics” the Bulletin and “Mathesis” publications made it possible to determine the positioning of the technology of teaching natural and mathematical disciplines as a science at the turn of the 19th and 20th centuries. We will present its main results.

Content analysis. From the very beginning, the “Journal of Elementary Mathematics” (Journal of Elementary Mathematics, 1884–1885) published articles from various sections of mathematics and physics. The efforts of Professor *V. P. Yermakov* concentrated, in addition to the general editorial issues of the

magazine, on the preparation and editing of mathematical material. In total, 36 issues of the magazine contained popular science articles on various topics of Elementary Mathematics: Properties of Numbers and Operations on them (for example, Vol. 1, No. 1), Identical Transformations of Algebraic Expressions (Vol. 1, No. 5), Properties of Geometric Figures (Vol. 1, No. 1, 5), Solving Equations and Inequalities (Vol. 1, No. 8), Theory of Probability (Vol. 1, No. 4), Properties of Functions (Vol. 2, No. 16). *E. K. Shpachynskyi* was responsible for the preparation and editing of materials on Physics in the journal. During the two years of publication, articles appeared on Electricity (Vol. 1, No. 8), Kinematics (Vol. 1, No. 3), Optics (Vol. 2, No. 4), Astronomy (Vol. 2, No. 5), Mechanics (Vol. 2, No. 6). The journal also featured articles on the History of Natural Science (Vol. 1, No. 12) and Technology of Teaching Mathematics and Natural Sciences (in the form of reviews of published textbooks and manuals for students – (Vol. 2, No. 3). Each issue of the magazine contained (at least 12.5% of the volume) texts of Elementary Mathematics problems for readers and a detailed analysis of their solutions. In general, the magazine *V. P. Yermakov* implemented the goals of developing and popularizing knowledge of Elementary Mathematics (and, partially, Physics) and was designed for teachers and students of secondary schools.

Compared to the "Journal of Elementary Mathematics", the "Bulletin of Experimental Physics and Elementary Mathematics" (Bulletin of Experimental Physics, 1886–1917) was a larger and more durable educational tool for students and teachers in the field of physical and mathematical sciences. That is why the Bulletin's program was expanded and consisted of articles on physics and mathematics (in reality, it was supplemented, in addition to those named, with materials on Astronomy, Chemistry, Biology, the History of Science and Philosophy), articles of pedagogical content, bibliographic indexes, reviews and criticism on the subjects of Physics and Mathematics, problems and questions from Physics and Elementary Mathematics and their solutions, a chronicle of scientific news, scientific bulletins, messages, notes and instructions.

A meaningful analysis of articles on Mathematics showed that a significant part of the volume of the Bulletin was devoted to articles on Geometry, and all materials can be divided into the following sections: a) Elementary Geometry, including the Geometry of a triangle; b) Basics of Geometry and non-Euclidean Geometry; c) Theory of Geometric Constructions; d) Special questions of Geometry. The most complete overview of the problems of Triangle Geometry was contained in the articles of *D. Yefremov* (No. 230–232, 234, 236, 239, 240, 244, 246, 249, 273, 281, 282) and *D. A. Kryzhanovskyi* (No. 571–574). More than two dozen articles were devoted to Constructive Geometry (see articles by *I. I. Aleksandrov* (No. 92), *S. O. Shatunovskyi* (No. 517), *V. F. Kagan* (No. 126, 127) and others). Bulletin became the first mathematical Journal in which the ideas of non-Euclidean geometry were popularized (see articles by *V. P. Yermakov* (No. 17), *Henri Poincare* (No. 143, 144), works by *V. F. Kagan* "Essay on Lobachevskyi's Geometric System" (No. 174–276), "Introduction to the teaching of the Basics of Geometry" (No. 662–666, 669–672), etc.). Special issues of Geometry were revealed in the articles of *K. Lezan* (No. 588)

(vector calculus), *A. Filipov* (No. 610–612) (inversion transformations), *M. Maliyev* (No. 621) (topology), and others.

Algebraic material on the pages of the Bulletin was presented by works on the factorization of polynomials, on issues of equivalence of equations and inequalities, on methods of extracting roots and solving equations of the 3rd and 4th degree, on the coverage of elementary techniques for the study of functions with one and two variables , on the theory of approximate calculations (see articles by *P. Sveshnikov* (No. 238), *P. S. Florov* (No. 664–665), *D. Yefremov* (No. 170, 171), *I. O. Kleiber* (No. 103, 104, 106), *V. G. Von-Bool* (No. 205, 207, 210) and others). Articles dedicated to the analysis of infinitesimally small quantities occupied a special place in Bulletin (see the works of *P. Sveshnikov* (No. 130), *R. Dedekind* (No. 191, 192). A voluminous block of articles in Bulletin was devoted to the problems of the Methodology of Teaching Mathematics. A significant problem, which became the subject of discussions on the pages of Bulletin, was the proposal to start transfer exams in schools, which was clearly aimed at the maximum dropout of students from schools. A rational approach to solving this problem was demonstrated in the article by *R. V. Przyshikhovskyi* (No. 189). General issues of the methodology were analyzed in the articles of *E. K. Shpachynskyi* (No. 26, 109, 110, 113), problems of Algebra teaching methods – in the works of *V. P. Yermakov* (No. 102), *E. K. Shpachynskyi* (No. 217), *B. A. Gern* (No. 197), methods of teaching Geometry – in the article by *S. Zhitkov* (No. 133, 134, 141). Reports on the activities of the International Commission on Teaching Mathematics became important materials of the Bulletin (see reports by *K. A. Posse* (No. 907), article by *D. E. Smith* (No. 570, 572–573). 1912–1914 on the pages of the Bulletin *V. F. Kagan* and *D. M. Syntsov*, the work of the 1st and 2nd congresses of Mathematics teachers (No. 553, 554, 556, 603) was covered. Materials on the features of the reform of Mathematics education posted on the pages of the Bulletin (articles by mathematicians *K. Shcherbina* (No. 658, 659–660), *A. Kiselyov* (No. 649), mathematicians *A. Shaposhnikov* (No. 418, 421), *K. Lebedyntsev* (No. 513), *S. Vinogradov* (No. 509*), A. K. Arndt* (No. 655–656), *I. I. Aleksandrov* (No. 204, 650–651) and others) played an important role in changing the guidelines in the mathematical training of the younger generation.

The editorial staff of Bulletin paid due attention to articles from various sections of Physics and Technologies of its Teaching. This became especially relevant for the creation of conditions for Physics and Natural Sciences in general to acquire the necessary meaning and scope of study in secondary schools of the late 19th and early 20th centuries. Thus, more than 500 articles were devoted to Physics issues, in which the problems of mechanics were covered (see, for example, articles by *H. Florinskyi* (No. 31), *B. Hern* (No. 217–224), *P. V. Shepelev* (No. 493), molecular physics (see articles by *K. Chernyshov* (No. 163, 165, 171, 173, 174, 176–178), *F. Shvedov* (No. 362), *I. Husakovskyi* (No. 15, 19, 26, 29, 33, 36), *B. Golitsyn* (No. 65, 67, 69, 71, 74, 76, 80, 86, 87), electricity and magnetism (see articles by *P. Bakhmetyev* (No. 31, 34, 36, 58, 59 , 70, 89), *H. Poincare* (No. 185, 186), *L. Mandelshtam* and *N. Papalleks* (No. 521), optics (see articles by *E. K. Shpachynskyi* (No. 58), *A. L. Korolkov* (No. 106), atomic and nuclear physics (see articles by *K. Sluzhevskyi* (No. 231, 232),

N. Pylchykov (No. 286, 289), *B. P. Weinberg*, *Z. P. Weinberg* (No. 335, 336, 338), *A. Rigi* (No. 409, 411, 412, 417). The magazine also published an original article by *A. Einstein* on the problems of the theory of relativity (No. 596). Problematic issues of physics teaching technology were highlighted in articles by *E. K. Shpachynskyi* "To the reform of the physics textbook" (No. 97), "On a new explanation of the doctrine of Electricity and Magnetism" (No. 153), "On the Methodology of Physics. To the question of the Basic Principles of Electrostatics" (No. 344), *F. Shvedov* "Introduction to the Methodology of Physics" (No. 172), *A. Wolfenzon* "Practical works on Physics in secondary school" (No. 320), *K. Posse* "On coordination of programs in secondary and higher education" (No. 555), "Issues of school teaching of Physics. Summary of lectures by Professor *P. Volkmann*" (No. 619) and others. Thus, in the articles of famous domestic and foreign physicists, the author's current views on the ways of development of university and school Physical Education were revealed.

The domestic and foreign congresses and congresses of natural scientists and mathematicians at that time became an important phenomenon for the formation of the views of scientists and teachers on the development of technology for teaching natural sciences and mathematics. It was here that new ideas were expressed and models of optimal organization of education for high school students in mathematics, physics, biology, chemistry, and geography were formed. A detailed description of the disclosure of the Bulletin of the peculiarities of holding scientific and educational gatherings of naturalists and mathematicians was made by us in (Pasichnyk, Rizhniak, & Deforzh, 2023).

An important role in the organization of experiments in the study of Physics was played by the "Experiments and Devices" section of the Bulletin. In the articles of *P. Bakhmetyev* (No. 146), *V. Obolenskyi* (No. 301, 306, 311), *I. Tochidlovskyi* (No. 314, 316, 318), *E. K. Shpachynskyi* (No. 329, 349, 351), *V. A. Kachok* (No. 364), *V. Lermantov* (No. 367), *A. Yanitskyi* (No. 550), *I. Haber* (No. 602, 604, 609, 613), *P. Smirnov* (No. 644–645) and other Methodist physicists the questions of the methodology and technique of the school physical experiment were revealed.

The organization of reviewing new Literature on Physics and Mathematics for secondary school was also a regular phenomenon for Bulletin. More than 200 textbooks, manuals, and problem books on Physics and Mathematics were reviewed during the magazine's publication period. For example, Algebra and Geometry textbooks by *A. Kiselyov* (No. 149), *Nikultsev's* algebras (No. 652), *V. Shidlovskyi's* book on differentials and integrals (No. 243), collections of problems in Geometry by *N. Rybkin* (No. 364) and arithmetic were reviewed *Shpakovich and Tereshkevich* (No. 169). The following were also reviewed: a Physics textbook by *S. Kovalevskyi* (No. 33, 35, 39), a course in Experimental Physics by *A. P. Shimkov* (No. 53), Physics Methodology by *F. Shvedov* (No. 199, 200), Physics course by *O. D. Khvolson* (No. 261), a collection of problems by *R. D. Ponomaryov* (No. 339), Manual for School Physical Experiment by *M. S. Lukyanov* (No. 375), a concentric Physics textbook by *I. I. Kosonogov* (No. 475–476) and other books. It should be noted that reviews of publications in Geography, Chemistry, Biology, Astronomy, and the History of Science also found a place on the pages of the Bulletin.

The editors of Bulletin considered providing students with historical information about the specifics of the development of Mathematics, Physics, Biology, Chemistry, and Geography as an important component of the organization of Science and Mathematics Education (see articles on the history of arithmetic by *I. Kleiber* (No. 34), on the History of the problem of squaring the circle by *V. Kagan* (No. 126, 127), from the History of the development of the doctrine of the foundations of geometry by *V. Kagan* (No. 380–403), from the History of spherical trigonometry by *V. Shidlovskyi* (No. 389), from the History of mathematical physics by *Henri Poincare* (No. 406–408), from the History of determining the speed of light by *B. Weinberg* and *Z. Weinberg* (No. 335, 336, 338), from the History of wireless telegraphy by *Gibson* (No. 616), from the History of the study of the physical state of gases by *I. Husakovskyi* (No. 15, 19, 26, 29, 33, 36 and others). A voluminous source of historical knowledge about the development of Natural Science and Mathematics is Scientific Biography, which occupied a significant volume in the materials of the Bulletin. We carried out a detailed analysis of the biographical and prosopographic materials of Bulletin about famous mathematicians and natural scientists in the article (Rigi, 1910).

"Mathesis" Publishing House specialized in publishing scientific and popular science works in the fields of natural and mathematical sciences, as well as in Philosophy, Technology, Astronomy, Meteorology, Spectroscopy, Geodesy, and the History of Natural Science and Mathematics. The largest number of books was published by the publishing house on Mathematics and Physics. "Mathesis" took an active position in supporting the reform of teaching Mathematics in secondary school, which originated from the initiative of the German mathematician *Felix Klein*. The essence of the reform was to strengthen the applied orientation of the mathematics course, as well as to implement the idea of introducing students to the beginnings of higher mathematics. Promotion of the reform was manifested in the publication and popularization of books written for its implementation by *E. Borel* (Borel, 1911, 1912) and *F. Kleyn* (Kleyn, 1912). *A. Filipov's* book (Filipov, 1912) was also valuable in the context of the implementation of the reform. In addition to books of a methodological nature, the publishing house published textbooks on various sections of mathematics for higher schools: "Course of Analytical Geometry" by *O. Dziobek* (Dziobek, 1911, 1912), "Introduction to the Calculus of Infinitesimals" (Kovalevskiy, 1909) and "Fundamentals of Differential and Integral Calculus" by *G. Kovalevskyi* (Kovalevskiy, 1911), "Theory of Geometric Constructions" by *A. Adler* (Adler, 1910), "Calculus of Finite Differences" by *A. Markov* (Markov, 1910), "The beginnings of the theory of determinants" by *E. Netto* (Netto, 1912), "Elementary textbook of algebraic analysis and calculus of infinitesimals" by *E. Cesaro* (Chezaro, 1913, 1914), "Paradoxes of the Infinite" by *B. Boltsano* (Boltsano, 1911). The publishing house produced the following mathematics publications for secondary school teachers and students: "Volume of a Sphere and Spherical Segment" by *V. Cimmerman* (Tsimmerman, 1908), "Continuity and Irrational Numbers" by *R. Dedekind* (Dedekind 1909), "Algebra of Logic" by *L. Couture* (Kutyura, 1909), "Encyclopedia of Elementary Mathematics" by *H. Veber* and *I. Velshteyn* (Veber & Velshteyn, 1911, 1910), "What is Algebra?" *V. Kagan* (Kagan, 1910), "Theorem of Pythagoras" by *V. Littsmann* (Littsmann, 1912),

"Terminology in an Elementary Course of Mathematics" by *K. Shcherbina* (Shcherbina, 1923). The publishing house also paid attention to "mathematics lovers", offering readers popular scientific publications: "Games with Matches" by *S. Tromgolt* (Tromgolt, 1907), "Geometric Exercises with a Piece of Paper" by *S. Rou* (Rou, 1910), "Mathematical Entertainment and Games" by *G. Schubert* (Shubert, 1911), "The Nature of Mathematics" by *F. Jourdan* (Zhurden, 1923) and others.

The formation of Physics teaching technology as a branch of science was associated with socio-cultural changes at the end of the 19th and the beginning of the 20th centuries, which sharpened society's attention to the state of school physical education. This is what led to the formation of the program for the publication of books on physics at the "Mathesis" Publishing House. Textbooks for higher education were also published: "Physics Course" by *H. Lorenz* (Lorents, 1910a, 1910b), "Modern Theory of physical phenomena" by *A. Rigi* (Rigi, 1910), "Corpuscular Theory of Matter" by *J. Thomson* (Tomson, 1910), "Course of theoretical mechanics" by *P. Appell* and *S. Doteville* (Appell & Dotevill, 1912a, 1912b), "Course of electricity and magnetism" by *G. Mi* (Mi, 1912, 1914). To organize practical and laboratory classes in physics in secondary schools, the publishing house offered the "Collection of Elementary Experiments in Physics" by *H. Abraham* (Abraham, 1905a, 1905b) and "A Short Guide for Practical Lessons in Physics" by *F. Kohlrausch* (Kolraush, 1914). As popular scientific literature on physics, "Mathesis" offered a wide list of publications: "Physics of the Sky" by *S. Arrhenius* (Arrenius, 1905), "Modern Development of Physics" by *V. Vetgem* (Vetgem, 1908), "Liquid Crystals and Theories of Life" by *O. Leman* (Leman, 1908), "Rotating top" by *J. Perry* (Perri, 1908), "Origin of spectral colors" by *P. Zeeman* (Zeyeman, 1909), "Wireless telephone" and "Attenuation and resonance of electric waves" by *A. Slaby* (Slabi, 1909a, 1909b), "Paradoxes of nature" by *V. Hampson* and *K. Schefer* (Hampson & Shefer, 1910). "The theory of relativity and its influence on scientific thought" by *A. Eddington* (Eddington, 1923) and others.

Two dozen titles of literature were offered to readers to study the problems of astronomy (see "Astronomy for all" and "Theory of the Moon's motion" by *S. Newcom* (Nyukom, 1905, 1910), "Formation of worlds" by *S. Arrhenius* (Arrenius, 1908), "Evolution of the solar system" *F. Moulton* (Multon, 1908), "Halley's Comet" by *K. Graff* (Graff, 1910) and others), more than 15 names – from chemistry (see "Exercises in inorganic chemistry" by *H. Biltts* (Biltts, 1910), "Introduction to the study of physical chemistry" *V. Ramsay* (Ramzay, 1910), "Stereochemistry" by *M. Mamlok* (Mamlok, 1911), "Introduction to Inorganic Chemistry" by *A. Smith* (Smit, 1911), "Introduction to Colloid Chemistry" by *V. Poshl* (Pyoshl, 1912), "Chemical Experiments for Youth" by *K. Sheid* (Sheyd, 1907) and others), about 10 titles – from biology (see "Lectures on bacteriology" by *N. Ushinskiy* (Ushinskiy, 1908), "Dynamics of living matter" by *Zh. Loeb* (Loeb, 1910), "Unity of vital phenomena" and "Biology cells as the basis of the teachings on embryonic development and reproduction" by *B. Verigo* (Verigo, 1912, 1913), "Human Biology" by *P. Saksl* and *K. Rudinger* (Saksl & Rudinger, 1915) and others). We should also note important natural history works – "Centuries and tides" by *R. S. Boll* (Boll, 1909), "Snow, frost,

hail, ice and glaciers" B. P. Veynberg (Veynberg, 1909), "The Picture of the World in the Light of Modern Natural Science" by *K. Snayder* (Snayder, 1909), as well as geography publications – "Modern Geography" by *M. Newbigin* (Nyubigin, 1923) and "Research of Polar Countries" by *K. Hassert* (Hassert, 1912).

In addition to the named books, two series were added to the treasury of publications. In the "Successes of Science" series, two issues of "Successes of Physics" were released, as well as publications revealing the latest achievements in the fields of modern Technology, Biology, Chemistry, Astronomy, and Geography. In a series of books on the History of Science, the works of *A. Ladenburg* on the History of Chemistry (Ladenburg, 1917), *F. Cajori* on the History of Elementary Mathematics (Kedzhori, 1910), *A. Clark* on the History of Astronomy (Klark, 1913), *F. Dannemann* on the History of Natural Science (Dannemann, 1913) were published. *E. Fourier* on the History of Elementary Geometry (Furre, 1912), *F. Rudio* on the History of the Quadrature of the Circle (Rudio, 1911), *P. Lacour* and *J. Appel* on the History of Physics (Lacour & Appel, 1908).

Thus, the content analysis of the publications "Journal of Elementary Mathematics", "Bulletin of Experimental Physics and Elementary Mathematics" and the volume of publications of the "Mathesis" Publishing House, which were printed on the territory of the Dnipro region at the end of the 19th – at the beginning of the 20th century, shows the wide coverage of the topics of the articles in the journals and books. Training in secondary school in subjects of the natural and mathematical cycle. In addition, the editors of both magazines and the management of the publishing house paid due attention to the publication of publications of a pedagogical nature, in which problematic issues of the technology of teaching natural and mathematical subjects were revealed.

Quantitative analysis. "The Journal of Elementary Mathematics" was published in 1884–1885. A total of 36 issues of this publication were published. "Bulletin of Experimental Physics and Elementary Mathematics" had 674 issues during the 30-year period of its publication. From the editions of "Journal of Elementary Mathematics" and Bulletin, we selected for analysis those materials that were directly related to the content of science and mathematics relevant for high school and to the technology of teaching these disciplines. Thus, we divided the materials of the "Journal of Elementary Mathematics" into the following categories: "Articles on Mathematics", "Articles on Physics", "Pedagogical Articles", and "Problems".

In the course of our research, we will use the median values for all indicators, and not the average, since the distributions in the samples differ from the normal distribution. It should be noted that the median values of the distribution of the volume of publications by the numbers of the "Journal of Elementary Mathematics" in the correspondingly defined categories are as follows: "Articles on Mathematics" – 10, "Articles on Physics" and "Problems" – 5, "Pedagogical Articles" – 0. Total volumes of articles the specified categories and the number of publications during the two years of publication of the magazine are presented in fig 1.

When analyzing the publications of the Journal of Research Physics and Elementary Mathematics, in addition to the aforementioned categories of the Journal

of Elementary Mathematics, we identified three more: “Experiments and Devices”, “Mathematical Trifles”, and “Inventions and Discoveries”. The total volumes and number of articles of the specified categories of the Bulletin during all years of its publication are presented in fig. 2.

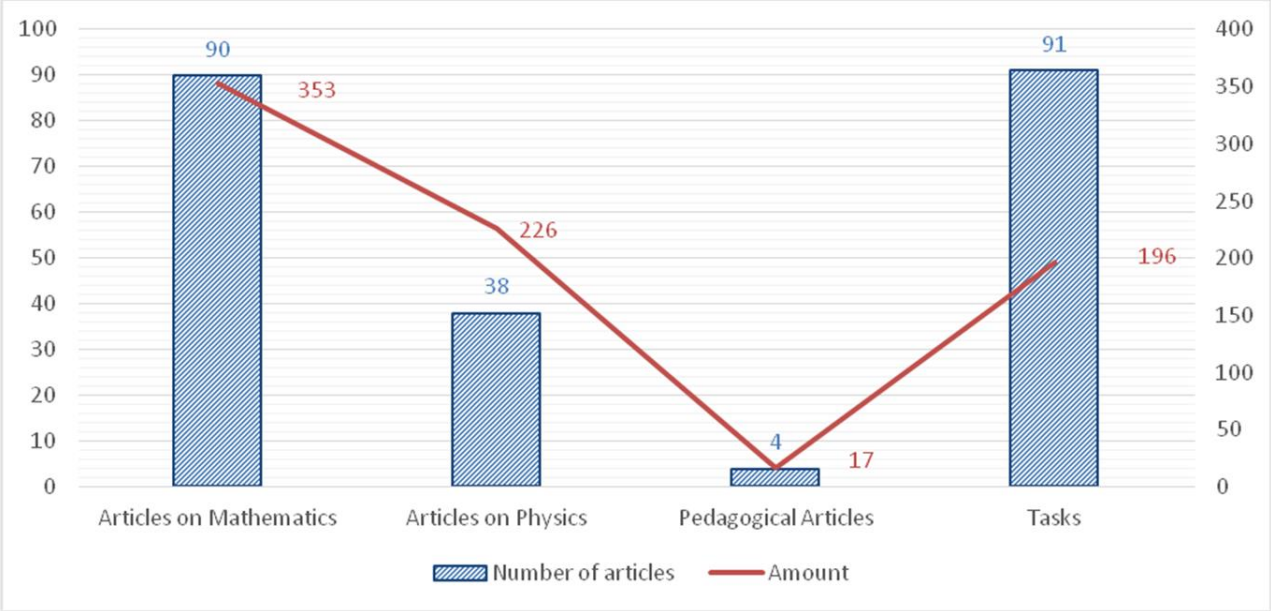

Figure 1. Total volume and number of articles of the “Journal of Elementary Mathematics” by category.

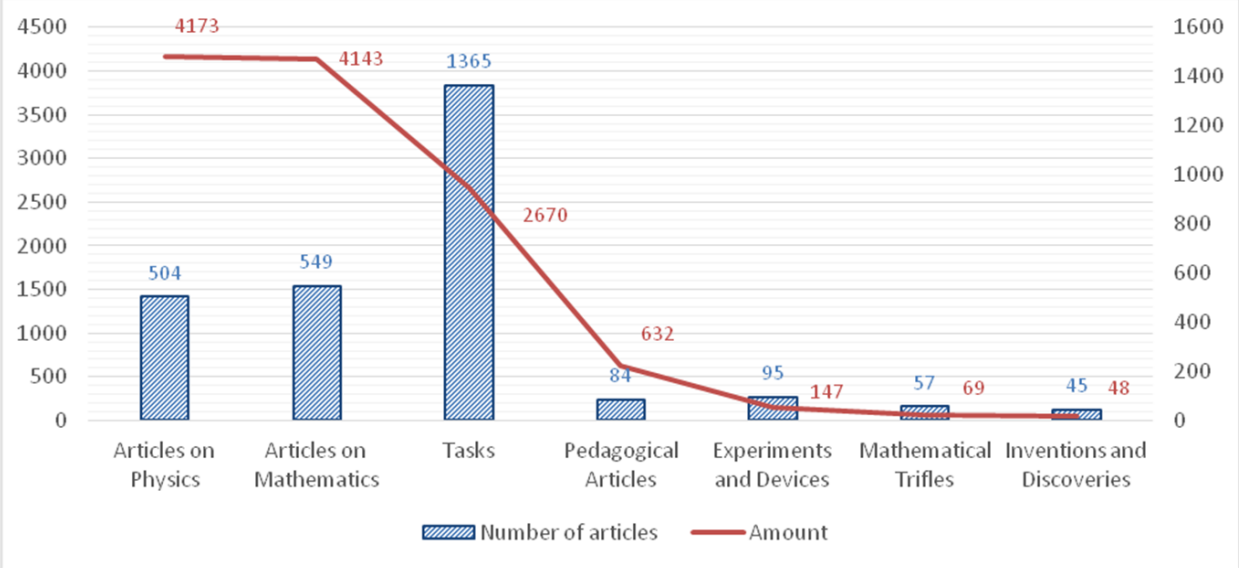

Figure 2. Total volume and number of articles of the Bulletin by category.

The median values of the distribution of the volumes of publications by the years of publication of the Bulletin according to the specified categories of articles are as follows: “Articles on Physics” – 147, “Articles on Mathematics” – 143, “Problems” – 89, “Pedagogical Articles” – 10, “Experiments and Devices” – 2, “Mathematical Trifles” and “Inventions and Discoveries” – 0.

The time series of changes in the total volume of publications of natural and mathematical materials and the technology of their teaching in the "Journal of Elementary Mathematics" (1884–1885) and in the "Bulletin of Experimental Physics and Elementary Mathematics" (1886–1917) is shown in fig. 3.

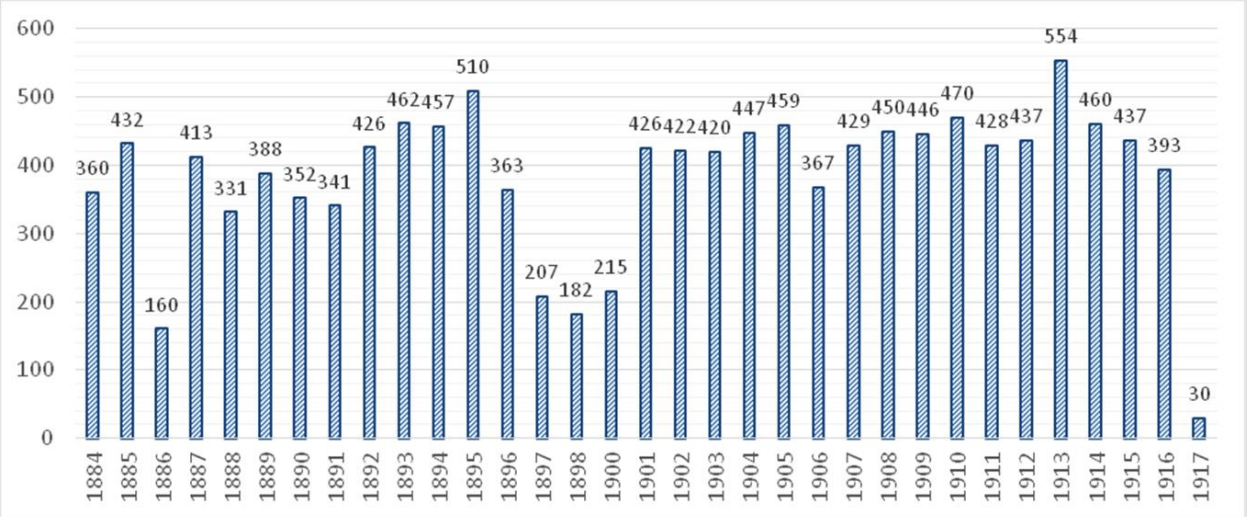

Figure 3. Time series of the dynamics of changes in the volume of natural and mathematical materials in the "Journal of Elementary Mathematics" and in Bulletin (1884–1917).

The time series of the dynamics of changes in the number of articles on natural and mathematical disciplines and the technology of their teaching in both magazines is shown in fig. 4.

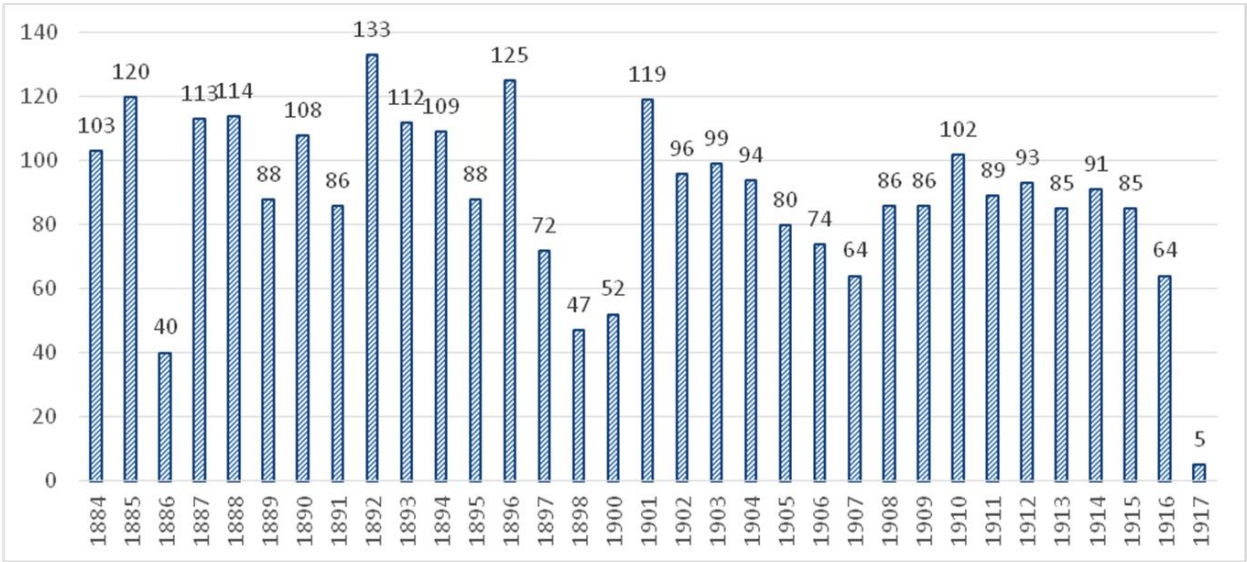

Figure 4. Time series of the dynamics of changes in the number of natural and mathematical materials in the "Journal of Elementary Mathematics" and in the Bulletin (1884–1917).

The time series of changes in the total volume of the "Pedagogical Articles" category in the "Journal of Elementary Mathematics" (1884–1885) and in the "Bulletin of Experimental Physics and Elementary Mathematics" (1886–1917) is shown in fig. 5.

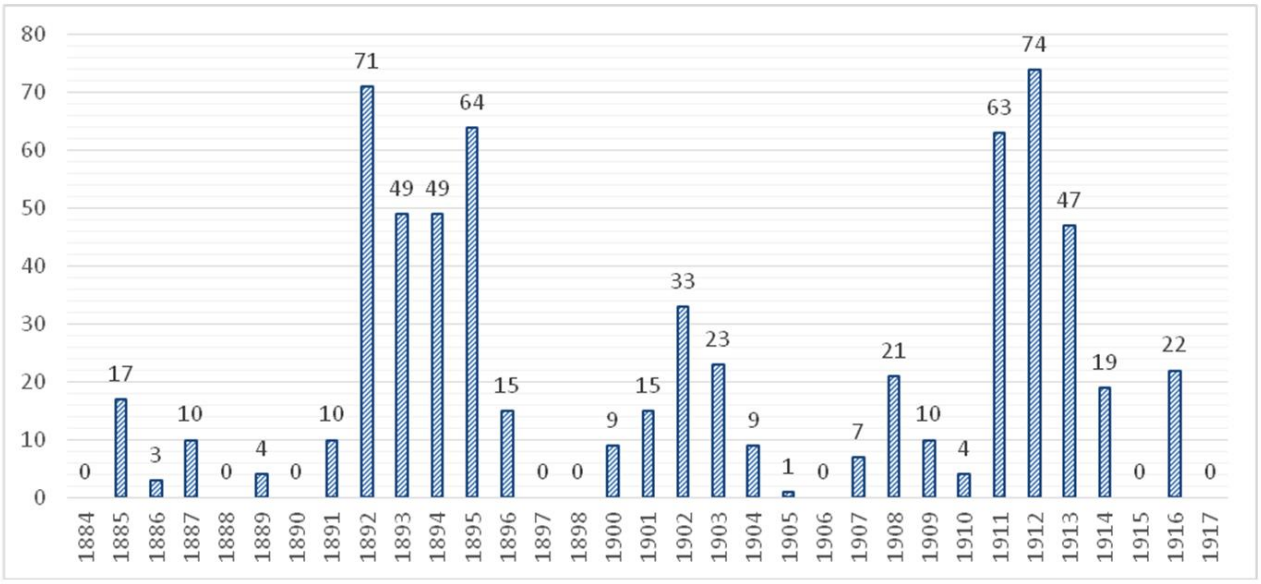

Figure 5. Time series of the dynamics of changes in the volume of materials in the "Pedagogical Articles" category in the "Journal of Elementary Mathematics" and in Bulletin (1884–1917).

The time series of the dynamics of changes in the number of materials in the "Pedagogical Articles" category in both journals is shown in fig. 6.

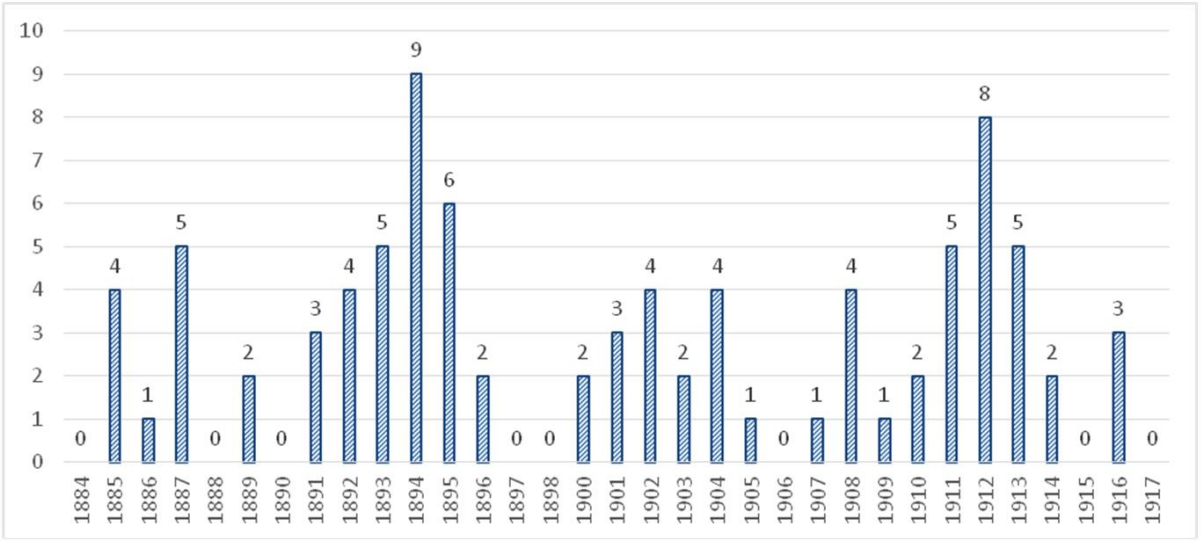

Figure 6. Time series of changes in the number of materials in the "Pedagogical Articles" category in the "Journal of Elementary Mathematics" and in Bulletin (1884–1917).

Almost 190 books (including reprints) were published by the "Mathesis" Publishing House during the 20-year period of its operation. We divided the entire volume of his book production into categories: "Mathematics", "Physics",

"Astronomy", "Biology", "Chemistry", "Geography", "Natural Science", "Philosophy", "Technology", "Meteorology", "Geodesy", "Spectroscopy". The number of published books and their total volumes by defined categories are shown in fig. 7.

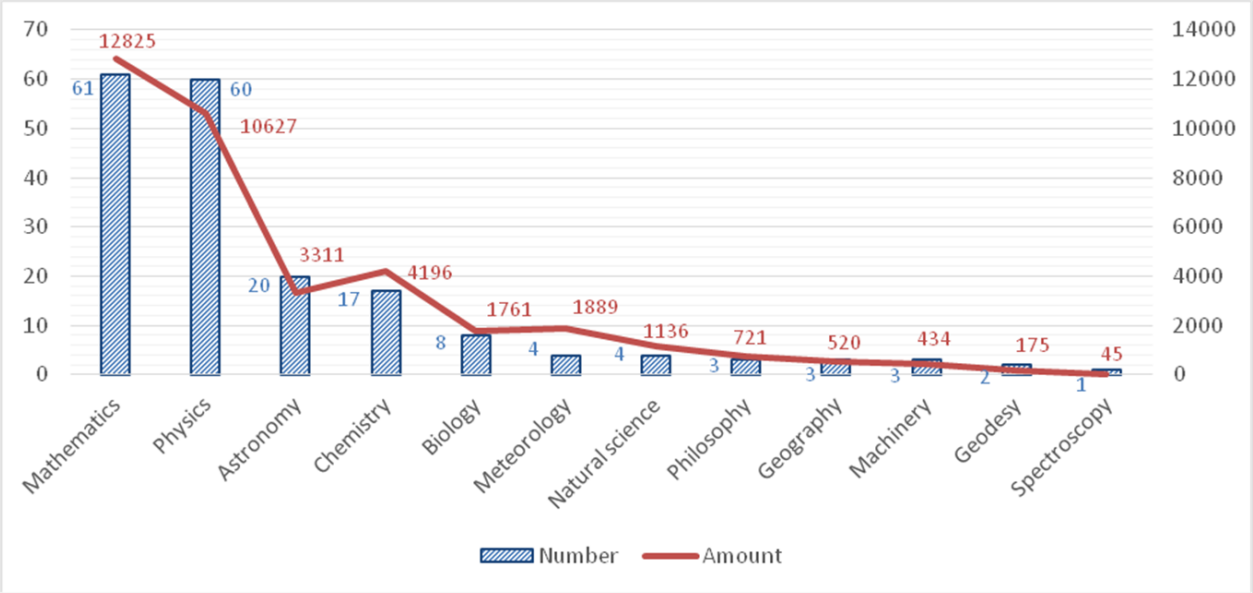

Figure 7. The number of books of the "Mathesis" Publishing House and their total volume by specified categories (1905–1925).

The median values of the distribution of volumes of books on natural and mathematical topics by years of operation of the publishing house according to the defined categories are shown in fig. 8.

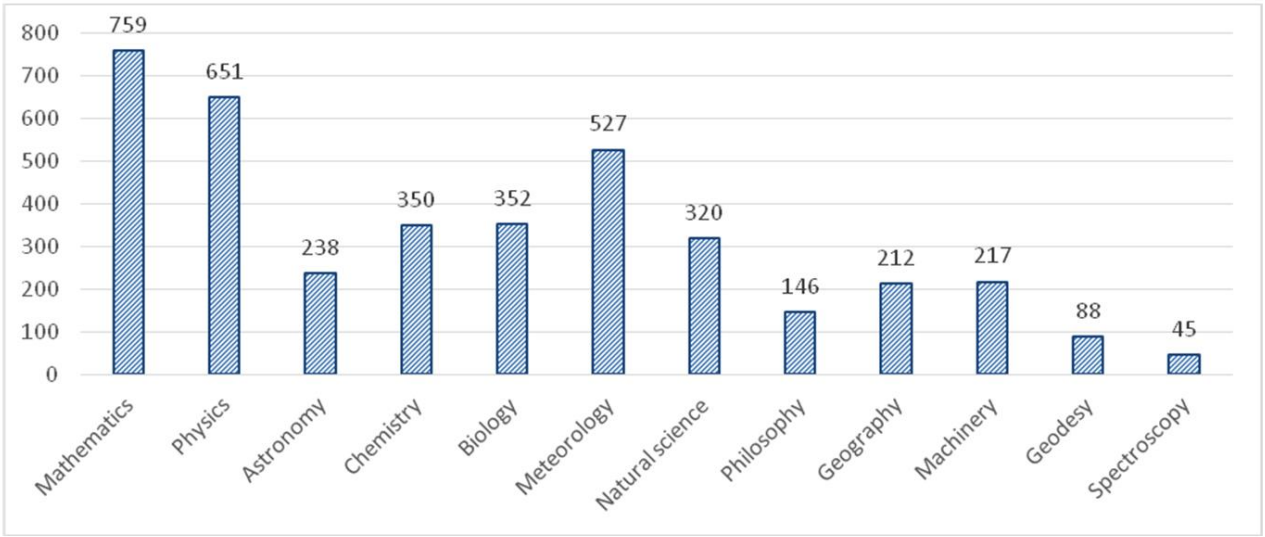

Figure 8. Median values of the distribution of the volumes of publications on natural and mathematical topics according to the defined categories ("Mathesis" Publishing House, 1905–1925).

The time series of changes in the number and corresponding volumes of publications in the field of natural and mathematical sciences and the technology of teaching natural and mathematical disciplines in the secondary school of the "Mathesis" Publishing House during the entire period of its operation is shown in fig. 9.

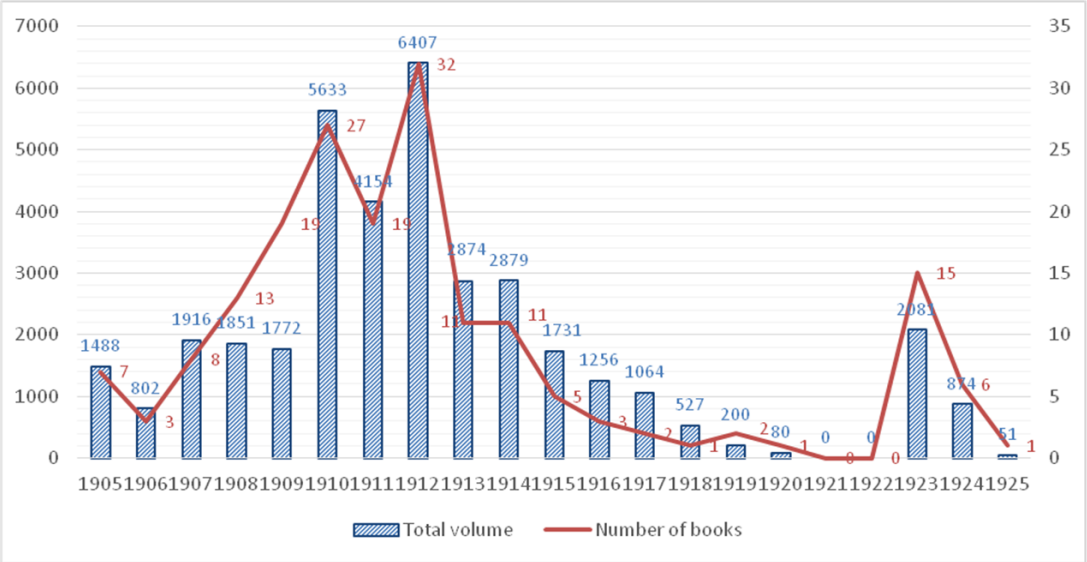

Figure 9. Time series of the dynamics of changes in the number and total volumes of publications on natural and mathematical topics of the "Mathesis" Publishing House (1905–1925).

The time series of changes in the number and total volume of books published by the "Mathesis" Publishing House, which were directly intended for the education of secondary school students (textbooks, manuals, pedagogical publications, popular science literature), during all the years of the publishing house's operation, is shown in fig. 10.

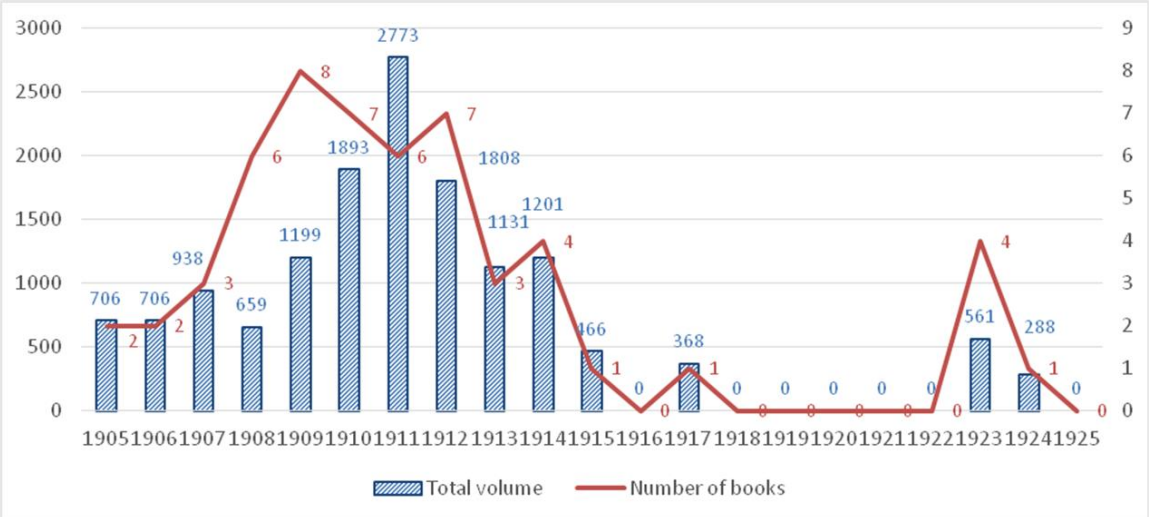

Figure 10. Time series of changes in the dynamics of the number and total volumes of books for teaching high school students ("Mathesis" Publishing House, 1905–1925).

Discussion.

Let's highlight some positions that arose in the process of conducting research. *First of all*, taking into account the peculiarities of the formation of learning technology, we will specify the positioning of the role of the publications analyzed in the article in the context of the generally accepted wording of the names and content of the stages, the passage of which ensures the formation of a body of knowledge into science. The global formation of the technology of natural and mathematical disciplines as a science went through several key stages, each of which had its own time frame and special meaning (Goncharenko, 2011):

1. At the initial stage (the middle of the 17th – the end of the 18th century), the main ideas and principles of didactics were formed (John Amos Comenius, "The Great Didactics" of 1657, the foundations of general didactics), the first attempts to systematize knowledge about learning and teaching natural and mathematical sciences appeared discipline, the study of mathematics and natural sciences is beginning to be integrated into educational programs.

2. The stage of the formation of methodological approaches (beginning – mid-19th century) is characterized by the active development of methods of teaching natural and mathematical disciplines (the works of Johann Heinrich Pestalozzi and Friedrich Froebel), the creation of the first textbooks and methodical guides in mathematics and natural sciences, the development of pedagogical education in European countries provided teacher training.

3. The stage of scientific substantiation of technology (late 19th – early 20th century) is characterized by the emergence of pedagogy as a science (the works of Herbert Spencer and John Dewey), specialized methodological schools appear, curricula, textbooks and methods of teaching mathematics and natural sciences are developed, the first empirical studies of the effectiveness of various teaching methods.

4. At the stage of institutionalization and development of technology (mid-late 20th century), the technology of natural and mathematical disciplines acquires the characteristics of an independent scientific field, departments and institutes are opened, scientific research is conducted, technology is integrated with other scientific fields, such as cognitive psychology, sociology of education, computer science.

5. At the current stage (late 20th – early 21st century), the role of information and communication technologies in education is increasing, new theoretical approaches to teaching are emerging, international cooperation in the field of technology of natural and mathematical disciplines is expanding, research is focused on adapting education to the needs of various groups of students, development of critical thinking and a creative approach to learning.

The educational system of the Russian Empire at the end of the 19th and the beginning of the 20th centuries was based on advanced European achievements. But, obviously, social cataclysms of this period, which were an integral part of imperial policy – wars with neighbors, uprisings, revolutions – had a powerful influence on educational processes. As a result, material support for educational reforms was implemented according to the residual principle. A clear proof of such a state policy is the actual complete lack of support for both periodicals and publishing houses, which

implemented the state policy regarding quality and comprehensive training of the young generation in the field of natural and mathematical sciences. The last thesis is confirmed by the results of the substantive analysis we conducted, as well as the circulation of publications (by the standards of the time, the circulation of the magazines analyzed in the work, which reached 500–700 copies (with discounted prices for educational institutions), was considered sufficient to meet educational needs, and the publishing house's circulation of 1 000–2 000 copies made it possible to distribute educational and popular scientific literature not only on the territory of the Dnipro region). That is why the advanced publishing activity of the publications "Journal of Elementary Mathematics" and "Bulletin of Experimental Physics and Elementary Mathematics" and the "Mathesis" Publishing House in the territory of the Dnipro region (and beyond its borders as well) can be assessed as creating the necessary conditions for normative, substantive and methodical ensuring the transition period from the stage of formation of methodological approaches to the stage of scientific substantiation of the technology of teaching natural and mathematical disciplines in secondary school.

Second position. Quantitative analysis of the research subject showed that the vast majority of the materials of both periodicals and the "Mathesis" Publishing House were focused on mathematics and physics. However, among numerous articles and books, there was also a large amount of materials that were meaningfully related to Astronomy, Biology, Chemistry, and Geography. Moreover, a popular phenomenon of many works was ideas and contents of an interdisciplinary nature. And this, in our opinion, vividly reflected the positions of both magazine editors and publishing house management regarding the integrative features of the world system, regarding the integrity of the laws of nature, regarding the mathematization of its descriptions. It is also interesting to note the fact that there is a large amount of problem-based material, in terms of the number of articles and their volumes in journals (see figs. 1 and 2), and the number and volume of problem books and publishing house workshops (see Physics – (Abraham, 1905a, 1905b; Kolraush, 1914), Mathematics – (Dzyk, 1914; Orbinskiy, 1919; Rou, 1910), Chemistry (Biltts, 1910; Sheyd, 1907), Technique (Venelt, 1923) and etc.) convincingly testifies to the editors' convictions (*V. P. Yermakov, V. P. Shpachinskyi, V. F. Kagan, E. L. Bunytskyi*) regarding the importance of the problem material as a crucial component of students' mathematical and scientific training.

Third position. All the time series of our research (see figs. 3–6, 9, 10) confirm the thesis formulated above about the colossal impact of social cataclysms and subjective conditions on the effectiveness of the creative activity of editorial teams of publishing institutions. The change of the editorship and name of the "Journal of Elementary Mathematics" to the "Bulletin of Experimental Physics and Elementary Mathematics", the relocation of the Bulletin's editorial office to Odesa, the revolutionary upheavals of 1905 and 1917, and the World War I – all this radically affected the number and volume of publications of the Bulletin and the productivity of "Mathesis". This caused a reduction in publications of educational literature, a decrease

in opportunities for organizational, substantive, and methodical support of the educational process. As a result, it led to educational losses.

There is no conditional form of statements in the story. But – if there were no obstacles, what would education be like, what would society be like? Would the forward movement really be powerful and decisive? Is it possible that losses are the payment for hope and the incentive for future accelerations?

Conclusions.

A meaningful and quantitative analysis of the results of the activities of the "Journal of Elementary Mathematics", "Bulletin of Experimental Physics and Elementary Mathematics" and the "Mathesis" Publishing House regarding their role in the formation of the technology of teaching natural and mathematical disciplines as science allows us to formulate the following conclusions.

1. During 1886–1925, on the pages of authoritative publications of the then Russian Empire, which functioned on the territory of the Dnipro region – "Journal of Elementary Mathematics", "Bulletin of Experimental Physics and Elementary Mathematics" and in the book editions of the "Mathesis" Publishing House, the ideas of science teaching technologies were actively developed – mathematical disciplines, the contents of textbooks and methodical manuals in mathematics and natural sciences were published and discussed, the peculiarities of teacher training were analyzed, methodical schools of prominent scientists and methodologists were started and fixed, curricula were reviewed. This shows that thanks to the activities of both magazines and publishing houses, real conditions were created for meaningful and technological provision of the transitional period from the stage of formation of methodological approaches to the stage of scientific substantiation of the technology of teaching natural and mathematical disciplines in high school in the global context of its formation as a science.

2. Social upheavals caused by the imperial policy of the state affected the productivity of both magazines and publishing houses. Moreover, neither the magazines nor the publishing house received state support. But the total volumes of publications, the total number of their articles and books, the quality of execution and the breadth of coverage of the content of natural and mathematical disciplines testify to the ability of the editors to carry out the planned measures for the production of meaningful and methodical support for teaching and the distribution of popular science publications to motivate a wide range of young people (and older members of the population) to study Mathematics, Physics, Astronomy, Biology, Chemistry and Geography. This is evidenced by the high level of activity of magazines and publishing houses during the "quiet" periods of their operation, median productivity indicators, as well as the total volumes of publication and distribution of literature.

3. Both journal editors and the management of the publishing house were aware of the important role of practice in the study of natural and mathematical disciplines. In general, for all analyzed institutions, more than a quarter of the volume of all publications was allocated for problem material and laboratory practicals.

4. Articles and books of a methodological nature became an important component of the publications, in which the peculiarities of the teaching technology were revealed, the subject terminology was clarified, discussions were organized about teaching models, the peculiarities of the speeches of famous mathematicians and natural scientists at various level congresses and congresses were highlighted, and the pedagogical and scientific heritage was disseminated famous scientists.

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Conflicts of interest.
The authors declare no conflict of interest.

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Природничо-математичні видання Наддніпрянщини кінця XIX – початку XX століття: Становлення технології навчання як науки

Анотація. *У статті визначена роль «Журналу елементарної математики», «Вісника дослідної фізики та елементарної математики» й видавництва «Матезіс» у трансформації сукупності знань про технології викладання природничо-наукових дисциплін у науку. При організації дослідження для змістовного аналізу його предмету використовувався аналіз інформації видань та узагальнення поданих у публікаціях елементів природничо-математичних знань і систематизація описів технології викладання природничо-математичних дисциплін. У процесі проведення кількісного аналізу використовувалися квантифікація тексту, збирання емпіричних даних, їх узагальнення та математико-статистична обробка. У результаті проведеного дослідження матеріалів обох журналів та продукції видавництва «Матезіс» протягом всього періоду їхнього функціонування автори дійшли таких висновків.*

По-перше, протягом 1886–1925 рр. на сторінках авторитетних видань тодішньої Російської імперії, які функціонували на території Наддніпрянщини – «Журналу елементарної математики», «Вісника дослідної фізики та елементарної математики» й книжкових виданнях видавництва «Матезіс» – активно розвивалися ідеї технологій викладання природничо-математичних дисциплін, видавалися та обговорювалися змісти підручників та методичних посібників з математики та природничих наук, аналізувалися особливості підготовки вчителів, започатковувалися й фіксувалися методичні школи видатних науковців та методистів, рецензувалися навчальні програми. Це свідчить про те, що завдяки діяльності обох журналів і видавництва створювалися реальні умови для змістовного й технологічного забезпечення перехідного періоду від етапу формування методичних підходів до етапу наукового обґрунтування технології викладання природничо-математичних дисциплін в середній школі у глобальному контексті її формування як науки. Сумарні обсяги видань, кількість їхніх статей та книг, якість виконання та широта охоплення змістового наповнення природничо-математичних дисциплін свідчать про здатність редакцій виконувати заплановані заходи щодо продукування змістовного та методичного забезпечення викладання та розповсюдження науково-популярних видань для мотивації широких верст молоді (і старших представників населення) вивчати математику, фізику, астрономію, біологію, хімію та географію. Обидві редакції журналів та керівництво видавництва усвідомлювали важливу роль практики у вивченні природничо-математичних дисциплін – за всіма аналізованими інституціями більше четвертої частини обсягу всіх видань було виділено для задачного матеріалу та лабораторних практикумів. Важливим компонентом публікацій стали статті та книги методичного характеру, в яких розкривалися особливості технології навчання, уточнювалася предметна термінологія, організовувалися дискусії щодо моделей навчання, висвітлювалися особливості виступів відомих математиків та природодослідників на різного рівня з'їздах та конгресах, поширювалася педагогічна та наукова спадщина відомих вчених.

Ключові слова: *навчально-наукова періодика; видавництво; технологія навчання; природничо-математичні дисципліни; наука*

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The history of cryotechnologies in reproductive medicine: From randomness to stability

Abstract. *The article provides an overview of the historical milestones in cryobiology, a scientific field that has found widespread practical application in reproductive medicine. Cryotechnologies have revolutionized assisted reproductive technologies, offering invaluable tools for the storage, protection, and management of reproductive cells such as sperm, oocytes, and embryos. The technology began with the first successful attempts at sperm cryopreservation, which not only demonstrated the possibility of preserving male gametes but also inspired a wave of research aimed at developing cryopreservation protocols for more sensitive and complex biological entities, including oocytes and preimplantation embryos. Cryopreservation has become a crucial component of fertility preservation, offering new opportunities for*

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individuals and couples facing medical treatments that could compromise their reproductive potential, as well as providing options for delaying parenthood. Given the critical role of cryotechnologies in modern reproductive medicine, this article delves into the historical context of these developments, exploring the key breakthroughs that have shaped this field. The authors conducted an in-depth analysis of existing literature, drawing on a wide range of scientific databases to highlight the global impact of cryobiology on the current successes in reproductive medicine. Furthermore, the article presents the results of the authors' own research and practical experience in the field of reproductive cryobiology, with a particular focus on the application of these technologies in Ukraine. The review underscores the challenges and opportunities that have emerged throughout the history of cryopreservation, as well as ongoing efforts to improve and optimize these methods to further enhance infertility treatment outcomes. The discussion also addresses ethical and logistical considerations related to cryopreservation, particularly in the context of long-term storage and future use of cryopreserved materials. As cryobiology continues to evolve, its integration into reproductive medicine will undoubtedly lead to further innovations, making it a cornerstone of infertility treatment and reproductive health worldwide.

Keywords: *cryopreservation; vitrification; slow freezing; thawing; in vitro fertilization; assisted reproductive technologies*

Introduction.

Over the past decades, we have witnessed a paradigm shift in the use of assisted reproductive technologies (ART), driven by the convergence of technological advancements, optimization of patient preparation protocols, and an increasing demand for infertility treatment services (Petrushko, Piniaiev & Yurchuk, 2021). Concurrently, there has been a development in cryotechnologies: from experimental stages to their modern innovative applications in reproductive medicine, which stands as a testament to the scientific ingenuity and perseverance of hundreds of talented cryobiologists and cryomedics. By offering innovative solutions for fertility preservation, cryotechnologies have profoundly transformed the field of reproductive medicine, elevating its efficiency to a higher level.

Cryotechnologies play a key role in preimplantation genetic diagnosis and preimplantation genetic screening, as cryopreservation enables genetic analysis and the subsequent selection of a healthy embryo for transfer into the uterine cavity (Giuliano, Maione, Vallefuoco, Sorrentino, & Zuccarello, 2023).

Thanks to donor gamete banks, unique micromanipulations are possible: the transfer of the second polar body, the oocyte nucleus, or the pronuclei of zygotes into a donor oocyte, which is crucial for therapies aimed at replacing defective mitochondria (Smeets, Sallevelt, & Herbert, 2023).

Future technologies in the field of genome editing are impossible without the use of cryotechnologies (Zhu, 2022).

Low-temperature storage ensures the long-term viability and integrity of biological material, which is important for the success of advanced biomedical technologies, contributes to improved patient outcomes, and advances assisted

reproductive technologies.

But the future is impossible without the present. And the present is based on past experience.

The aim of this work is to explore the historical stages of the development of cryotechnologies in reproductive medicine, their impact on current practices, and future prospects in the context of infertility treatment and fertility preservation.

The main objectives of the study include:

1. Analyzing key historical events and discoveries in the field of cryopreservation of reproductive cells and tissues.
2. Examining the evolution of cryopreservation technologies for gametes and embryos.
3. Assessing the impact of the latest cryotechnologies on the development of modern infertility treatment methods.
4. Identifying the main challenges and prospects for the advancement of cryotechnologies in reproductive medicine.

Research methods.

The methodology of the research is based on literature search in scientific databases (Scopus, Web of Science, Pubmed, Google Scholar, MedLine, Embase, Cochrane Library, ScienceDirect) about chronology and milestones of cryobilogical techniques for reproductive medicine.

Results and Discussions.

Sperm Cryopreservation.

The first mention of reproductive cells storing at low temperatures was recorded in 1776. At that time, an Italian cleric and scientist, L. Spallanzani (1729–1799), who studied male gametes, reported the immobilization of sperm placed on ice (Ledermann, 2020). This gave rise to the idea of freezing the sperm of Italian soldiers so that their wives, in the event of their husbands' death in war, could still have a child together.

It should be noted that until the first half of the 20th century, the effects of low temperatures on cells were mainly studied empirically. In 1938, B. Luyet (1892–1965) and E. Hodapp (1907–1996) reported the first successful attempt at vitrification of frog sperm using a 0.2 M sucrose solution (Luyet & Hodapp, 1938). B. Luyet was the first president of the World Society for Cryobiology. In 1940, he, together with his sister, published a book titled "Life and death at low temperatures".

By 1945, many scientists attempted to cryopreserve the sperm of various animal species, but they were unable to preserve its fertilizing ability. Significant cellular damage was caused by ice crystals formed during the cooling of cells. To solve this problem, specific substances were added to the solution in which the cells were frozen. These substances helped prevent the formation of ice crystals inside the cells and lowered the freezing temperature. Such substances are called cryoprotectants, and besides protecting against damage caused by cryopreservation factors, they must have low toxicity for the cells. Glycerol turned out to be an effective cryoprotectant for sperm, with its cryoprotective properties discovered in 1949. While studying the

movement of rooster sperm by adding a few drops of glycerol to a Petri dish, K. Polge (1926–2006) observed an unexpected effect from freezing sperm in liquid nitrogen – the cells remained viable. He described the result of his "accidental" observation in the scientific journal "Nature" (Polge, Smith, & Parkes, 1949). Like many other great discoveries, the protective property of glycerol was discovered by mistake. A sperm sample was treated with Meyer's solution, traditionally used to fix smears before staining, which was apparently mislabeled as fructose. Using glycerol, K. Polge and his colleagues successfully froze and thawed bird and bull sperm, achieving viable sperm cells after thawing. This breakthrough enabled the successful freezing and thawing of sperm without significant loss of viability, laying the foundation for the development of human sperm cryopreservation.

K. Polge's experiments were further developed by Dr. J. Sherman, who is considered the first to successfully cryopreserve human sperm. In 1953, he established the world's first cryobank. He was able to inseminate a woman with thawed donor sperm and achieve a successful pregnancy. At that time, the American legal system prohibited the insemination of women with donated sperm, as it was considered "contrary to public policy and good morals". Therefore, the news of the birth of a child using cryopreserved sperm was not disclosed until 10 years later (Sherman, 1963).

During this period, scientists were also studying the properties of other substances in reducing the destructive power of ice crystals during the freezing of biological specimens. In 1959, J. Lovelock (1919–2022) and M. Bishop (1922–1984) discovered the protective properties of dimethyl sulfoxide (DMSO) (Lovelock, 1954). The advantages of this new cryoprotectant lay in its greater permeability through cell membranes compared to glycerol. In 1964, a dedicated group of scientists founded the International Society for Cryobiology, aimed at promoting research on the effects of low temperatures on all organisms, organs, tissues, and cells (Pegg, 2002). One of the members of this society was the founder of reproductive cryobiology, P. Mazur (1928–2015). In the 1960s and 1970s, P. Mazur determined the permeability characteristics of cell membranes for water and cryoprotectant solutions (Pegg & Kleinhans, 2016). In 1972, P. Mazur outlined the main postulates and basic characteristics of the biological and physical processes that occur during the gradual freezing of living objects. This theoretical framework, which became known as the "two-factor theory of P. Mazur", states that there are two main factors that damage cells during freezing: 1) intracellular ice crystals; 2) high concentrations of salts, which increase when extracellular water begins to crystallize and the salt ions end up in the smaller volume of supercooled water outside the ice. Considering these factors, P. Mazur concluded that excessively rapid cooling destroys cells due to the formation of intracellular ice. On the other hand, excessively slow cooling damages cells due to the toxicity of increasing salt concentrations and mechanical external damage. Thus, P. Mazur's research results became the biophysical basis for experiments in the cryopreservation of human gametes and embryos. Based on the "two-factor theory", scientists have proven that the extent of cell damage depends on the permeability coefficient of the cell membrane for water molecules and cryoprotectants, as well as the cooling rate.

It was established that protocols optimal for one type of cell were ineffective for another. The methods for cryopreservation of mammalian reproductive cells could not be extrapolated to human gametes due to their distinct anatomical, physiological, and biochemical properties (Arav, 2014).

During the 1960s and 1970s, researchers refined cryopreservation methods for different cell types, optimizing freezing and thawing protocols. Sperm banks were created to provide long-term storage for individuals seeking to preserve their fertility. Over the decades, researchers improved cooling and warming methods, developed new cryoprotectants, and designed new cryocontainers, which expanded the applications of cryotechnologies. However, the problem of low fertilization rates after using cryopreserved sperm remained. Cryopreserved sperm was characterized by lower motility and fertilizing ability (see Figure 1).

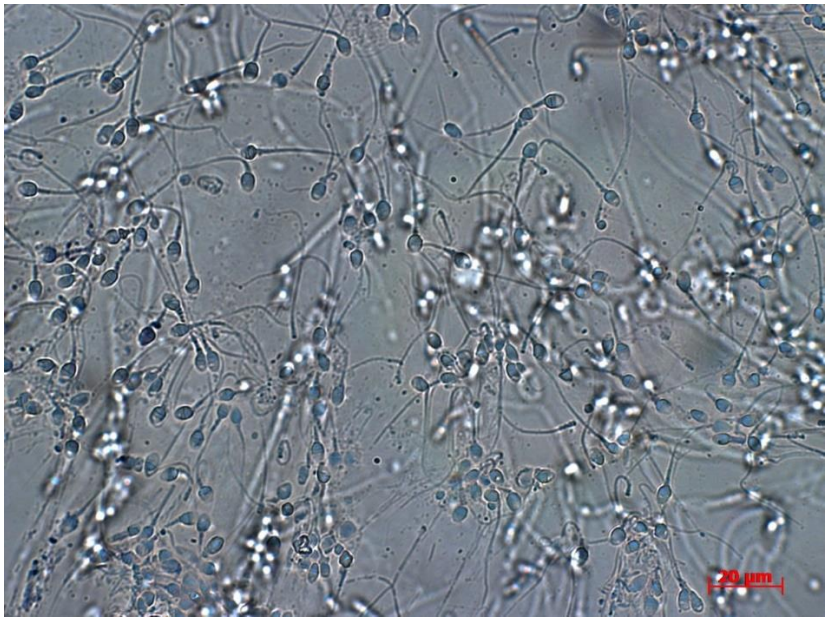

Figure 1. Human spermatozoa after cryopreservation (Author's source).

This issue was addressed in 1995 with the introduction of the innovative method of intracytoplasmic sperm injection (ICSI) (Palermo, Joris, Devroey, & Van Steirteghem, 1992).

This development not only enhanced the effectiveness of infertility treatments but also provided new ways to utilize genetic material previously considered infertile. The discovery of ICSI spurred the development of methods for cryopreservation of single sperm obtained through testicular and epididymal biopsy (see Figure 2). Such sperm were predominantly cryopreserved using the vitrification method. Vitrification is a rapid freezing technique that converts biological specimens into a glass-like state without forming ice crystals.

The first successful vitrification of human sperm was reported by a group of scientists from the University of Cologne (Nawroth et al., 2002). This vitrification technique led to the first pregnancies through intrauterine insemination of a patient with severe oligoasthenozoospermia, with the first live births worldwide recorded in 2012 (Isachenko, Rahimi, Mallmann, Sanchez, & Isachenko, 2011). Researchers

continue to investigate and propose new, original approaches to cryopreserving sperm from men with spermatogenesis pathology (Petrushko et al., 2021).

Figure 2. A Petri dish for ICSI (Author's source).

Cryopreservation of Human Oocytes and Pre-Implantation Embryos.

The technology for oocyte cryopreservation has developed over the past few decades, overcoming numerous scientific and technical challenges. The concept of oocyte cryopreservation emerged in the 1970s and 1980s. Early experiments focused on understanding the viability of oocytes after freezing and thawing (see Figure 3).

However, these initial attempts faced significant problems due to the unique cellular structure of oocytes, making them particularly sensitive to ice crystal formation and other damage during the freezing and thawing processes.

The first method developed for oocyte cryopreservation was based on slow freezing (see Figure 4).

This technique involved gradually lowering the temperature of oocytes in the presence of cryoprotectants. Despite some success, the slow freezing method often resulted in low survival rates due to ice crystal formation and cellular damage (Tharasanit & Thuwanut, 2021).

It wasn't until 1986 that a birth was reported following oocyte cryopreservation using the slow freezing method (Chen, 1986). The protocol involved gradually adding chilled DMSO to the oocytes, lowering the temperature to –7°C to induce ice formation, then further lowering the temperature to – 36°C at a rate of 0.5°C per minute. The oocytes were then transferred to liquid nitrogen at –196°C for storage. Despite significant progress with the slow freezing procedure, by the late 1990s, the pregnancy rate following embryo transfer from frozen oocytes was only 1–2% (Stachecki & Cohen, 2004). Due to the very low success rate of this method (5 pregnancies in 10 years), experimental research activity in this direction decreased.

Figure 3. Human oocyte after cryopreservation (Author's source).

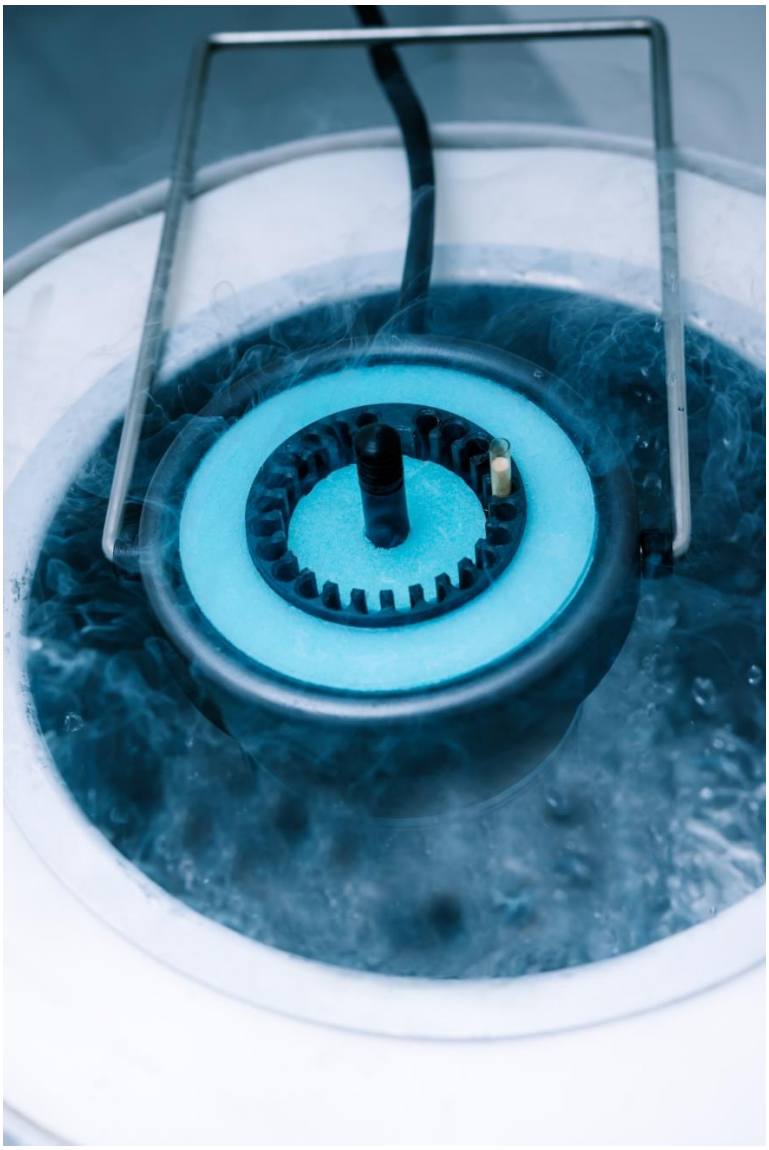

Figure 4. A cryochamber with a straw plunged in liquid nitrogen to oocytes slowly cool (Author's source).

The vitrification technique, which emerged later, represents a breakthrough in oocyte cryopreservation. This method has significantly improved the survival rates and developmental potential of cryopreserved oocytes, leading to higher pregnancy rates and better clinical outcomes. Researchers continue to explore and refine vitrification protocols to enhance their efficacy and reliability, making it a preferred method in reproductive medicine today (see Figure 5).

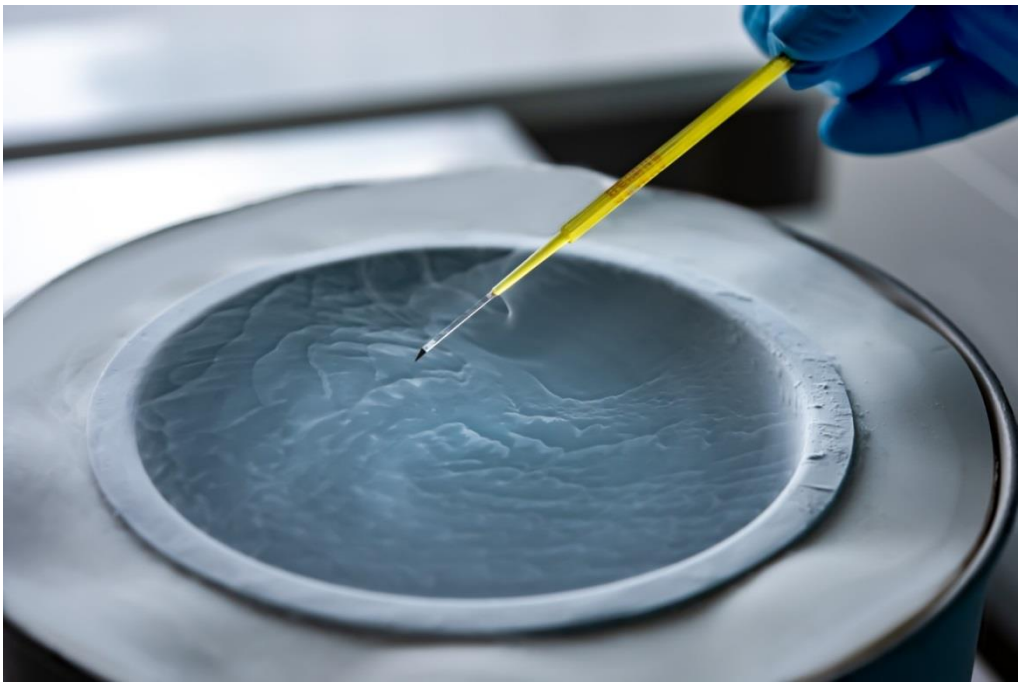

Figure 5. Cryodevice with oocytes before plunging into liquid nitrogen (Author's source).

The birth of a healthy girl was reported in 1999 (Kuleshova, Gianaroli, Magli, Ferraretti, & Trounson, 1999). Oocytes were vitrified in a highly concentrated cryoprotectant solution (40% w/v ethylene glycol and 0.6 mol/L sucrose) and placed into open straws, then submerged into the liquid nitrogen -196 °C. Rewarming was conducted in a sucrose solution at 37 °C.

The Cryotop method was developed in 2005, using an open carrier for the cryopreservation of both oocytes and embryos (Kuwayama, Vajta, Kato, & Leibo, 2005) (see Figure 6).

The Cryotop method became the preferred choice of many embryologists worldwide, with open carriers being the most widely used devices. By the early 2010s, vitrification according to the Kuwayama-methods had become the gold standard for oocyte cryopreservation.

Numerous fertility clinics worldwide began offering egg freezing services, and this technology was increasingly used for various clinical indications, including oncofertility (preservation of fertility for cancer patients) and elective fertility preservation (for women delaying childbirth for personal or professional reasons).

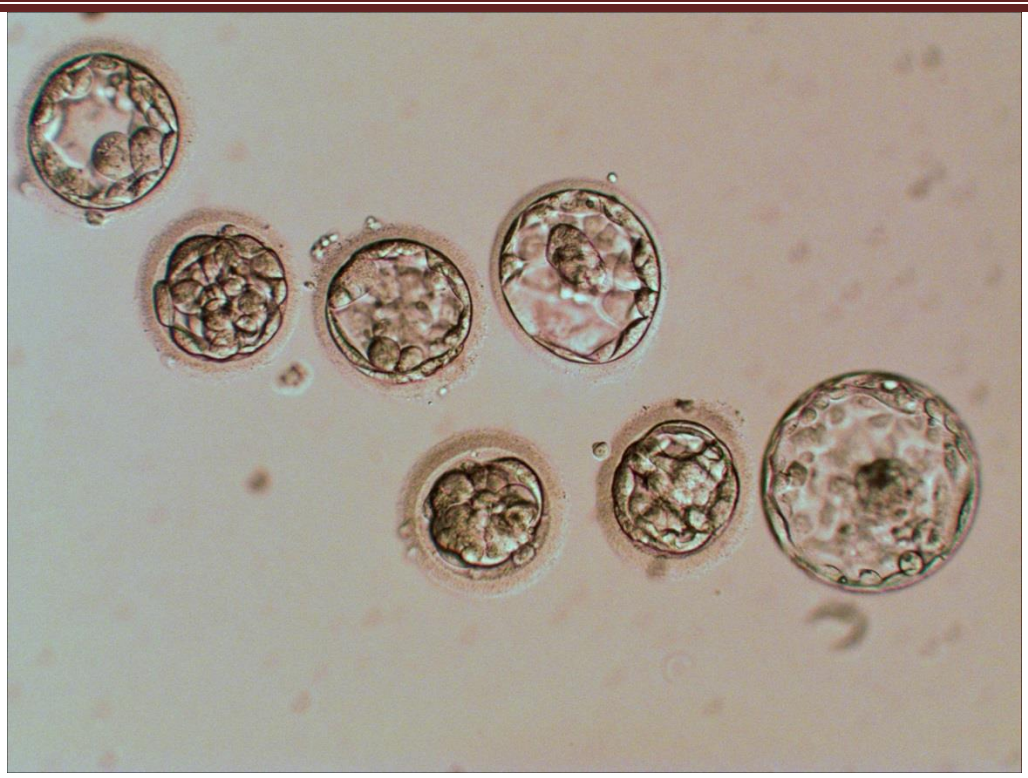

Figure 6. Human embryos of pre-implantation stages of development (Author's source).

Most cycles of infertility treatment using oocyte cryopreservation technology were conducted in Italy, as this country had laws prohibiting the freezing of human embryos (Porcu et al., 2004). In July 2006, a group of Italian scientists led by K. Oktay published a statistical analysis of the effectiveness of ART cycles with cryopreserved oocytes obtained from clinics in the country (Oktay, Cil, & Bang, 2006). They reported that the pregnancy rate following embryo transfer into the uterine cavity using slow frozenoocytes was 29.4%, while it was 51% with vitrified oocytes. A meta-analysis in 2006 of oocyte cryopreservation outcomes revealed a low incidence of pregnancies following ART cycles with frozen-thawed oocytes. The effectiveness of oocyte cryopreservation methods increased only in 2011, after five years of active fundamental research into cryodamage and cryoprotection of oocytes, the development of freezing and thawing protocols, and the search for safe cryoprotectants (Cobo & Diaz, 2011).

In 2000, the Department of Health in the United Kingdom allowed the use of frozen oocytes for infertility treatment but set a maximum storage period of 10 years in liquid nitrogen to prevent the negative impact of background radiation on the oocyte genome. In 2013, following the publication of results from randomized controlled trials conducted between 2008 and 2010 (Cobo, Meseguer, Remohí, & Pellicer, 2010; Rienzi et al., 2010), the American Society for Reproductive Medicine (ASRM) changed the status of oocyte cryopreservation technology from “experimental” to “clinical practice” due to identical main embryological parameters and pregnancy rates following embryo transfer into the uterine cavity using freshly retrieved and frozen-

thawed oocytes. This approval further confirmed the effectiveness of oocyte cryopreservation technology and encouraged its broader use.

Researchers have sought to improve existing cryopreservation protocols by attempting to automate the process (Brunetti et al., 2021). However, semi-automatic devices for gamete and embryo vitrification have not yet gained widespread adoption in clinical practice.

The history of embryo cryopreservation technology has been complex due to moral, ethical, legal, and religious controversies. The first pregnancy following the transfer of a slow frozen embryo was achieved as early as 1983 (Trounson & Mohr, 1983), although this pregnancy ended in miscarriage at ten weeks. The first child birth resulted from the transfer of a slow frozen embryo was on March 28, 1984, at the Queen Victoria Medical Centre in the United Kingdom (Zeilmaker et al., 1984). Ultra-rapid freezing of embryos was first applied in 1987 (Trounson, Peura, & Kirby, 1987). In 1985, the first child was born from a blastocyst embryo (Cohen et al., 1985), and in 1996, an embryo from a woman's natural cycle before chemotherapy was successfully cryopreserved (Brown, Modell, Obasaju, & King, 1996).

The history of reproductive cryomedicine has also seen unusual cases. For instance, in 2009, a 33-year-old American woman, Nadya Suleman, gave birth to six boys and two girls. Her doctor irresponsibly transferred twelve thawed embryos obtained from previous stimulated IVF cycles into her uterus. The California medical board deemed the transfer of such a large number of embryos a "practice that threatens life" and denied the doctor a license.

The history of reproductive cryobiology in Ukraine.

The birthplace of cryotechnology in Ukraine is undoubtedly the Institute for Problems of Cryobiology and Cryomedicine of the National Academy of Sciences of Ukraine (IPC&C NAS of Ukraine) on February 25, 1972. This institution is unique not only in Ukraine but worldwide, as it comprehensively develops and improves methods for hypothermic and low-temperature preservation of various types of cells, tissues, and even organs. Based on fundamental research results under the leadership of academician of the NAS of Ukraine Valentin Grischenko (1928–2011), the first service for artificial insemination with cryopreserved reproductive cells was established in Ukraine at the Department of Obstetrics and Gynecology of Kharkiv Medical University (Lytvynova, Trishch, & Terenda, 2023).

The first report of successful cryopreservation of a human embryo and the birth of a child was made in 2002 by a team of scientists from the cryobiology of reproduction systems department at the IPC&C NAS of Ukraine. In a favorable cycle, thawed embryos were transferred into the uterine cavity, and the patient became pregnant. Nine months later (on August 25, 2003), a healthy full-term boy was born (Grischenko, Petrushko, Gerodes, Terpyachaya, & Gurina, 2003).

Today, researchers at the IPC&C NAS of Ukraine are developing various methods to improve the outcomes of cryopreservation of sperm, oocytes, and human embryos, taking into account individual characteristics and the specific stages of their development (Petrushko, Yurchuk, Buderatska, & Piniaiev, 2018; Petrushko, Yurchuk,

Piniaiev, & Buderatska, 2019; Yurchuk, Likszo, Witek, Petrushko,& Skarzynski, 2024) (see Figure 7).

Figure 7. An employee of the IPC&C NAS of Ukraine working in cryo-storage (Author's source).

Every year, more than 30,000 children are born worldwide from cryopreserved oocytes and embryos (Han & Seifer, 2023).

The 21st century marked the first successful outcomes of cryopreservation of reproductive tissues. In Belgium, after autologous orthotopic transplantation of cryopreserved ovarian cortex, a healthy child was born (Donnez et al., 2011). However, the scientific community questioned the source of pregnancy. It was unclear whether the pregnancy resulted from fertilization of oocytes from the transplanted tissue or from

the reactivation of the dormant ovary. In 2000, scientists first transplanted human ovarian tissue after freezing and prolonged storage (Oktay & Karlikaya, 2000). In 2004 reported the first childbirth after orthotopic transplantation of cryopreserved ovarian tissue (Donnez et al., 2004). In 2006, a group of American scientists successfully cryopreserved human ovaries with their vascular pedicle (Bedaiwy, Hussein, Biscotti, & Falcone, 2006).

The successful cryopreservation of human testicular tissues was first reported by Belgian scientists. They demonstrated that thawed testicular tissue could maintain cellular ultrastructure, tubule morphology, and tissue function (Baert et al., 2013).

The prospects for the use of cryotechnologies in the field of ART are primarily seen in genetic diagnostics and genome editing. Cryotechnologies can be employed for the long-term preservation of DNA samples, cells, or embryos, allowing for genetic testing and diagnostics at any stage. This enables the detection of genetic diseases or mutations even before birth, which is crucial for treatment planning (Simpson, Kuliev, & Rechitsky, 2019). Additionally, cryotechnologies can be integrated into genome editing processes, such as CRISPR/Cas9, to preserve edited cells or embryos, positively impacting reproductive health and the development of personalized medicine.

Thus, the history of the development of cryotechnologies in reproductive medicine demonstrates significant progress from experimental research to widespread clinical application. Despite the successes achieved, questions regarding the efficiency and safety of these methods remain the subject of active scientific debate.

One of the main issues is the impact of cryopreservation on the long-term viability of gametes and embryos. Despite significant progress since the discovery of the cryoprotective properties of glycerol and other substances, cryopreservation is not an entirely risk-free procedure. The reasons for this are related to various scientific aspects, including physical, biochemical, and genetic phenomena that occur during the freezing and thawing of cells.

Additionally, the scientific community continues to discuss the ethical considerations of using cryotechnologies in reproductive medicine. Notably, the issue of storing and disposing of surplus embryos not used in ART cycles is a topic of debate (Ethics Committee of the ASRM, 2021).

Another important aspect of the discussion is the social and legal implications of using cryotechnologies. For example, the cryopreservation of oocytes to preserve fertility in women who delay childbirth for personal or professional reasons elicits mixed reactions. On the one hand, this method provides women with greater freedom in planning their lives, but on the other, it raises questions about social expectations and pressures that may compel women to freeze oocytes due to fears of age-related fertility decline (Bolton, Hayden, Robinson, Abdo, & Pericleous-Smith, 2023).

Despite all achievements, cryotechnologies remain a field for ongoing scientific research, ethical debate, and legal regulation. Therefore, it is important to continue research in this area, with the goal of not only improving fertility preservation methods but also ensuring their safety and ethical justification.

Thus, in the context of the historical foundations of reproductive cryobiology, our study highlights certain aspects that should be considered when analyzing key stages in the development of this field. Specifically, we place greater emphasis on the influence of historical circumstances and scientific discoveries on the formation of cryopreservation approaches, whereas other authors (Iussig et al., 2019) focus on specific technical aspects. This distinction underscores the multifaceted nature of the topic under study and the need for a comprehensive approach to researching the history of cryobiology methods in reproductive medicine.

We hope that in the future, scientists will make many more discoveries in the field of cryopreservation of reproductive cells, pre-implantation embryos, tissues, and organs. Fundamental research in cryobiology and cryomedicine, molecular biology, genetics, physics, biochemistry, and physiology will uncover new mechanisms of cryoresistance and cryosensitivity of bioobjects at different levels of organization and create new cryotechnologies to ensure the birth of a healthy child.

Conclusions.

Based on the study, it can be concluded that cryotechnology has played a decisive role in the advancement of reproductive medicine. The history of cryopreservation of sperm, oocytes, and preimplantation human embryos illustrates the relentless pursuit of scientific innovation, evolving from the randomness of early accidental successes to the stability of today's sophisticated vitrification techniques. Each new and pioneering approach to cryopreservation has brought significant improvements in fertility preservation and the effectiveness of ART. This evolution has enabled millions of people to fulfill their dream of having healthy children. As cryotechnology continues to progress, future advancements promise not only to further enhance the effectiveness and accessibility of cryopreservation but also to offer renewed hope for those aspiring to parenthood.

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Conflicts of interest.

The authors declare no conflict of interest.

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Історія кріотехнологій у репродуктивній медицині: Від випадковості до стабільності

Анотація. *Стаття містить огляд історичних віх кріобіології, наукової галузі, яка знайшла широке практичне застосування в репродуктивній медицині. Кріотехнології зробили революцію в допоміжних репродуктивних технологіях, надаючи безцінні інструменти для зберігання, захисту та управління репродуктивними клітинами, такими як сперматозоїди, ооцити та ембріони. Технологія почалася з перших успішних спроб кріоконсервування сперматозоїдів, які не тільки продемонстрували можливість зберігання чоловічих статевих клітин, але й надихнули хвилю досліджень, спрямованих на розробку протоколів*

кріоконсервації більш чутливих і складних біологічних об'єктів, включаючи ооцити та передімплантаційні ембріони. Кріоконсервування стало важливим компонентом збереження фертильності, пропонуючи нові можливості для окремих осіб і пар, які стикаються з медичним лікуванням, яке може поставити під загрозу їхній репродуктивний потенціал, а також надаючи варіанти для відстрочення батьківства. Враховуючи критичну роль кріотехнологій у сучасній репродуктивній медицині, ця стаття заглиблюється в історичний контекст цих подій, досліджуючи ключові прориви, які сформували цю сферу. Автори провели поглиблений аналіз існуючої літератури, спираючись на широкий спектр наукових баз даних, щоб підкреслити глобальний вплив кріобіології на сьогоденні успіхи репродуктивної медицини. Крім того, у статті представлено результати власних досліджень та практичний досвід авторів у галузі репродуктивної кріобіології з особливим акцентом на застосуванні цих технологій в Україні. Огляд підкреслює проблеми та можливості, які виникали протягом історії кріоконсервації, а також поточні зусилля щодо вдосконалення та оптимізації цих методів для подальшого покращення результатів лікування безпліддя. Обговорення також стосується етичних і матеріально-технічних міркувань, пов'язаних із кріоконсервуванням, зокрема в контексті тривалого зберігання та майбутнього використання кріоконсервованих матеріалів. Оскільки кріобіологія продовжує розвиватися, її інтеграція в репродуктивну медицину, безсумнівно, призведе до подальших інновацій, зробивши її наріжним каменем лікування безпліддя та репродуктивного здоров'я в усьому світі.

Ключові слова: *кріоконсервація; вітрифікація; повільне заморожування; розморожування; екстракорпоральне запліднення; допоміжні репродуктивні технології*

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Karl Popper's "Critical Rationalism": The way to freedom and democracy

Abstract. *In the history of science, there are known cases when people come into life whose vocation is to make a series of discoveries, which then change the scientific views of entire generations. The name of the philosopher Karl Popper became world-famous during his lifetime, because the achievements of this scientist impress with the originality and boldness of ideas, a high level of scientific knowledge and the scale of world perception. The article is devoted to the analysis of the life and activities of the outstanding philosopher and sociologist of the 20th century. Karl Raimund Popper, who was best known for his scientific works on the methodology and philosophy of science, as well as social and political philosophy. It is shown that his logical concept of the growth of scientific knowledge, which he began to develop in the 20s of the 20th century became the basis for the creation of the principle of falsification, which he proposed as a criterion for demarcation between science and pseudoscience. It is noted that in the following logical and methodological works of the scientist, a transition is observed in the field of scientific research of the scientist from logical and methodological problems of epistemology or the theory of scientific knowledge to the general theory of knowledge and evolutionary epistemology, as well as a transition from already obtained results to socio-political problems. The process of formation of the theory of critical rationalism was highlighted, which was that any theory, hypothesis, scientific knowledge should be as objective as possible and not depend on the opinion of individual people or communities. An analysis of the scientist's works in the field of social philosophy was carried out, which were based on the concepts of scientific knowledge and cognition developed by him. It has been studied that such a concept as "historicism" takes an important part in the formation of a totalitarian*

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society, and the utopian ideas of Marxism, socialism and communism only lead to the inhibition of the development of any society. K. Popper's position on this issue is highlighted. The difference between an open and a closed society, which is traced in the scientist's scientific heritage, is reflected. And the impact of K. Popper's scientific heritage on the modern realities of Ukraine and the entire democratic world in the conditions of an international armed conflict is also determined.

Keywords: *Karl Popper; history of philosophy; philosophy of science; principle of falsification; critical rationalism*

Introduction.

In the history of science, there are known cases when people come into life whose vocation is to make a series of discoveries, which then change the scientific views of entire generations (Haig, 2024; Mansouri, 2024; Strelko, Pylypchuk, O. Ya., & Pylypchuk, O. O., 2024). The name of the philosopher Karl Popper became world-famous during his lifetime, because the achievements of this scientist impress with the originality and boldness of ideas, a high level of scientific knowledge and the scale of world perception.

In Ukraine, the scientific works of Karl Popper are known to a small circle of philosophers and researchers. This was primarily caused by the presence of Ukraine throughout almost the entire 20th century. in the Soviet Union, where the doctrine of Marxism-Leninism and the socialist socio-political system prevailed. And K. Popper was an ardent opponent of Marxism, which, in fact, determined the attitude of his scientific heritage among scientists of the Soviet Union in general and in Ukraine in particular. Researcher of Karl Popper's work V. S. Lisovyi wrote on this occasion: "The significance of Karl Popper's theory in the context of philosophical ideas of the 20th century. so great that the interest in them goes beyond professional. In addition, if for a Western reader K. Popper's ideas today do not always retain the character of novelty, for a Ukrainian reader familiarity with these ideas is relevant. This is explained by the fact that the so-called "materialist dialectic", supported in the thinking of both naturalists and social scientists, establishes a kind of such stereotypes, the sources of which are sometimes very deep: they cannot be overcome by a simple denial of Marx's philosophy" (Lisovyi, 1994, p. 4–5). The main directions of his scientific activity were scientific studies (methodology and philosophy of science) and social philosophy. Scientific theories of the scientist – the principle of falsification and critical rationalism at one time gained powerful development, became the basis of the scientific school of K. Popper and the basis for the formation of postulates of the scientist in the field of social philosophy. And his ideas were so bold that they affected the interests of both well-known scientific doctrines and entire nations.

At first glance, it may seem that the scientific legacy of Karl Popper has long been studied and cannot be the object of scientific research. Regarding his scientific views, scientists are divided into two camps: the first supports and develops the scientific legacy of K. Popper, the second constantly refutes and criticizes it (Scruton, 1994; Agassi, 2014; Reynolds, 2023). And this is not surprising, because scientists love recognition. Who would like the results of his scientific activity to be refuted? Karl

Popper was far from vanity and spent his whole life in search of the truth, which is why he questioned certain scientific theories. He longed for the truth. But the influence of his ideas continues to this day. In many European cities there are groups of people – his followers, especially philosophers. Karl Popper became the founder of a powerful scientific school, which only develops over time. After all, with the help of his scientific theories, you can study the past and the present, you can confidently look into the future.

The phenomenon of K. Popper is that his scientific views are relevant at any time. And if there are important socio-political changes in society that affect the interests of every citizen, then it is time to turn to the postulates of this outstanding scientist in order to understand what is happening. To consider the main theoretical positions of the scientist, to show the influence of his scientific concepts on society, as well as to analyze their significance for modern times is the main goal of this article.

Research Methodology.

When writing the article, we used generally accepted approaches, principles and methods of scientific research (Pylypchuk & Strelko, 2020; Pylypchuk, O. Ya., Strelko, & Pylypchuk, O. O., 2021, 2022). The main methodological approach, which determines the holistic reflection of reality and the development of socio-historical practice, is the theory of cognition. Its application made it possible to understand and reproduce the history of K. Popper's scientific and practical activities and show the importance of his scientific heritage for modern times. After all, the theory of knowledge connects human cognitive abilities with the world-historical development of the general system of knowledge, reflected in the scientific and practical results of mankind. The historical approach made it possible to analyze the activities of the scientist in the relevant socio-political conditions and their influence on the results of his scientific work. The chronological approach helped to present the historical material in chronological order. The systematic approach made it possible to explore all areas of the scientist's scientific heritage. Therefore, it was possible to create a general picture of the development of K. Popper's scientific theories and ideas. The principle of historicism made it possible to consider the formation of K. Popper's scientific heritage as a final historical process that took place over time, in specific conditions and circumstances. After all, the principle of historicism is always applied to the consideration of phenomena that have a beginning and an end, and also studies the connection between certain phenomena in space and time in the context of the development of a single and gradual world-historical process. The principle of scientificity contributed to the clarification of the cause-and-effect relationship between the phenomena and processes of the studied period in the context of the development of historical events and facts. After all, it is the principle of scientificity that makes it possible to acquaint contemporaries with the events of the past, and also shows the prospects for the development of science. The principle of multifactoriality united a number of different factors, socio-political and economic events, which became the basis for determining the actual scientific questions and problems in K. Popper's scientific works. The principle of specificity made it possible to consider

the results of a scientist's scientific activity not as an abstract phenomenon, but as a combination of his scientific activity and concrete scientific results. This is an adequate expression of the scientific heritage of a scientist who worked in a certain period, in a certain place and in a certain field of science. The application of general scientific methods of analysis and synthesis made it possible to investigate the process of development of science and social philosophy in the first half of the 20th century in the scientific works of K. Popper and combine separate information, facts and events into a general picture. The methods of induction and deduction, on the basis of previously presented evidence, made it possible to draw appropriate conclusions. The methods of abstraction, concretization and generalization contributed to the elucidation of certain scientific concepts and statements within the historical development of the relevant field of science and social philosophy. The methods of reductionism and holism helped determine the role of K. Popper's scientific heritage within the general development of science and social philosophy.

Results and Discussion.

Karl Raimund Popper was born on July 28, 1902 in Vienna in the family of Simon Sigmund Karl Popper, professor of law at the University of Vienna, and Jenny Schiff. Karl's father was an educated man, a lawyer, a book lover, interested in philosophy, sociology, and politics. His circle of communication included many educated people, scientists, representatives of the liberal intelligentsia, in particular, he was a close friend of Sigmund Freud's sister, Rosa Graf. Mother was engaged in the cultural upbringing of the young future scientist, instilled in Karla a love for nature, art, the surrounding world and music, which became one of the forces of the development of his thought. The Popper family had a large library, so from a young age Karl got acquainted with scientific works on classical and social philosophy of such famous thinkers as Marx, Engels, Bernstein, Kautsky. After all, the father always discussed philosophy, sociology and political science with his son. That is why philosophy became a true vocation for the future scientist. Even before university, he was interested in the problems of the philosophy of education.

In 1918, Karl Popper entered the University of Vienna, where he studied mathematics and physics for 2 years. Philosophy and music were his personal passions. During his studies in the process of creative search, the future scientist mastered various professions: carpentry (mahogany carving), music (he studied for a year at the Vienna Conservatory), music history, psychology became an important hobby of the young Popper (Derksen, 2019). From 1921 to 1924, he worked as a volunteer in the children's clinics of Alfred Adler – a famous psychiatrist, psychologist, founder of the theory of individual psychology, which he created on the basis of the theory of psychoanalysis of Z. Freud. It was from that time, observing Adler's method, K. Popper continued his acquaintance with the scientific works of outstanding thinkers of our time, in particular such as Freud and Einstein, and for the first time began to think about scientific problems. For example, how do the new doctrines of Adler, Freud, and Marx differ from already recognized and empirically proven scientific theories, such as

Albert Einstein's theory of relativity. At one time, the scientist would base these reflections on his well-known principle of falsification (Popper, 2002).

The formation of the personality and scientific outlook of the young Popper took place in the conditions of a liberal-democratic environment in which, at the beginning of the 20th century, attention to social problems and society's inability to solve them was constantly growing. This determined, from a young age, his interest in social issues. At the same time, K. Popper was influenced by the atmosphere of interest in the epistemology of science, which reigned within the walls of the University of Vienna. This determined the future scientist's interest in the current problems of the philosophy of science.

Thus, scientific directions – methodology and philosophy of science, as well as social philosophy became the two main directions of K. Popper's scientific activity. In 1925, K. Popper received a diploma as a primary school teacher, got married and began his professional career as a teacher of mathematics and physics at a school. In 1928, he defended his doctoral dissertation on the topic: "Methodology of cognitive psychology". The greatest popularity of Karl Popper was brought by his logical concept of the growth of scientific knowledge, which he began to develop in the 20s of the 20th century. It was based on criticism of some provisions of logical positivism, a direction that arose in the 20s of the 20th century on the basis of the famous Vienna circle in philosophical circles.

It was the first half of the 20th century, that is, the period from 1917 to 1937, that formed Popper's main philosophical and sociological beliefs. Thus, in 1934, his first scientific work "The Logic of Scientific Knowledge" appeared, in which he proposed his logical theory of the scientific method. The main task of which he considered to be the search for a criterion of demarcation between science and pseudoscience. And as such a criterion, he proposed *the principle of falsification*, according to which one should look not for evidence of a scientific theory, but for methods of its refutation (Duggan, 2021; Uygun Tunç, Tunç, & Lakens, 2023). That is, for example, in the process of choosing two competing scientific theories, the verification of truth should be carried out not by proving them, but by refuting them.

Such ideas of the scientist were at odds with the ideas of logical empiricism of the Vienna circle, which were widespread at that time in Western Europe, which led to active discussions and clashes. K. Popper was never a member of the Vienna Circle, he did not accept their idea that any scientific idea or theory must be verified empirically, in particular with the help of the verification criterion - the procedure for checking the truth of knowledge. After all, logical empiricism aimed to develop a system of criteria for evaluating the quality of theoretical ideas (Hawkins, 2022).

Thus, Popper's falsificationism came into conflict with the verificationism of neopositivists. A good, simple and well-known example of the collision of these two theories is the idea of black crows. For example, someone claims that all crows are black. The principle of falsification refutes this statement, because in order to empirically prove it, it is necessary to check all living ravens today, all those who lived before, and all those who will be born and live (Walker, 2019). And this is impossible. It was because of such examples in life and science that logical positivism was

destroyed, because it was built exclusively on empirical research. And not everything in this life can be proven empirically. For example, Ch. Darwin's theory of the origin of species. It is still unproven. There are no intermediate species in paleontological science that would prove that man, for example, descended from a monkey. This theory is safe for society and is still dominant in science due to the fact that it is profitable and fills the white spot in science that arises from the question "Where did life really come from on Earth? ".

Until the 50s of the XX century. logical empiricism was the recognized leader of Western philosophical science. And when he later entered a period of deep crisis, K. Popper noted that he had killed logical positivism (Popper, 2002).

But let's go back to pre-war times.

In 1933, the National Socialist German Workers' Party led by A. Hitler came to power in Germany, which marked the beginning of Nazi Germany, which lasted for 12 ears. And although after the World War I, according to the Versailles and Saint-Germain peace treaties, Austria and Germany remained separate independent states, the government of Nazi Germany considered this situation unacceptable and sought to correct it. After all, Austria and Germany had the same language, history and closely related economic systems. Therefore, in 1938, during the negotiations between Hitler and Austrian Chancellor Kurt Schuschnigg, Germany announced an ultimatum to Austria, agreeing to which Austria would lose its sovereignty and independence.

On this occasion, the Austrian newspaper "Jewish Press" wrote: "The difficult international situation favors the actions of those people whose stars rise only at night. The power of justice, morality, ethics, humanity have become just fashionable meaningless words. The world bows down to those who rattle weapons and intimidate people... Contracts – those scraps of paper that solemnly guaranteed rights – are no longer valid" (Jewish press, 1938).

Pogroms and persecution of anti-fascists and Jews began throughout Austria. In his book "Yesterday's World: Memories of a European", Stefan Zweig wrote about it as follows: "Unlimited free will was given outside of man... Urban robberies, as you know, took place hundreds of years ago, during medieval wars, but there was shameless pleasure here from public torture, mental torture, sophisticated humiliations... In former times, what happened in the unfortunate Vienna would have been enough for an international boycott. In 1938, the world conscience was silent or only slightly complained" (Zweig, 1970).

The Nazis canceled the Austrian referendum on independence and held theirs for the Anschluss of Austria and Germany. This is how A. Hitler brought Nazism to his homeland. And in the wake of Nazism, anti-Semitism strode through the streets of K. Popper's native Vienna. Therefore, Jewish families were in a hurry to leave Austria. Foreseeing the dire consequences for his homeland, K. Popper emigrated to New Zealand in 1937, where he received a teaching position at Canterbury University College of the University of New Zealand in Christchurch (Kierstead, 2019). And although in the early period of his research activity, K. Popper focused his attention on the methodology of natural science, in the 30s and 40s of the 20th century he began to actively engage in social philosophy and the methodology of social sciences, the

impetus for which was precisely the political events in Austria in the 1930s of the 20th century. It was here, in New Zealand, during the World War II, that he wrote such famous scientific works on social philosophy as The Poverty of Historicism (1944) and The Open Society and Its Enemies (1945). He dedicated them to all the dead and injured people in the World War II.

After the end of the World War II in 1945, the scientist returned to Europe and settled in Great Britain, in London, and received citizenship. He worked as a professor at the London School of Economics and Political Sciences of the University of London, dean of the Faculty of Philosophy, Logic and Scientific Method. Here he continued his work on issues of science.

Thus, in 1963, the second logical and methodological work of the scientist "Assumptions and refutations: the growth of scientific knowledge" was published, in which, first of all, the scientist sums up certain results of the work already done and observes the transition in the field of scientific research of the scientist from logical and methodological problems of epistemology or the theory of scientific knowledge to the general theory of knowledge and evolutionary epistemology, as well as the application of already obtained results to socio-political problems (Popper, 2014).

Subsequently, in 1972, the third scientific work of the scientist in this direction was published – "Objective knowledge: an evolutionary approach", in which *the theory of critical rationalism* was formed, which consisted in the fact that any theory, hypothesis, scientific knowledge should be maximally objective and not dependent on the opinion of individual people or communities.

Working on this theory, the scientist took as a basis the scientific views of Thales of Miletus, an ancient Greek philosopher, the founder of the Ionian school of natural philosophy. He is also called the father of science. He encouraged the students of the school to improve their studies. Thus, students criticized their teacher and tried to improve his ideas. This was the beginning of a real history of ideas.

"Although rationalism, as I have described it, is still very rare in Europe, and can hardly perhaps be regarded as one of the characteristic religions of Europe, although the ideas of rationalism are discussed nowadays with great contempt by almost all intellectuals, nevertheless rationalism of Thales of Miletus is an idea and a tradition without which our European civilization would not exist at all. After all, nothing is so characteristic of our European civilization as the fact that it is exclusively a scientific civilization. It is the only civilization that created natural science, and in which science itself plays a decisive role. However, this natural science is a direct product of rationalism. It is a product of the rationalism of ancient Greek philosophy", the scientist wrote about this (Popper, 2013b, pp. 26–27).

Critical rationalism began to be applied during research, using methods of criticism, observation, consideration of contradictions and inconsistencies, calling for a critical, balanced, reasoned approach to any problem, using the policy of small steps (Haig, 2024; Mansouri, 2024; Sepetyi, 2024). After all, there is a big difference between just an opinion that is most convenient and acceptable for a person, and the same opinion, substantiated, proven and presented for public review. Critical rationalism gives the scientist the opportunity to independently check his scientific

hypothesis and prove its scientificity, opening up new opportunities for its study and development.

In this aspect, the scientist emphasized that knowledge in the subjective and objective sense differs significantly from one another, because subjective views and expectations always lose to objective facts and evidence. And in order to bring a scientific opinion to the level of dogma, it must be objectified, that is, empirically proven and substantiated through critical analysis. As the scientist wrote: "A critical attitude is a critically important innovation that makes science what it is. And this is achieved, first of all, with the help of an objective, open, scientific formulation of its theories. This usually leads to disagreements and thus to critical discussion. Debates can often go on for years... And we have no guarantees that every scientific discussion will necessarily lead to a solution. There are no guarantees of scientific progress" (Popper, 2013a, p. 26). From the point of view of scientific methodology, the scientist noted that new, bold ideas in science should not be cumulative, but revolutionary in nature. That is, not to supplement existing knowledge, but to replace earlier theories with new ones that will solve the same problems just as successfully, but on a different, more progressive level, going beyond the framework of old beliefs.

According to Popper, "it is not contagious for a scientist to have a refuted hypothesis behind his shoulders" (Popper, 2013a, p. 28), you need to gather courage and formulate it so precisely and convincingly that other scientists have a desire to deny it. And in this process, as you know, a unique truth can be born, a stunning result that the scientist does not even expect. This was precisely the colossal liberating power of Popper's teaching on the scientific method.

As we can see, K. Popper's critical rationalism implies a realistic view of the world. The scientist was convinced that realism could neither be proven nor disproved, but it could be argued. Realism is part of common sense, and it is very closely related to science. With the help of our theories, we can describe the existing objective reality around us. And the emergence of a critical method in the process of scientific research is a rather rare and unprecedented phenomenon, when such concepts as a realistic worldview and the idea of approaching the truth are combined into one. This is a necessary factor for understanding the idealizing nature of science. In addition, a realistic view of the world, according to the scientist, makes it possible to look at the world from the point of view of humanity and morality. This is how we can accept all the mistakes and shortcomings of the society in which we live.

Karl Popper was always a supporter of the unity of the scientific method. He argued that the same methodology should be used both in natural and social sciences. The goal of philosophy should be to invent the "ideal" language of science. K. Popper aimed to turn science into a single reliable basis for solving all problems. He sought to create the so-called "intellectual authoritarianism". In fact, he made an attempt to find defined limits of science, which would be combined with the tendency to turn the philosophy of science into a kind of ideology – the ideology of scientism.

The community of scientists is never in a situation of complete freedom, according to the scientist. It always deals with the already existing context of theories and ideas, against the background of which a new problem is solved. However, some

researchers of Popper's methodology believe that he failed to offer a sufficiently promising opposition to the existing conventionalism due to the scientist's refusal to assert the empirical base as the "firm" basis of science (Popper, 1979; Merritt, 2017; Duerr, 2023).

Of course, in modern science there are directions and scientific schools where idealism occupies a prominent place. But K. Popper believed that scientific theories filled with idealism necessarily contain the quality of error, no matter how close they are to the truth. The struggle for realism and objectivism is fully justified, because only it can lead scientific theory beyond its own limits and combine its scientific results with the problems of future generations. In general, in these works, the scientist focused on the analysis of the logical structure of the critical method of scientific knowledge – fallibilism – the teaching that any scientific knowledge is not final, but only an intermediate interpretation of the truth. In London, he created his powerful philosophical and scientific school, which was very popular in Europe, America and other continents. He retired in 1969, but continued to be active as a scientist and teacher until his death in 1994 (Popper, 2002).

The works of the scientist in the field of social philosophy, which he wrote at the end of the World War II and later, are of special importance for our research. Of course, works on social philosophy were read in Ukraine only by individual scientists, and there was no discussion of K. Popper's works. This is caused by the poverty of scientific libraries in Ukraine for philosophical works in foreign languages. Sometimes excerpts from the works of K. Popper were published by the journal "Philosophical and Sociological Thought" (Kyiv). Later, during the time of independent Ukraine, some of K. Popper's works were translated into Ukrainian. In these works, we see how the scientist's reflections on society, history, and politics are based on the concepts of scientific knowledge and cognition developed by him.

In the scientific work "The Poverty of Historicism", which was published in 1944, the scientist compares the concepts of "history" and "historicism". In his opinion, a healthy historian studies the past, draws conclusions for the future, is in search of historical truth, because all history is not only facts about events, but also their interpretation by historians of his time. The historian knows that the past influences the future, but he is convinced that no one knows the history of tomorrow.

And the historian believes that history can be created, it can be directed in a profitable way, it can be driven into a framework and controlled. Historians make sociology a powerful tool in the hands of politics. They actively develop social engineering at the level of large masses of the population, entire peoples and nations, using manipulation and propaganda. Usually, these are the methods of anti-democratic regimes that aim to artificially create such a society that a small handful of people who call themselves political power want and lead their people away from the truth.

Historians use history as prophecy, extracting from it precisely those facts that are advantageous to them, giving them a powerful meaning on a par with religion. For this, they use institutional means (state administration) in order to psychologically transform not only the entire country, but also each individual, to direct the development of society according to a defined plan.

History knows a number of scientific works of famous philosophers of different times who tried to create utopian ideas of an ideal state on the pages of their works: Plato "State", T. More "Utopia", T. Campanella "City of the Sun" and others.

History also knows totalitarian regimes, their development and end. History proves that any intervention in the nature of the development of society does not end in anything good. Society is a living organism that always fights for its natural development and social health. That is why the fate of tyrants is usually so cruel. At the appropriate moment, the social organism confronts the source of violence and neutralizes it.

The great mistake of historians is that, using social engineering to quench their political ambitions, they have no scientific practical experience, so the path of development of such a society is always one big experiment that cannot be repeated. And due to the fact that such experiments affect large masses of the population, it is almost impossible to learn from mistakes, because many events take place in a large society. It is impossible to understand what exactly caused this or that result. In this situation, it is impossible to combine social planning with scientific methods. After all, unlike power, knowledge cannot be centralized, it is divided among people (von Mises, 1999).

Therefore, the idea of historicists that society, like a physical body, can move in one predetermined direction is a utopia and a misunderstanding. After all, there are no laws of movement of society analogous to the laws of movement of physical bodies. In society, there are only trends in the development of society, which have the ability to change in different periods of time. To confuse laws and trends is a mistake that at one time became the basis for such great scientific theories as Marxism and Darwinism. There are no undeniable laws of biological evolution and irreversible laws of social movement.

Trends depend on conditions that need to be found and identified. But the historian does not want to be objective. He chooses exactly that trend or those conditions that he likes, by which he necessarily commits violence against the people. Historians always give some leader the main role in history. And according to his political direction, they write the history they need. They do not accept a large number of historical interpretations.

The main danger of this state of affairs is that it is simply impossible to check the results of such an experiment in advance. As K. Popper pointed out, an evolutionist who is convinced that it is possible to control human nature with the help of science, does not understand how impossible this requirement is, because the main driving force of evolution and development is the variety of material from which selection takes place. The same applies to society – every person in it has the right to his own individuality and uniqueness, to choose directions of movement and development, to form his values. It is this diversity of individuals that ensures the development of society. And control, which leads to equalization of minds, means the end of progress (Popper, 1966).

K. Popper's second well-known scientific work on political philosophy was the book "The Open Society and Its Enemies", in which he criticizes the theories of Plato,

Hegel, and Marx and accuses them of creating the ideological base of totalitarianism, and characterizes a closed society.

As an ardent defender of democracy, K. Popper had a very negative attitude towards Marxism and all the consequences it brought to European countries in the 20th century. In particular, socialism is a state-political system that looked quite good in theory, but taking into account human nature, in practice it became a despotism and threw the countries of socialism into a totalitarian regime.

Marxism simply crashed on the rocks of critical rationalism, because time has proven that this theory is unsustainable in human society. The socialist organizations of classical formation existing today in other states do not bring improvements to their countries. In our opinion, over time, not a single country with a socialist socio-political system will remain on Earth. After all, man, as a species, is a predator. Therefore, the best socio-political conditions for the development of humanity, although not the most simple, are democracy and capitalism. Man and the entire living world are created in this way. They do not develop and do not live long in conditions of infantile inactivity, which is actually what socialism promoted. Otto von Bismarck, a German politician known in history for uniting the independent German states around the Kingdom of Prussia into one large country – the German Empire – said very correctly in this regard: "Socialism can be built. The main thing is to find a country that is not sorry" (Popper, 2020).

K. Popper knew throughout his life that socialism would not last long, and he was right. In an interview with the German newspaper "Spiegel", he noted that such social experiments impose a great responsibility on those who created them for future generations. And first of all, for this you need to remove the glasses of ideology. Yes, the socialism that was built in the Soviet Union had little in common with the initial theories of K. Marx. After all, in his book "Poverty of Philosophy" in 1847, K. Marx wrote that the class struggle must end with a social revolution that will lead to the construction of a classless, communist society. Which is a priori impossible due to the corresponding class nature of humanity. This is exactly the mistake we mentioned earlier – don't confuse laws with trends.

But the most important delusion of K. Marx was that he considered capitalism in the West as a huge evil. And this became one of the postulates of the ideology of socialism – the fight against capitalism. Marxism, as a utopia, from the very first day chose violence as the main method to achieve its goals. Instead, everything happened quite the opposite.

"The Caribbean crisis clearly showed what Marxism was capable of in its ideology: it tried to destroy capitalism by force with the help of nuclear weapons. This should never be forgotten. As a result of this attack, not only America would die, the whole world would die in atomic bombings. Although this would last several terrible years", the scientist wrote (Popper, 2013b, p. 167).

At the end of K. Popper's life, in 1993, the publication "All Life – Solving Problems" was published in 2 volumes, in which he collected separate, in his opinion, the most interesting scientific articles and reports. In Volume 2 "Thoughts on History and Politics" he underlined a number of socio-political events of the 20th century. and

raised questions about peace and the possibility of war in our time, freedom, responsibility, the meaning of history, the importance of democracy in an open society (Mohammadi Alamuti, 2022). This scientific work became a kind of testament of the scientist for future generations, which was formed by him during the long years of life in the difficult times of the 20th century.

K. Popper called on the whole world to fight as hard as possible against nuclear weapons in the world. After all, the development of the hydrogen bomb by Academician Sakharov in Russia exceeds the bomb dropped on Hiroshima by many thousands of times. We cannot agree with this. It will just destroy the world. He believed that all civilized countries should fight against such crazy, otherwise you will not name them, politicians by creating an appropriate strike group – the use of nuclear weapons should be prevented by force. "For the sake of peace, we have to wage wars", the scientist noted (Popper, 2013b, p. 169).

K. Popper was convinced that the democratic world should do everything to ensure that such ideologies never seize power again. The enormous, years-cultivated aggression of the socialist world against capitalism led to the fact that the Soviet Union over the years accumulated a huge arsenal of weapons, including nuclear warheads. And all this was intended to fight the world that does not exist, with the illusion.

In this regard, he noted: "Capitalism" in the historical sense in which Marx used this concept has never existed in this world. There has never been a society with some internal development trend similar to Marx's law of increasing impoverishment or the hidden dictatorship of capitalists. All this was and remains an absolute illusion. I agree that life before the industrialization era was very difficult. However, industrialization also meant an increase in labor productivity, and the latter, in turn, meant mass production. Obviously, mass production eventually found its way to the masses. Marx's understanding of history, together with his predictions, is not only wrong – it is simply impossible: it is impossible to make a mass product for a small number of rich capitalists, which is constantly decreasing" (Popper, 2013b, p. 196).

The scientist emphasized that the capitalist world, of course, was never a paradise on earth. But it was much closer to paradise than the Soviet reality. And for disarmament, he proposed to follow the following plan, both in the field of international relations and internal social changes: more freedom, control over responsibility, world peace, the fight against poverty, the fight against the demographic explosion, the education of non-violence, and the limitation of bureaucracy.

From the point of view of modernity, this is a rather idealistic plan. But Karl Popper was a very courageous scientist and always set a high bar for his results. This character trait appeared in him at the age of 7, when he got acquainted with Fritjof Nansen's book "At night and in the cold. The Norwegian Polar Expedition 1893–1896", the author of which, after the World War I, became one of the founders of the League of Nations. This book about a 3-year stay among the polar ice sparked little Karl's interest in research, especially bold theories, and influenced his scientific activity throughout his life. F. Nansen's projects were built on rather risky ideas that were severely criticized by society, but F. Nansen developed his brilliant plan in such a way that the expedition was a success.

K. Popper wrote in his memoirs that even then, at the age of 7, he understood that success comes to those who put forward the most daring hypotheses and are ready to test them experimentally. That real science requires courage and responsibility, as well as constant discoveries. In particular, he noted that Ch. Darwin always claimed that you can't experiment without hypotheses, and F. Nansen generally said that an absurd idea is better than none at all. This is how the principle of falsification and critical rationalism was born. From the personality formed in childhood. K. Popper was not afraid to refute his own ideas. He was higher than vanity.

Yes, K. Popper loved the Western world. He considered it imperfect, of course, but the best of all political worlds existing in history. After all, in it, people choose political freedom precisely because it makes it possible to get such a life in which people can bear responsibility for themselves. They have the right to choose and the right to vote – which are key concepts of democracy.

A society in which freedom lives does not require self-proclaimed prophets who use dubious propaganda methods in their politics. K. Popper was always against the anarchic power of the people without observing the norms of democracy. After all, the uncontrolled power of the people gives birth to dubious philosophers, such as Fichte, Schelling and Hegel, leaders of German idealism, who led their country to an intellectual and social disaster. Tragedy that had a huge destructive and numbing effect on society.

"Unfortunately, the desire to impress others, not to teach, but to deceive, is too widespread among intellectuals. They act as leaders, as prophets, partly because prophecies are expected of them – they are expected as heralds of the unknown secrets of life, the world, peace and man, history and existence.

Here, as is often the case, constant demand, unfortunately, creates supply. Leaders and prophets are sought. And it is not surprising what they find. However, "grown-up people don't need leaders", as H. Wells once said, and grown-up people should also know that they don't need leaders" (Popper, 2013b, pp. 19–20).

After all, a healthy, free person needs a legal state that recognizes the needs and rights of every citizen. And it also needs protection. And the state, which takes upon itself the duty to defend its country, must also worry about the health and well-being of its citizens, so that they, in turn, are ready for defense. It must control the country's economy, because in the event of an armed conflict, large resources will be spent on it. And this is possible only in a democratic state. The difference between attack and defense cannot be leveled, and it is necessary to develop social institutions that distinguish between aggression and counter-aggression.

According to Popper, the political freedom of a country is possible when the rulers can do without bloodshed. And let's emphasize that this does not apply to the state with which the war was started, but to the state that started the war. In the aggressor state, political freedom does not exist in principle. Another question is how the nation allowed such a state of affairs. In our opinion, these are the features of the nation, its national character – features of temperament, expression of emotions, feelings, national superstitions, common habits, traditions, stereotypes, features and specifics of behavior, value orientations, needs and tastes, rituals. National character, first of all,

manifests itself as a system of socio-cultural and moral norms. And by starting a war, the aggressor state demonstrates to the whole world the level of development of this system. As K. Popper wrote, relying on the works of Spinoza: "The tyrant may always try to snatch our freedom, but he will never be able to take it away from us" (Popper, 2013b, p. 23).

We want to end our study with a quote from a prominent scientist, which has never been as relevant as it is now, since it was written. Never before have the words of K. Popper been perceived as so relevantly prophetic: "Never before have such a number of such terrible weapons been concentrated in so many irresponsible hands – a thousand times more than after two world wars. Our leading politicians are responsible to us for this situation and for putting up with it. We have to blame it on all of them…

After the wars, disarmament was discussed. Western democracies have made significant progress in disarmament. But they are the only ones. The League of Nations, and later, after the World War II, the United Nations, was founded on a wonderful idea – the idea that moral and military superiority obligates them to secure the world until others realize and learn their duty. No one doubts that we are on the verge of retreating from this position. We do not explain this to voters: we are afraid to sacrifice it. We avoid going into adventure, calling adventure what is our duty...

From the crimes of World War I, which led to the Kellogg Pact, and the crimes of World War II, which led to the creation of the United Nations, arose a rather powerful political movement of all men of good will. But what is gained by one generation may be lost by the next.

It is lost. And we have to revive the lost. We must remember our duty. And we have to remind our politicians that their death (or their resignation) does not relieve them of responsibility" (Popper, 2013a, pp. 8–11).

Conclusions.

History is being written now. The remnants of socialism, transformed for modern realities, are at war with capitalism, in their opinion. And this war is not only against Ukraine. This war is against the entire democratic world. The peculiarity and novelty of the totalitarian regime of the Russian Federation lies in the fact that it is trying to return to the past, and with the help of an armed conflict to drag long-independent, post-Soviet, modern countries there. And this, as we described earlier, is impossible. Totalitarian regimes with weapons in hand came against the democratic world. Another utopian idea of social engineering. Based on history, we understand that the results of this social experiment will lead to major changes in a number of countries and on the international arena. No one will make predictions and prophecies. The only thing we can say with confidence is that the democratic world will fight for victory until the end. Only we ourselves now, more than ever, influence our future. Karl Popper's critical rationalism and falsification principle will certainly work in this case as well. After all, as this outstanding scientist noted:

"Optimism is a duty. It is necessary to concentrate on things that should be done and for which one should bear responsibility. We must live so that our grandchildren, if possible, were even better than we were" (Popper, 2013b, p. 178).

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«Критичний раціоналізм» Карла Поппера: Шлях до свободи і демократії

Анотація. *В історії науки відомі випадки, коли з'являлися люди, покликання яких – зробити ряд відкриттів, які потім змінюють наукові погляди цілих поколінь. Ім'я філософа Карла Поппера стало всесвітньо відомим ще за його життя, адже досягнення цього вченого вражають оригінальністю та сміливістю ідей, високим рівнем наукових знань та масштабністю світосприйняття. Стаття присвячена аналізу життя та діяльності видатного філософа та соціолога XX століття Карла Раймунда Поппера, який був найбільш відомий своїми науковими роботами з методології та філософії науки, а також соціальної та політичної філософії. Показано, що його логічна концепція зростання наукового знання, яку він почав розвивати в 20-х роках XX століття, стала основою для створення принципу фальсифікації, який він запропонував як критерій розмежування науки і псевдонауки. Зазначається, що в наступних логіко-методологічних працях вченого спостерігається перехід у сфері наукового пошуку вченого від логіко-методологічних проблем гносеології чи теорії наукового пізнання до загальної теорії пізнання та еволюційної гносеології, а також перехід від уже отриманих результатів до соціально-політичних проблем. Висвітлено процес формування теорії критичного раціоналізму, яка полягала в тому, що будь-яка теорія, гіпотеза, наукове знання повинні бути максимально об'єктивними і не залежати від думки окремих людей чи спільнот. Проведено аналіз праць вченого в галузі соціальної філософії, в основу яких покладено розроблені ним концепції наукового знання та пізнання. Досліджено, що таке поняття як «історизм» бере важливу участь у формуванні тоталітарного суспільства, а утопічні ідеї марксизму, соціалізму та комунізму призводять лише до гальмування розвитку будь-якого суспільства. Висвітлено позицію Карла Раймунда Поппера з цього питання. Відображено різницю між відкритим і закритим суспільством, яка простежується в науковій спадщині вченого. А також визначено вплив наукової спадщини Карла Раймунда Поппера на сучасні реалії України та всього демократичного світу в умовах міжнародного збройного конфлікту.*

Ключові слова: *Карл Поппер; історія філософії; філософія науки; принцип фальсифікації; критичний раціоналізм*

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Foundations of ophthalmology in Dutch East Indies: A look at distribution of early ophthalmology medical facilities (1900–1942)

Abstract. *This research examines the development of ophthalmology as a medical specialty in the Dutch East Indies between the years 1900 and 1942. The research is focus on the establishment of ophthalmology medical facilities, consist of ophthalmology hospitals, departments of ophthalmology, and ophthalmology outpatient clinics. The methods used in this research are a literature review of archival documents and spatio-temporal analysis. The primary source of archival documents for this study are the Medical Journal for the Dutch East Indies (Geneeskundig Tijdschrift voor Nederlandsch-Indie), Communications from the Civil Medical Service (Mededeelingen van den Burgerlijk Geneeskundige Dienst), Communications from the Public Health Service (Mededeelingen van den Dienst der Volksgezondheid), and Kolonial Verslaag. A spatio-temporal analysis was conducted to look at the distribution of medical facilities over time, using a phase division into three periods: 1900–1910, 1901–1930, and 1931–1942. This research indicates that the establishment of ophthalmology medical facilities was a response to the prevalence of eye health problems in the Dutch East Indies during the nineteenth century. During the period between 1900 and 1910, a notable advancement in ophthalmology occurred with the establishment od ophthalmology hospital. These facilities were predominantly concentrated in Java, particularly in cities that served as administrative centers, such as Bandung and Semarang. From 1911 to 1930, the number of medical facilities increased with the establishment of departments of ophthalmology in hospital and ophthalmology outpatient clinics.*

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The construction of medical facilities commenced in Sumatra, particularly in Padang and Perbaoengan. In contrast, the medical facilities constructed during the period between 1931 and 1942 were exclusively outpatient clinics. The findings indicate that the early ophthalmology medical facilities were concentrated in Java and Sumatra. Additionally, this study delves into the diagnostic and therapeutic measures employed by ophthalmologists to address a spectrum of eye diseases. Based on these findings, it can be inferred that the establishment of ophthalmology medical facilities in the Dutch East Indies signified the acceptance of ophthalmology as a specialized field dedicated to advancing public health and encouraged further research into eye diseases and their treatment.

Keywords: *ophthalmology; eye care; medical history; hospital; outpatient clinic; Dutch East Indies*

Introduction.

Poor eye health was one of the health problems in the Dutch East Indies (now Indonesia). In 1891, Koningh reported that in 1890 eye disease was the fifth most common disease among ten categories, with 1417 cases. This was below the categories of other diseases (27359 cases), malaria (14129 cases), venereal diseases (9561 cases), and beriberi (4517 cases) (p. 204). Meanwhile, Steiner (1894) reported about his research in Surabaya and surroundings in 1894. Steiner highlighted the prevalence of blindness among the Javanese and the considerable damage caused by eye disease. Approximately 20% of the population suffering from eye diseases had lost their sight, mainly due to trachoma (Steiner, 1894). High cases of eye diseases are also found in other parts of Dutch East Indies, including Maluku and Aceh (Zondervan, 2016).

At the same time, medical facilities for people with eye diseases was not readily available in the region, which exacerbated the condition of those affected (Steiner, 1894). Although medical science has been introduced since the seventeenth century, with the establishment of the first hospital on July 1, 1626 (Schoute, 1937), it has not been able to reduce the high mortality rate. This is due to the inability of the medical services to treat various tropical diseases (including trachoma and other eye diseases) (Muhsin Z., 2012), as well as the limited medical services provided by the hospitals, which only offer preventive health services (Baha'uddin, 2005; Mumuh Muhsin, 2012) and are exclusively for the military (Baha'uddin, 2005; Zondervan, 2016),

That eye health is an essential need for humans to perform daily activities, therefore, eye care are important to overcome these problems. Ramke et al., (2022) defined eye care (or eye health services) as any type of intervention to improve eye health, which includes a spectrum of promotion, prevention, treatment, and rehabilitation. In medical terminology, the term eye care refers to the field of ophthalmology, a branch of medicine which involves the diagnosis and treatment of conditions affecting the eye and visual system (Lewis, 2020). Ophthalmology is a specialized field which encompasses a number of medical and surgical sub-specialties (Lewis, 2020).

Previous research by Marmion (2005) showed that the field of ophthalmology was accepted as a specialized field with the establishment of ophthalmology hospitals. Referring to this definition, ophthalmology in Dutch East Indies was only accepted as a specialized branch in the early 20th century with the establishment of the first eye outpatient clinic. Previous research in this area has not yet explored the early development of ophthalmology, although this research can help to illuminate contemporary issues. In a recent study, Dhakal (2023) posited that a comprehensive investigation of ophthalmology's historical development could offer invaluable insight into the fundamental principles of modern ophthalmology, ultimately leading to enhanced diagnostic and therapeutic approaches. In accordance with this argument, Coldefy and Curtis (2010) suggested that this type of research can assist in the formulation and evaluation of policies designed to enhance the provision of health services, with a particular focus on eye care. Consequently, research on the nascent field of ophthalmology in the Dutch East Indies is crucial for comprehending its evolution and the subsequent impact on the present state of eye care in Indonesia.

The historical studies of ophthalmology in Asia has been previously examined in Taiwan (Hou et al., 2016), India (Nair, 2012; Raman, R., & Raman, A., 2020; Sen et al., 2023), and China (Yusufu & Wang, 2018). Meanwhile in Dutch East Indies, although the historical studies of medical science and the colonial health system has been widely conducted, research on ophthalmology is still limited. Previous studies have explored the historiography of medicine and healthcare (Baha'uddin, 2005; Bergen et al., 2017; Hesselink, 2011; Indrawan & Isawati, 2022; Kurniawan & Agustia, 2021; Pols, 2018; Schoute, 1937); hospital system (Zondervan, 2016); medical education (Pols, 2024); medical research (Akbar & Handayani, 2022); and company healthcare (Ochsendorf, 2018). Specialized medicine, on the other hand, is still limited to psychiatry (Edington & Pols, 2016; Kloos, 2014; Pols, 2006, 2007, 2012; Pols & Wibisono, 2017), leprosy asylum (Snelders et al., 2019; van Bergen, 2018), the nursing profession (Gede Juanamasta et al., 2021; Hesselink, 2018), as well as maternal and child healthcare (Itawan, 2020).

This gap in research presents a significant challenge to fully comprehend the early development of ophthalmology as a specialized field and its evolution within the focus of early ophthalmology hospitals. This article aims to address this gap in knowledge by answering the following question: How did the distribution of early ophthalmology medical facilities in the Dutch East Indies evolve between 1900 and 1942? The research period selected is the early decades of the 20th century, a period of significant transformation in the health sector marked by the enactment of Ethical Politics and the first ophthalmology medical facilities was built during that time. Additionally, 1942 represents the conclusion of Dutch colonial rule. This research also highlights the early development of ophthalmology medical facilities as a transformation in eye care that was previously practiced traditionally and without the use of medical technology. By documenting the distribution, this research provides an interpretation of the areas of early influence in ophthalmology.

This research is related to the works of Zondervan (2016) and Doesschate (2017). Zondervan (2016) provides an overview of the history of hospital development in

Dutch East Indies, including ophthalmology medical facilities. However, the discussion lacks a detailed description of the hospitals and the types of eye care services provided. In contrast, Doesschate (2017) focuses on the treatment of trachoma, but it does not provide a comprehensive overview of ophthalmology medical facilities in Dutch East Indies.

Research Methods.

This research utilizes a literature review to reconstruct the distribution of ophthalmology medical facilities during the period 1900–1942. The first step of the research involved collecting archival documents, consisting of: Medical Journal for the Dutch East Indies (*Geneeskundig Tijdschrift voor Nederlandsch-Indie*), Communications from the Civil Medical Service (*Mededeelingen van den Burgerlijk Geneeskundige Dienst*), Communications from the Public Health Service (*Mededeelingen van den Dienst der Volksgezondheid*), *and Kolonial Verslaag*. The literature review phase was conducted by analyzing the reports to find information regarding the name of the hospital, year of establishment, type of treatment, and patient demographics. Three types of ophthalmology medical facilities were identified from the initial data collection, namely 1) ophthalmology hospitals (termed *gasthuis voor ooglijders* or *ophthalmologische kliniek* in archival documents), these facilities offer both inpatient and outpatient care; 2) hospital with departments of ophthalmology; and 3) ophthalmology outpatient clinics (termed *polikliniek voor ooglijders* in archival documents). The next step was to compile a database of hospitals and classify the types of medical facilities.

A spatio-temporal analysis was performed to examine aspects of hospital distribution. This analysis involved looking at both spatial (geographic) and temporal (time base) aspects to understand patterns and trends in the establishment of eye hospitals (Dong & Guo, 2021). The spatial data were processed using a QGIS application to create a spatial representation of ophthalmology medical facilities. By plotting the data on a map, this application helps to visualize the distribution of medical facilities over time. The temporal aspect is examined to analyze the distribution of medical facilities across different period. Zondervan (2016) has developed a historiographical framework of hospital care in the Dutch East Indies. It is divided into three periods: Period of Turmoil (1890–1910), Period of Expansion (1910–1930), and Period of Decentralization (1930–1942). We modified this periodization to account for the limited time frame of the study at the beginning of the 20th century, when ophthalmology medical facilities began to be established. In addition, we assessed that the boundaries presented by Zondervan are not clear; for example, the year 1910 cannot be defined as belonging to the period of turmoil or expansion. Therefore, in this study, the research phase is divided into:

1) Period 1900–1910: characterized by the beginning of the 20th century, where the ethical policy came into effect in 1901, which had an impact on the health sector, including the introduction of subsidies in 1906.

2) Period 1911–1930: Transition institutions for medical service from the Military Medical Service, to the Civil Medical Service, and subsequently to Public Health Service
3) Period 1931–1942: A period of stagnation due to the economic depression that led to the reduction of subsidies.

Thus, the spatio-temporal analysis will produce a visualization of the trend of medical facilities distribution based on the above phases. This analysis will lead to an interpretation of the areas that were first influenced by the field of ophthalmology and the direction of its spread by looking at where medical facilities were located.

Results.

The influence of Europe in Indonesia was significant in the evolution of the medical field between the seventeenth and twentieth centuries. In general, this can be observed in the establishment of medical facilities (hospitals, clinics, and outpatient clinics), institutions for medical service, educational and research institutions, and epidemic prevention institutions. This research is directly pertinent to the establishment of medical facilities and is also relevant to the work of institutions for medical service.

The earliest medical facility in the form of a hospital was constructed in Batavia on July 1, 1626 by Dutch East India Company (VOC) (Schoute, 1937). Until the early nineteenth century, VOC was responsible for the provision of medical care in the region, offering only limited services, particularly hospitals for military personnel and Europeans (Baha'uddin, 2005; Etten, 2017; Mumuh Muhsin, 2012; Zondervan, 2016). Following the dissolution of the VOC and the transition of authority in the region to the government of Dutch East Indies, a number of medical facilities has been established for the benefit of both military personnel and the civilian population (Etten, 2017). It must be acknowledged that the establishment of medical facilities in the Dutch East Indies was influenced not only by the Dutch East Indies government, but also by charity organizations, companies, and private philanthropy (Zondervan, 2016).

Conversely, the institutions for medical service also underwent modifications subsequent to the dissolution of the VOC. The government of Dutch East Indies undertook a reorganization of medical services, establishing the Medical Services (*Geneeskundige Dienst*), which were organized and provided by the state. The Medical Services were constituted of two distinct types, both under military supervision. The Military Medical Service (MMS) were provided for the military by army doctors, who were designated as health officers. The Civil Medical Service (CMS) were provided by civilian doctors for Europeans in three cities in Java (Jakarta, Semarang, and Surabaya) and by health officers in the colonies (Etten, 2017). In 1911, the CMS was separated from the MMS, becoming an independent institution. Subsequently, in 1925, the institution was renamed the Public Health Service (PHS) (Boomgaard, 1993).

The issues of eye care became a concern, mainly due to the high incidence of trachoma in the Dutch East Indies throughout the 19th century. Trachoma, as defined

by Giessen (1939), is a primary infectious disease of the conjunctiva with secondary spread to anatomical areas including the deeper tissues of the eyelids, cornea and lacrimal sac. It is characterized by the appearance of granules consisting mainly of inflammatory formation of lymph adenoid tissue and healing with scarring (Giessen, 1939). Trachoma is considered a leading cause of preventable blindness, with a significant impact on people who do not have access to clean water and proper sanitation (Mohammadpour et al., 2016).

The first case of trachoma was reported in the Medical Journal for the Dutch East Indies in 1863 (Doesschate, 2017). Steiner's report of his survey of the blind in Surabaya and the surrounding area found that 20% of the population suffered from eye disease, losing their sight mainly due to trachoma (Steiner, 1894). In addition to trachoma, other common eye diseases included blennorrhea conjunctivitis, xerophthalmia, keratomalacia, cataract and others.

On the other hand, the lack of special medical facilities for people with eye diseases in the 19th century exacerbated the impact of this case (Steiner, 1894). The report of Wijn (1905) in Ngawi also mentioned that trachoma patients in Ngawi were treated locally, but the treatment was long-term and patients often returned in the same condition as before.

Distribution of Ophthalmology Medical Facilities in 1900–1910.

The idea of establishing specialized medical facilities for ophthalmology originated in the early 20th century, although hospitals had been providing eye treatment as early as the 19th century. In the period between 1900 and 1910, five medical facilities were constructed in Java. These included four ophthalmology hospitals in Bandung, Ngawi, Semarang, and Kertosono, in addition to an ophthalmology outpatient clinic at the Modjowarno Missionary Hospital.

The establishment of the ophthalmology hospital in Bandung is inextricably linked to the contributions of Dr. C. H. A. Westhoff. He was a German ophthalmologist who studied ophthalmology in Utrecht and was trained by Gerrit Jan Mulder, Von Miquel, Donders, and Snellen. He returned to the Dutch East Indies in 1900 with broad experience as an ophthalmologist and a grasp of the fundamentals of education for the blind (Wilkens, 1913).

Westhoff initially established an eye clinic in Batavia, subsequently founding an Ophthalmology Outpatient Clinic in Bandung (*Oogheelkundige Polikliniek te Bandoeng*). The clinic was initially situated in the residence of Doyer, later relocating to the *Pradjoerits* barracks (Wilkens, 1913). In 1905, the outpatient clinic has provided treatment to 1,258 patients. This number has increased for three consecutive years (see Figure 1). The outpatient clinic provided services not only to patients from Bandung but also to those from other areas within the Preanger Residency (Geneeskundigen Dienst, 1910).

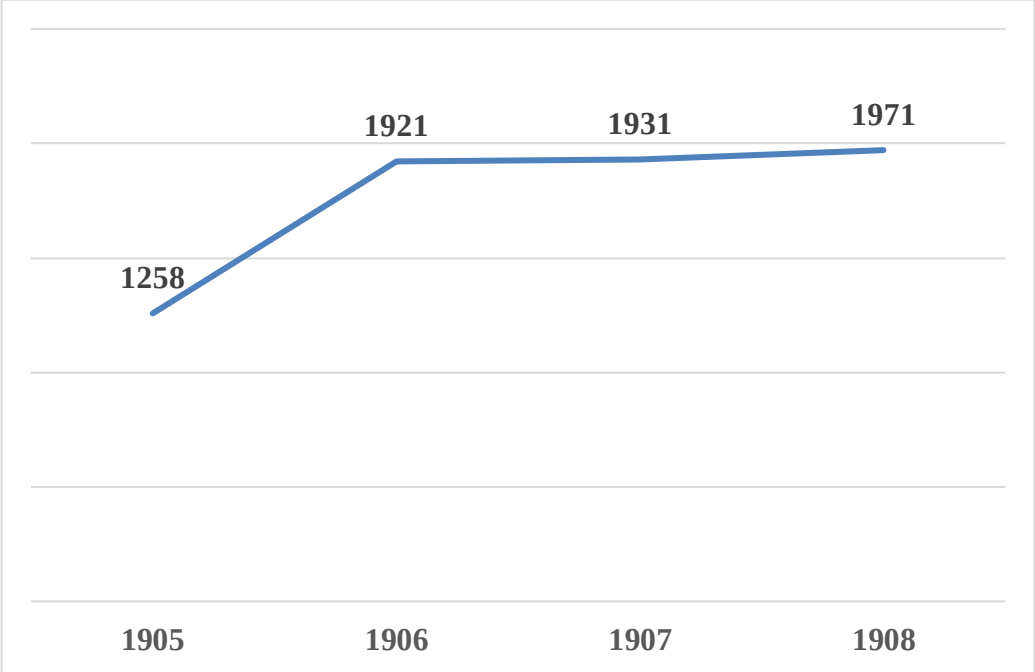

Figure 1. Number of Patients at Ophthalmology Outpatient Clinic in Bandung 1905–1908 (Geneeskundigen Dienst, 1906, 1907, 1908, 1910).

The establishment of the outpatient eye clinic was not Westhoff's sole contribution to the field of ophthalmology. In 1901, Westhoff established the Institute for the Blind (*Blindeninstituut*) in Bandung. This was followed by the establishment of Association for the Improvement of the Fate of the Blind in the Dutch East Indies (*Vereeniging tot verbetering van het lot der blinden in Nederland-Indie*) in 1906, of which Westhoff was the inaugural president (Wilkens, 1913). Additionally, Westhoff provided training for the indigenous ophthalmologists, known as "*doekoen mata*," but the training was discontinued in 1912 due to the lack of satisfactory outcomes (Wilkens, 1913).

In order to provide improved eye care, the Dutch East Indies government proceeded to construct an eye hospital. The hospital was inaugurated on January 3, 1909, by Governor General J. B. van Heutsz and designated as the Queen Wilhelmina Eye Hospital (see Figure 2) (*Koningen Wilhelmina Gathuis voor Ooglijders*). Westhoff was appointed as the inaugural director of the hospital (Westhoff, 1910). In 1909, a total of 2,536 patients were registered at the outpatient clinic, equating to an average of 77 eye patients treated per day. Of these, the most prevalent disease was trachoma, affecting 336 patients. Additionally, 496 eye patients were treated at the clinic, including 39 Europeans, 46 Chinese, and 411 indigenous people (Geneeskundigen Dienst, 1910).

Figure 2. The operating room with ophthalmologists and patients in the Queen Wilhelmina Eye Hospital in Bandung in 1920 (collectie.wereldmuseum.nl TM-ALB-0140-86).

In 1905, health officer P. Wijn published his report in the Medical Journal for the Dutch East Indies, expressing concern about the high prevalence of eye disease upon his arrival in Ngawi (Residentie Madiun) in August 1903 (p. 723). Wijn then initiated the establishment of the *Ophthalmologische Kliniek te Ngawi*. During the year 1904, a total of 1,432 indigenous patients were treated at the clinic, of whom 1,046 were suffering from eye diseases (p. 723). Wijn treated patients not only from Ngawi but also from outside the area. Some patients even stayed in there for one to three months for daily treatment. Furthermore, the provision of surgical assistance prompted individuals from surrounding communities to seek medical treatment (p. 723).

A report in the Medical Journal for the Dutch East Indies in 1906 indicated that during 1905, 1,679 patients were registered at the clinic, with the majority suffering from eye diseases, including 617 operations (Geneeskundigen Dienst, 1906). During the years 1906 and 1907, the number of patients treated was 1,080 and 824, respectively, with 832 and 518 surgical procedures performed, respectively (Geneeskundigen Dienst, 1907, 1908).

Meanwhile, an outpatient clinic has been opened in Modjowarno Missionary Hospital (Jombang District, Surabaya Residency, Oost Java) (see Figure 3). Van Twist (1907) reported that the number of patients receiving treatment for eye-related conditions reached 1,398 in 1906. However, due to the limited assistance available, comprehensive examinations were not feasible in many cases, particularly those involving the internal structures of the eye (van Twist, 1907).

The majority of patients presented with trachoma. The treatment was conducted with caustic agents, including the use of silver nitrate, zinc sulfate, and copper sulfate. In certain cases, the use of Knapp roller tweezers was deemed necessary. Of the cases that required surgical intervention, entropion and trichiasis were treated through the Snellen Operation, which was performed on 181 individuals. Additionally, 15 cataract

operations, four pterygium operations, two ectropium operations, and one staphyloma enucleation were conducted. All of these operations were successfully completed (van Twist, 1907). During 1908 and 1909, the number of patients with eye conditions was 1,260 and 1,281, respectively (van Twist, 1909, 1910).

Figure 3. Eye examination at the Ophthalmology Outpatient Clinic of Modjowarno Missionary Hospital (collectie.wereldmuseum.nl TM-10000795).

In the meantime, the inaugural eye hospital in the Semarang region of Central Java was established in 1907 by Dr. Vilhem A. Wille, a Danish ophthalmologist. The construction of the hospital was initiated by the Salvation Army in 1908 and was named Salvation Army Eye Clinic in Semarang (*Oogkliniek van het Leger des Heils te Semarang*) (Wille, 1914; Zondervan, 2016).

In 1914, Wille reported that the rate of cases in Semarang experienced a notable surge following the inauguration of the hospital (see Figure 4 and 5) (p. 8). The majority of cases involved major and serious surgical procedures, such as entropion (Wille, 1914). Meanwhile, trachoma treatment also received attention because it had an impact on other cases that required further treatment, such as keratitis ramificata. Trachoma treatment was divided into two categories: the first aimed to improve the condition, while the second sought to cure the disease. The former was more readily achieved through the use of *sulphascuricus, protargol*, *Cuysol*, and other disinfectant eye washes. However, this treatment was quite time-consuming. In contrast, the latter was a more difficult task that required specialized treatment, yet it facilitates a more rapid recuperation (Wille, 1914).

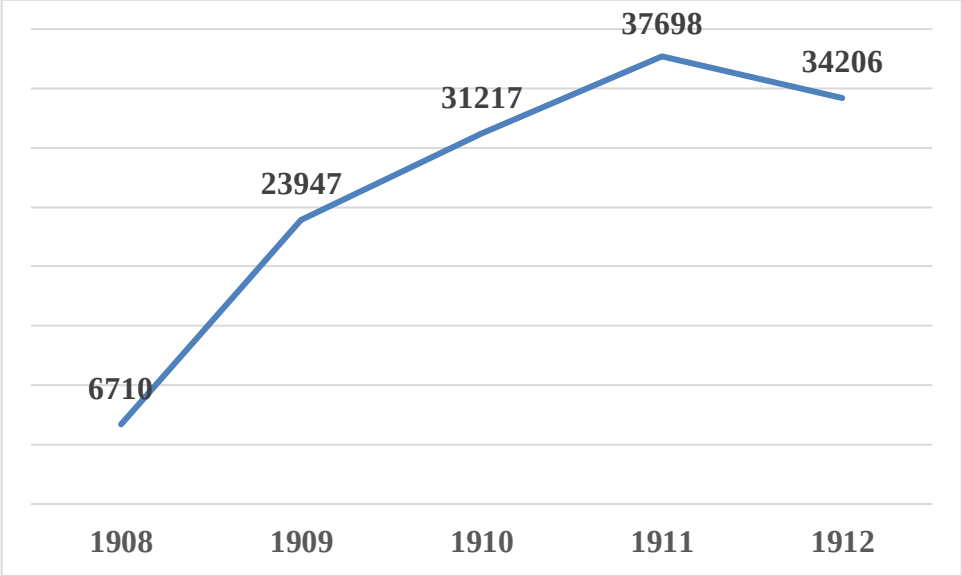

Figure 4. Number of consultations in Salvation Army Eye Clinic in Semarang 1908–1912 (Wille, 1914).

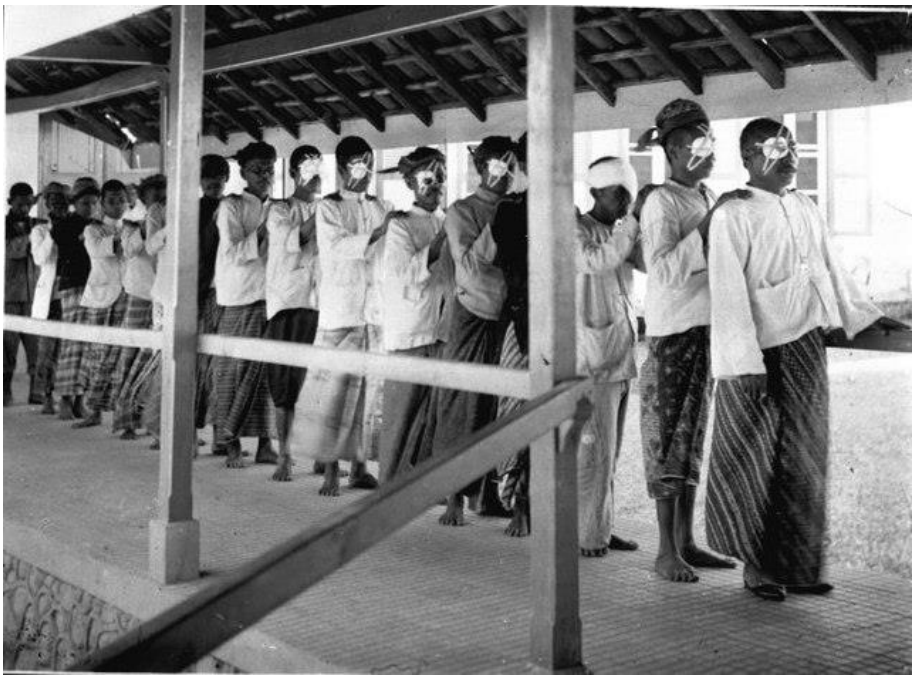

Figure 5. Patients from the Salvation Army's William Booth Eye Hospital in Semarang march to the clinic where they will be treated (collectie.wereldmuseum.nl TM-ALB-0039-92).

Towards the end of the initial decade of the 20th century, a hospital has been established in the village of Kertosono (Kediri Residency, Central Java) following the initiative of Liem Tik Koey. In the 1910 Koloniaal Verslag, it was noted that a hospital named "*Ziekenverpleging Liem Tik Koey*" and the basic articles of which had been approved by government on November 20, 1909. This hospital aimed to treating the sick and injured, especially those with eye problems, regardless of nationality (Koloniaal Verslag, 1910).

Distribution of Ophthalmology medical facilities in 1911–1930.

The number of medical facilities increased during the period of 1911 to 1930, with the opening of three ophthalmology hospitals, two departments of ophthalmology within hospitals, and four ophthalmology outpatient clinics.

The Surabaya Ophthalmology Clinic (*Soerabaische Oogheelkundige Kliniek*), a private hospital, was established on October 15, 1915, under the guidance of Dr. A. Deutman. The association has granted legal status by the government od Dutch East Indies on January 3, 1916. Its objective was to provide comprehensive eye care to individuals from diverse backgrounds (Dutch East Indies, 1918).

The 1919 CMS report indicated that eye health care has been established within the department of ophthalmology in the Central Civil Hospital (*Centrale Burgerlijke Ziekeninrichting*) in Salemba and the Military Hospital (*Militair Hospitaal*) in Surabaya. Furthermore, additional ophthalmology outpatient clinic has been opened at Red Cross Kemajoran, Tjikini Hospital, and Health Service (*Gezondheidsdienst*) in Surabaya (Burgerlijk Geneeskundige Dienst, 1922b).

The Department of Ophthalmology at the Central Civil Hospital constituted part of the STOVIA student practice area. It was initially established by the Military Hospital in collaboration with the military authorities. As the Central Civil Hospital in Salemba commenced operations, the clinic was subsequently relocated (Burgerlijk Geneeskundige Dienst, 1922b). In 1919, the ophthalmology clinic received 1,152 patients (Burgerlijk Geneeskundige Dienst, 1922b), and this number increased to 1,376 patients in 1920 (Burgerlijk Geneeskundige Dienst, 1922a). Furthermore, the Department of Ophthalmology at STOVIA was further developed by Dr. Bakker, who became a lecturer in the field of ophthalmology (Burgerlijk Geneeskundige Dienst, 1922a).

In a further development, an ophthalmology hospital has been established in the Djokjakarta Resident under the initiative of Dr. Yap Hong Tjoen. In his 1926 report, Dr. Yap outlined the various entities that provided support for the hospital's establishment. These included the *Vorstenlandsche Landbouwvereeniging* the Djokja department, which covered operational costs; the Djokjakarta Sultanate, which donated the location of the hospital free of charge; and the Dutch East Indies Government, which contributed significantly to the creation of the hospital (Tjoen, 1926).

Tjoen (1926) explained that the initial iteration of the ophthalmology hospital was an outpatient clinic that commenced operations on June 20, 1921, in a rented house in Gondolajoe. One year later, on November 21, 1922, the establishment of the hospital commenced with the laying of the first stone by Sultan Hamengku Buwono VIII, the Sultan of Djokjakarta (p. 144). Subsequently, on May 29, 1923, the hospital was formally inaugurated by the Governor General of the Dutch East Indies, Mr. D. Fock, and designated as the Princess Juliana Hospital for Eye Disease Patients (*Prinses Juliana Gasthuis voor Ooglijders*) (p. 144). The hospital initially had the capacity to accommodate only 16 patients and by the end of December 1925, the hospital had treated 72 inpatients (see figure 6 and 7) (p. 144).

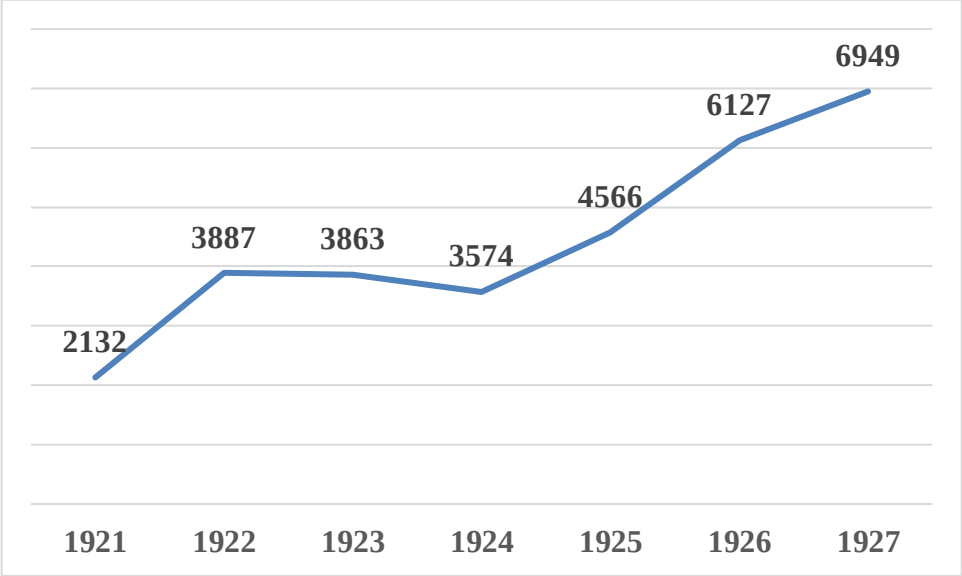

Figure 6. Number of Patients in the Outpatient Clinic and Princess Juliana Hospital for Eye Disease Patients 1921–1927 (Lian, 1928, p. 1075; Tjoen, 1926, p. 144).

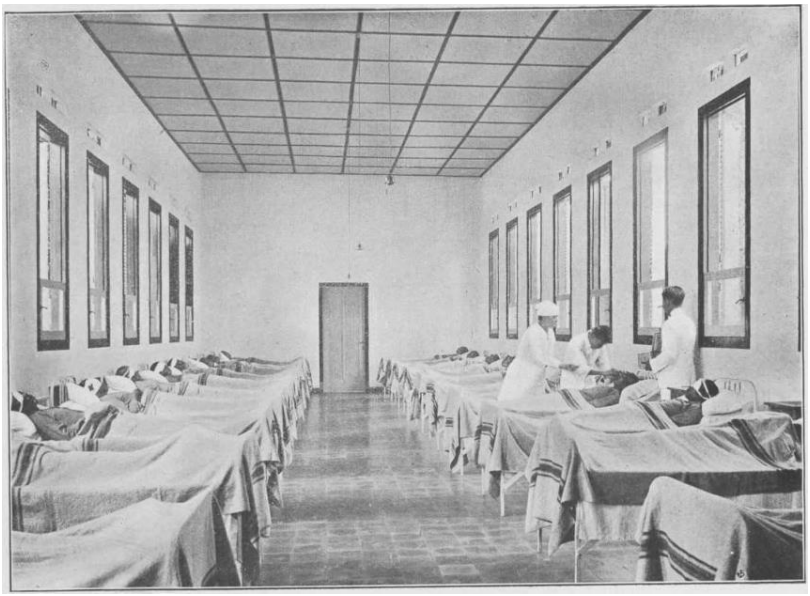

Figure 7. Treatment of patients in Princess Juliana Hospital for Eye Disease Patients (Tjoen, 1926, p. 144).

During the period between 1911 and 1930, the construction of ophthalmology hospitals commenced outside of Java. Peverelli (1930) published an article describing the Eye Patients Hospital Whitlau Foundation (*Ooglijders Hospitaal Whitlau-Stichting*) in Padang in Medical Journal for Dutch East Indies (p. 302). The hospital was established through a private initiative and funded by community contributions. Moreover, the local community pledged to provide annual financial support for the operational costs, while the government of Dutch East Indies was responsible for the remuneration of doctors and nurses. The hospital comprised both an outpatient facility and a ward with accommodation for 30 inpatients (Peverelli, 1930).

In addition to the ophthalmology hospital in Padang, outpatient clinics were established in Fort de Kock (Peverelli, 1930) and in Perbaoengan (Louwerier, 1923). In a report published in Medical Journal for the Dutch East Indies 1923, J. Louwerier outlined his efforts to construct an ophthalmology outpatient clinic in Perbaoengan. Since 1915, Louwerier had gained access to the Serdang Landscape Hospital (*Hospitaal van het Landschap Serdang*), where he treated patients from diverse of backgrounds. The most prevalent disease was trachoma, which necessitated prolonged treatment regimens and surgical intervention in numerous cases. Louwerier emphasized the necessity of constructing a specialized hospital for ophthalmological patients and work facilities for the visually-impaired people in the region, where they could develop the skills to become self-sufficient (Louwerier, 1923). It is regrettable that in the year 1920, Louwerier departed from the eastern coast of North Sumatra, after having lived in the region for an extended period of time (Burgerlijk Geneeskundige Dienst, 1921).

Distribution of ophthalmology medical facilities in 1931–1942.

During the period between 1931 and 1942, the growth and expansion of ophthalmology medical facilities was primarily limited to the establishment of outpatient clinics, with a geographical concentration on the islands of Java and Sumatra.

It is notable that during this period the concept of the 'Travelling Ophthalmologist' was first introduced. This was initiated by ophthalmologist Dr Tjissen, who practiced eye care by moving around (Zondervan, 2016). A report in the Medical Journal for Dutch East Indies, written by Winckel (1932), indicates that dr. Tjissen had resided in Langsar, Aceh since 1913–1929. In 1923, Tjissen conducted an examination of individuals with vision impairment from four villages situated along the northern coastline of Aceh. The findings revealed the presence of 226 individuals afflicted with eye disease, with 129 of them having lost their corneas or undergone scar tissue formation (Winckel, 1932).

In order to investigate the case further, Tjissen travelled to the area in late 1931, residing in Idi, on the east coast of Sumatra, for a period of two months. In this location, Tjissen collaborated with a male Javanese nurse in the hospital ward. Tjissen performed 45 cataract operations on 25 individuals, 23 of whom were able to regain sufficient vision (Winckel, 1932). Subsequently, Tjissen relocated to Loeng Poetoe, where he established an outpatient ophthalmology clinic in a small residence. The local government initiated a program to identify and collect individuals with blindness, which provided Tjissen with a source of patients for his cataract surgery practice. In a period of 25 days, Tjissen performed 105 cataract operations on 83 individuals, with the patients wearing occlusive dressings for a minimum of five days. A total of 55 patients with 71 operated eyes were examined; the results were classified as good in 58 cases, moderate in seven, and poor in six (Winckel, 1932). Following his time in Aceh, Tjissen relocated to Tapanoeli, Nort Sumatra, a region with a population of 90,000 lacking access to medical care. He proceeded to perform 247

eyelid operations on 148 patients diagnosed with trachoma and 17 operations on patients with cataracts (Winckel, 1932).

The work of Tjissen inspired the board of SIMAVI, a Christian organization dedicated to improving medical care for the native population in Dutch East Indies to dispatch ophthalmologist J. G. van Manen to Sumatra in 1937. Based on report by van Manen (1938), twofold: to serve as a traveling eye specialist and to evaluate Tjisssen's efforts for potential replication (van Manen, 1938). In his report, van Manen stated that he established an ophthalmology outpatient clinic in Taroetoeng, Tapanuli, North Sumatra (see figure 8). Over the course of a year, a total of 3,079 patients were registered, comprising 2,052 Batak, 514 Nias, 248 Malay, 125 Javanese, 79 Chinese, 26 Foreign Easterners, and 35 Europeans. The total number of operations performed was 663 in 394 different individuals on 549 eyes (van Manen, 1938).

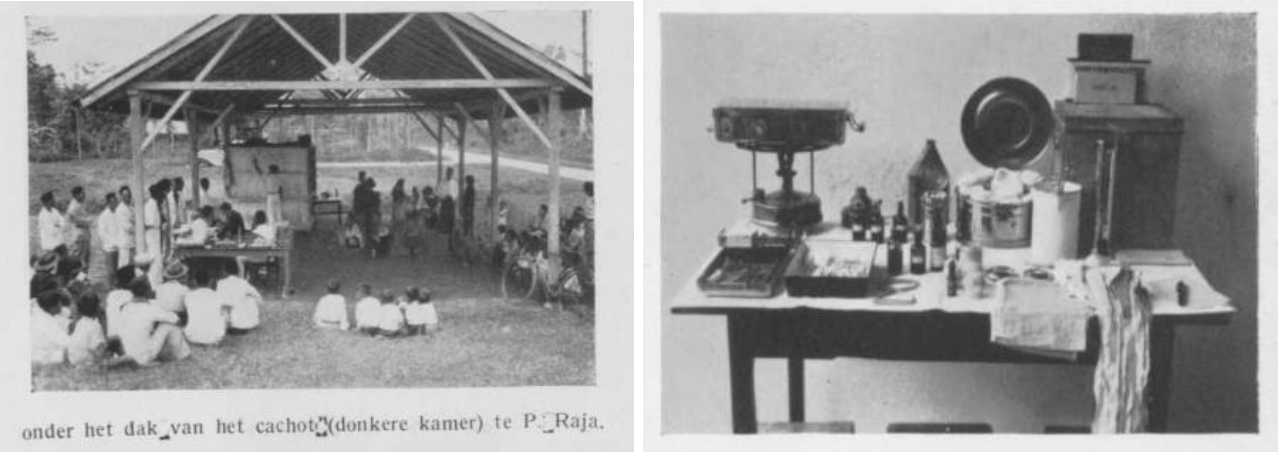

Figure 8. Ophthalmology Outpatient Clinic in Taroetoeng (left) dan operating table (right) (van Manen, 1938).

Van Manen worked in Sumatra for a year before returning to work in Java. He was then stationed in North Krawang to work with Dutch East Indies Association for the prevention and control of blindness (*Nederlandsche Indische Vereeniging tot voorkoming en bestrijding van blindheid*) and the West Java Mission to work toward alleviating the problem of blindness, particularly that caused by trachoma (van Manen, 1938). Van Manen also reported that this missionary doctor had an ophthalmology department in Krawang where he could treat patients with chronic trachoma, blennorrhea, and other eye diseases with which he had become more familiar during these preparatory months. Serious cases, for instance cataract operations, were sent to Dutch East Indies Association for the prevention and control of blindness in Batavia, (van Manen, 1938).

Remaining in the West Java region, the Medical Journal for Dutch East Indies in 1935 also mentioned that there were 7 ophthalmology outpatient clinics in Banten. In the second half of the year, 16,319 trachoma consultations were provided (Dienst der Volksgezondheid, 1936). An ophthalmology outpatient clinics has also been established in South-East Cheribon, where a 1938 report stated that several eye patients from Koeningan had been treated and well served (Dienst der Volksgezondheid, 1939).

A high number of trachoma cases were also found in Pemalang and Tegal (Pekalongan Residency, Central Java). Based on the PHS report of 1936, doctors were specifically assigned to eradicate trachoma in the region in 1935. The first doctor was stationed at the South and West Tegal Resort, which was assigned to outpatient clinics in Tegal, Ketanggoengan, Boelakamba, Klampok, Brebes, Kaligangsa, Adiwerna, Balamoas, Pangkah and Slawi (Dienst der Volksgezondheid, 1936). During 1935, the number of trachoma patients in this region reached 4,334 (Dienst der Volksgezondheid, 1936). A doctor was also stationed at the Pemalang and East Tegal resort, which managed outpatient clinics in Pemalang, Soegihwaros, Taman, Petaroekan, Tjomal, Soerodadi, and Kramat (Dienst der Volksgezondheid, 1936). During 1935, the number of trachoma patients in this area reached 4,334 (Dienst der Volksgezondheid, 1936). A report from 1938 indicated that 82 operations had been performed at the clinic in Pemalang (Dienst der Volksgezondheid, 1939). Eye health propaganda was also conducted by nurses, especially through home lectures (Dienst der Volksgezondheid, 1938).

Trachoma eradication was also carried out in North Surabaya. The PHS report of 1937 stated that trachoma outpatient clinic was routinely organized by nurses in Patjiran (Lamongan Residency). These nurses also routinely conducted consultations in other locations (Dienst der Volksgezondheid, 1938). A year later, the number of consultations at the Patjiran outpatient clinic decreased. In addition, there were also outpatient clinics in Brondong, Weroe, and Sentoel (Dienst der Volksgezondheid, 1939)

Discussion.

The early 20th century marked a significant period in the development of ophthalmology in the Dutch East Indies. The establishment of ophthalmology outpatient clinics in Bandung by Dr. Westhoff marked the beginning of a significant expansion in the provision of medical facilities dealing with eye care. During the period between 1900 and 1910, four ophthalmology hospitals and one ophthalmology outpatient clinic were established. All five medical facilities were located in Java, particularly in cities that served as administrative capitals for the colonial government (see Figure 9). Additionally, Westhoff undertook training initiatives to equip local medical professionals with the skills to become ophthalmologists, or "*doekoen mata*" but this program was ultimately discontinued due to its inability to meet the desired outcomes.

The transition of medical institutions in the Dutch East Indies from the MMS to the CMS and subsequently to the PHS had a significant impact on the proliferation of ophthalmology medical facilities during the period between 1911 and 1930. During this period, nine new medical facilities were established, comprising three hospitals (in Surabaya, Yogyakarta, and Padang), two departments of ophthalmology (Central Civil Hospital Salemba in Batavia and Military Hospital in Soerabaja), and four ophthalmology outpatient clinic (two in Batavia, Surabaya, and Sumatra). During this period, the distribution of hospitals began to extend beyond the island of Java, with

the establishment of medical facilities in Padang and Poerbangan (Sumatra) (see Figure 10).

Figure 9. Distribution of ophthalmology medical facilities in 1900–1910.

Figure 10. Distribution of ophthalmology medical facilities in 1911–1930.

The period between 1931 and 1942 was characterized by an economic recession in the Dutch East Indies, which resulted in a reduction of the allocated budget for healthcare (Baha'uddin, 2005; Zondervan, 2016). It seems reasonable to conclude that there was no new ophthalmology hospitals established during this period, which was likely a consequence of the prevailing economic recession. The establishment of ophthalmology medical facilities was directed towards the development of ophthalmology outpatient clinic in both Java and Sumatra, including in regions situated beyond the administrative capital the Dutch East Indies government (see Figure 11). A noteworthy development during this period was the advent of the 'Traveling Ophthalmologist', a program initiated by Dr. Tjissen and subsequently adopted by SIMAVI and van Manen. This initiative involved not only the provision of permanent treatment in a single location but also the deployment of ophthalmologists to other sites. This demonstrates a tendency to extend services to areas outside the city center, particularly in regions with a high prevalence of eye disease. Polyclinics are an optimal choice in these settings, as they require fewer resources to construct than hospitals, yet they can still deliver effective eye care and reach remote communities.

Figure 11. Distribution of ophthalmology medical facilities in 1931–1942.

This study reveals that the initial distribution of ophthalmology medical facilities was concentrated in Java, subsequently spreading to Sumatra. This finding demonstrates that the two regions were the initial recipients of medical influence in the field of ophthalmology. Conversely, this finding demonstrates the disparity

whereby ophthalmology medical facilities have yet to be established in other locations across the Dutch East Indies.

It is important to note that while no ophthalmology medical facilities were identified outside these two regions, treatment efforts were still being carried out. For example, in 1922 and 1923, F. Kopstein conducted research in Ambon and the island of Oeliassers. Kopstein determined that the most prevalent ocular disease was conjunctivitis, affecting 20% of school-aged children. Although this disease is harmless, it can lead to misdiagnosis due to its resemblance to trachoma. Additionally, trachoma was identified in 10% of the population (Kopstein, 1926). Further research was conducted by health officers Barto and A. Bobbert. In his report published in 1926, Bobbert offered a different perspective on conjunctivitis. He contended that the disease was, in fact, trachoma (Bakker, 1927). Subsequently, Bakker conducted further research and published his findings in the Medical Journal for the Dutch East Indies in 1927. The findings indicated that the majority of trachoma cases were likely conjunctival granulosis, a disease marked by the presence of large granules in children, with a proclivity for spontaneous resolution (Bakker, 1927). Furthermore, eye research was conducted in Makassar by Karamoy, who discovered a prevalence of trachoma in 15% of school-aged children (Bakker, 1927). A research also conducted in East Kalimantan revealed a prevalence of 2% for trachoma (Kuhlewein, 1930).

It can be concluded that the establishment of ophthalmology medical facilities in the early 20th century can be considered a catalyst that influenced the practice of eye medicine in present Indonesia. In the field of healthcare, medical facilities have been responsible for a significant cultural shift, whereby traditional forms of care are increasingly being replaced by medical treatment. The establishment of these medical facilities signified a new era for ophthalmology, marking the acceptance of this field as a specialized discipline. It is evident that the establishment of eye medical facilities has had a dual impact on the field of ophthalmology. On the one hand, it has facilitated the delivery of patient care. On the other hand, it has also encouraged the advancement of education and research in the field.

A number of the earliest hospitals constructed in the early 20th century are still in use today. The Queen Wilhelmina Eye Hospital is now the Cicendo Eye Hospital, the Salvation Army Eye Clinic in Semarang became the William Booth General Hospital, the Surabaya Ophthalmology Clinic is now the Undaan Eye Hospital, and the Princess Juliana Hospital for Eye Disease Patients is now the Dr. Yap Eye Hospital.

Conclusions.

This research has provided a historical overview of the development of ophthalmology in the Dutch East Indies in the early twentieth century with a focus on the distribution of medical facilities. The establishment of ophthalmology medical facilities was a response to eye health problems in the Dutch East Indies in the nineteenth century. This marked the advent of modern medical treatment methods, including the use of chemical drugs and surgical techniques such as eye surgery,

marking a transition from the traditional medical practices that had been employed in the Dutch East Indies.

During the first decade of the 20th century, the medical facilities built were hospitals and outpatient clinics. The distribution of these medical facilities was still concentrated on Java, especially the cities which were the centers of Dutch East Indies government. This characteristic shifted during the period 1911–1930, when an increasing number of medical facilities were built due to changes in health policy. The distribution also expanded with the opening of medical facilities outside Java, namely in Padang and North Sumatra. Meanwhile, the economic recession at the beginning of the period 1931–1942 affected the establishment of medical facilities. In this case, outpatient eye clinics were built. Until the end of 1942, the establishment of medical facilities was still concentrated in Java and Sumatra, while outside these two regions there were no ophthalmology medical facilities established and only research on eye diseases was carried out.

Moreover, this research also considers the role and contributions of ophthalmologists with regard to the provision of eye care services to patients. Their contributions to eye care efforts, including the training of eye doctors, the establishment of organizations for the blind, the concept of "traveling ophthalmologists," and lectures by nurses, have been instrumental in the eradication of eye disease in the region.

By documenting the history of ophthalmology and distribution of early medical facilities in the Dutch East Indies, this research provides a fundamental understanding of how ophthalmology has developed and influenced the way ophthalmology continues to practice in present Indonesia. This study focuses on the distribution of ophthalmology over time during the three periods that signaled the beginning of attention to eye health and the development of research and methods on the treatment of eye diseases. Therefore, further research is needed related to technological innovations used in the treatment of eye diseases.

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Conflict of interest.

The authors declare no conflict of interest.

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Основи офтальмології в Голландській Ост-Індії: Погляд на розподіл перших офтальмологічних медичних закладів (1900–1942)

Анотація. *Це дослідження аналізує розвиток офтальмології як медичної спеціальності в Голландській Ост-Індії в період з 1900 по 1942 роки. Дослідження зосереджується на утворенні офтальмологічних медичних закладів, зокрема офтальмологічних лікарень, відділів офтальмології та офтальмологічних амбулаторій. Методи, що використовуються у дослідженні, включають огляд літератури архівних документів та просторово-часовий аналіз. Основними архівними джерелами є «Медичний журнал Голландської Ост-Індії» (Geneeskundig Tijdschrift voor Nederlandsch-Indie), «Повідомлення цивільної медичної служби» (Mededeelingen van den Burgerlijk Geneeskundige Dienst),*

«Повідомлення служби громадського здоров'я» (Mededeelingen van den Dienst der Volksgezondheid) та Kolonial Verslaag. Просторово-часовий аналіз був проведений для оцінки розподілу медичних закладів у часі, поділивши їх на три періоди: 1900–1910, 1911–1930 та 1931–1942 роки. Це дослідження показує, що створення офтальмологічних медичних закладів стало відповіддю на поширені проблеми захворювань очей у Голландській Ост-Індії в дев'ятнадцятому столітті. У період між 1900 і 1910 роками відбувся значний розвиток офтальмології з відкриттям офтальмологічних лікарень. Ці заклади здебільшого були сконцентровані на Яві, особливо в адміністративних центрах, таких як Бандунг і Семаранг. З 1911 по 1930 роки кількість медичних закладів зросла завдяки створенню офтальмологічних відділень у лікарнях та офтальмологічних амбулаторій. Будівництво медичних закладів розпочалося також на Суматрі, особливо в містах Паданг і Пербаунган. На відміну від цього, медичні заклади, створені в період з 1931 по 1942 роки, були виключно амбулаторними клініками. Результати вказують на те, що ранні офтальмологічні медичні заклади були зосереджені на Яві та Суматрі. Окрім цього, у дослідженні розглядаються діагностичні та терапевтичні заходи, які офтальмологи використовували для лікування широкого спектра захворювань очей. Згідно з цими дослідженнями, можна зробити висновок, що створення офтальмологічних медичних закладів у Голландській Ост-Індії свідчило про визнання офтальмології як спеціалізованої галузі, присвяченої розвитку громадського здоров'я, а також стимулювало подальші дослідження захворювань очей та їх лікування.

Ключові слова: *офтальмологія; догляд за очима; історія медицини; лікарня; амбулаторія; Голландська Ост-Індія*

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Work at the Kharkiv Electromechanical and Turbo-Generator Plant on the project of electromagnetic torpedo tubes (1936–1938)

Abstract. *The article, based on archival documents of the Kharkiv Electromechanical Plant, highlights the activities of scientists of this enterprise during 1936–1938 on the project to create electromagnetic systems for bubble-free torpedo firing, which in today is completely new information for historians of science and technology, and for specialists in the field of electrical machine engineering too. This project arose as a result of a confluence of several circumstances, one of which was the need of the Soviet naval submarine fleet on the eve of World War II to improve itself torpedo armament with systems that would not reveal submarines when firing torpedoes from a submerged. Another circumstance was that since 1934 the Kharkiv Electromechanical Plant was the main enterprise in the Union of the Soviet Socialist Republic for the production of electromechanics for ships of all classes and for all coastal defense facilities, and therefore its administration and the scientific and technical personnel who were involved in defense issues at the plant, were aware of this problem. At the same time, some of the latter, working part-time at the Kharkiv Electrotechnical Institute, from the first half of the 1930s, along with the studies problems of rotary electric machines, actively developed the direction of electric machines with the axial [linear] direction of rotor movement, and achieved significant results in this. Thus, by 1936, conditions had been formed when meeting the need to provide Soviet submarines with bubble-free torpedo firing systems became theoretically possible through the use of electromagnetic torpedo launching according to the methods developed by Kharkiv scientists for linear electric machines, and by torpedo tubes whose corresponding equipment for which's could be manufacturing at Kharkiv Electromechanical Plant. However, this theoretical possibility required practical confirmation, for which the "Magnetic Torpedo Pusher" project was organized, carried out by the same specialists who were engaged in the study of linear*

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electric machines both at the Kharkiv Electromechanical Plant and at the Kharkiv Electrotechnical Institute. The purpose of the project was to select a possible version of the fundamental design of an electromagnetic torpedo tube and test the functionality created according to the chosen design option using model experiments. Studies have shown that pushing a torpedo out of a torpedo tube within the framework of the modes established by the customers of the project is possible with the help of a running magnetic field, however, the electromagnetic method of launching a torpedo does not make it completely bubble-free, but only leads to a decrease in the volume of the air bubble formed during the firing. Wherein, the use of electromagnetic launch of torpedoes on existing and designed projects of Soviet submarines turned out to be impossible due to significant changes in the weight and size characteristics of the electrical power equipment, that need to be installed in this case. Meanwhile, the same degree of reduction of the air bubble without any significant additional costs has already been achieved in the designs of pneumatic torpedo tubes of Stalinets-type submarines, projected by order of the Soviet Union by German and Holland designers, which completely deprived the project of torpedo tubes with electromagnetic action of its attractiveness, and led to its closure. At the same time, despite the unsuccessful result of this project in the context of creating a bubble-free torpedo firing system, its implementation allowed Kharkiv scientists to validate and verify the methods they created for calculating and designing linear electric machines, as well as to determine the optimal designs of magnetofugal stators, which was subsequently used in the creation special electromechanical equipment for the mining and construction industries.

Keywords: *bubble-free torpedo firing; electromagnetic launch; linear electric machines; submarine*

Introduction.

During World War I, the problem of submarines discovering themselves at the moment of launching a torpedo by them from submerged condition at an attacked ship was revealed. It occurred as a result of a bubbles of air rising from under the water at the location of the submarine, which formatted after pneumatic push out of torpedoes from the torpedo tubes. This phenomenon led both to decrease in the effectiveness of attacks by submarines [since the enemy could timely detect the launch of a torpedo and take appropriate measures to evade a meeting with a torpedo], and to an increased risk of damage or even loss of submarines [since a submarine that had unmasked itself might not have time to take actions that would allow her to hide from enemy anti-submarine weapons]. Therefore, in the interwar period, virtually all countries that had underwater shipbuilding were looking for ways to organize bubble-free firing of submarine torpedo tubes, and the Soviet Union was no exception, although Soviet specialists didn't manage to achieve any most results in this area before beginning World War II (Beloshitskiy & Baginskiy, 1960). The only series of Soviet submarines equipped with means that partially reduce the volume of the air bubble released during

the pneumatic launch of torpedoes from a submerged position [*Stalinets*] was designed in 1933–1935 by the German company *DeSchiMAG*. However, these devices, the operating principle of which was based on the piston-less removal of air from the torpedo's ejection into the interior of the submarine, were still quite primitive at that time – they did not remove the entire volume of air and had significant limitations on the maximum depth from which torpedoes could be launched, and until the early 1940s [when these shortcomings were eliminated] were used by German shipbuilders only for export versions of submarine projects. For their own needs, they, like other leading global submarine manufacturers, created more advanced bubble-free firing systems in the 1930s that did not allow the air bubble to escape at all when launching a torpedo – both pneumatic [piston] and pneumohydraulic, as well as all kinds of mechanical ones. But the former were expensive to manufacture and still had limitations on the depth at which torpedoes could be launched, while the latter, without such limitations and being cheaper, were quite bulky [which did not allow their use in small-displacement submarines and significantly worsened the performance characteristics of large submarines] and, in addition, did not guarantee the desired [more than 10 m/s] speed of the torpedo exit from the pipe of the torpedo tube (Gabler, 1972).

Meanwhile, the designs of the systems that ensured completely bubble-free firing were kept in the strictest confidence, and Soviet intelligence was unable to gain access to them, at least to the extent that they could obtain the relevant technical documentation in sufficient quantities for Soviet industry to create its own similar serial devices based on them. At the same time, taking into account the aforementioned shortcomings of the bubble-free firing systems used abroad, it was desirable for the command of the Soviet submarine fleet to obtain at its disposal such torpedo launchers, the design of which, on the one hand, would exclude their occurrence in principle, and on the other hand, would be universal for all types and kinds of torpedoes, the improvement of which in the interwar years occurred at a rapid pace (Kirby, 1972). And since the international situation in the second half of the 1930s tended to annually approach a global military conflict, an urgent solution to this problem for the Workers-Peasants Red Fleet [*WPRF*] of the USSR was quite important.

Based on this situation, the Soviet government decided to look for alternative ways to foreign borrowings to create its own bubble-free torpedo firing systems, one of which involved an electromagnetic launch of a torpedo from a torpedo tube. In 1936, this device option for a bubble-free launch system was proposed to be studied to a team of researchers at the Kharkiv Electromechanical Plant [*KhEMP*], since 1934, by decision of the Soviet government, *KhEMP* was designated the head enterprise in the USSR for the production of electromechanics for ships of all classes and for all coastal defense facilities (Annienkov, 2019). The very emergence of the idea of electromagnetic launching of torpedoes is due to the fact that in the early 1930s in the Soviet Union the advantages of using an electromechanical drive, which were achieved thanks to its widespread distribution due to the intensive electrification of all spheres of public life during the 1920s, became obvious. And at the same time, the range of

areas of use of electric machines, as their designs were improved, continued to expand, which allowed both the country's leadership and electrical machinery scientists to imagine more and more new possible forms of application of electromechanics, including those which operating principles were based on non-traditional ways to use the energy of the electromagnetic field. In the era discussed in this article, these methods also included those, due to the use of which the rotor of the electric motor performed not rotational, but rectilinear or curvilinear movement. In the Ukrainian SSR at that time, the problems of linear electric machines were actively studied at the Kharkiv Electrotechnical Institute [*KhETI*] and at *KhEMP*, which we can also assume, along with the previously indicated role of the latter in the production of naval electromechanics in the USSR, favored the placement by the Soviet government of an order for research into the possibility of creating electromagnetic systems for bubble-free torpedo firing exactly in Kharkiv.

In parts, the issue of research work of Kharkiv scientists in the field of linear electric machines is clarified: in the monograph Essays on the history of the development of applied technical sciences in Ukraine: From the experience of the Kharkiv Polytechnic Institute (Tverytnykova, Posviatenko, Melnyk, 2015), in the dissertation *Contribution of scientists of Kharkiv Technological and Electrotechnical institutes to development of electrotechnical branch of Ukraine (1885–1950)* (Tverytnykova, 2009) and in the publication *Research work in the field of electric drives at the Kharkiv Electrotechnical Institute (30–40 years of the twentieth century)* (Tverytnykova, 2008). However, in these scientific works only the relevant activities of *KhETI* scientists are considered and no attention is paid at all to the study of the problem of linear electric motors on *KhEMP*, despite the fact that in the presented publications the main place of work of most of the researchers mentioned in connection with the topic of linear electric machines was *KhEMP*, and in *KhETI* they worked part-time. Also, in the cited publications, the research work of Kharkiv scientists in the field of linear electric motors is considered superficially, in contrast to the work in the field of traditional electric machines, which can be explained by the fact that the real consumer properties of the linear electric drive achieved in the interwar period throughout the world [including *KhEMP* and *KhETI*] in many cases were much inferior to the expected ones, and were often even worse than the properties of the non-electric drive of units, for the replacement of which, in fact, the corresponding linear electric machines were developed (Shturman, 1948a). That is, the achievements of both *KhEMP* and *KhETI* scientists in the development of linear electric motors were significantly inferior to their achievements in the development of rotary motors, so much significantly so that a more in-depth mention of this issue by historians has unfairly would level the overall indicator of research results conducted at these institutions in the 1930s, which the above authors would apparently like to avoid.

Moreover, since the end of the 1940s, judging by the avalanche-like decline in the publication activity of Kharkiv scientists in the subject of linear electric machines, the corresponding issues began to be studied by them episodically, while the activity in

studying the problems of rotary electric machines remained consistently high until the beginning of the 1990s. Hence, taking into account the fact that the studies of rotary machines in Kharkiv at the time of preparation of the analyzed historiographic material had almost a century-long history of highly dynamic development, and the study of linear electric machines began in parallel with the previous process only in the mid-1930s and by the end of the 1940s had left the dynamic phase, we can talk about its acquisition of a certain secondary importance [or fragmentariness] in the history of scientific support for the development of Ukrainian electric machine building, and, as a consequence, less interest of historians in this event. In any case, the previously mentioned superficiality of historians' coverage of the issue of research by Kharkiv scientists into linear electric machines has influenced the fact that even in those minor references to the facts of achievements of domestic scientists in the field of linear electric motors that are found in the historiography of Ukrainian electrical machinery, information about work on military topics is completely absent, and there is only information about the civilian use of the corresponding developments of Ukrainian specialists.

However, it should be noted that the issue raised in this article had the status of extreme confidentiality for a long time, as a result of which the relevant archival documents were declassified only in the 1990s and 2000s, and it was never mentioned in any forms in widely available publications. Even the initiator of the systemic research organization in the field of linear electric machines in Ukraine, who was directly related to the emergence of the project for the creation of electromagnetic systems for bubble-free torpedo firing – G. I. Shturman, mentioning in the second half of the 1940s the work carried out in Kharkiv since the mid-1930s on the creation of electric machines of magnetofugal action, does not indicate the original purpose of this work and avoids any technical and technological specifics that could give at least a hint of the military application of the results of the corresponding developments. He limits himself to more general formulations, such as: “magnetofugal induction motors” or “cylindrical magnetofugal engines”, by the way, directly indicating that the leading organization in carrying out this work was *KhEMP*, and not *KhETI* (Shturman, 1948a, 1948b). Later researchers of the theory of linear electric motors, who did not participate in the project to create electromagnetic systems for bubble-free torpedo firing, especially do not indicate this aspect of research activities at *KhEMP* and *KhETI* in their scientific papers, concentrating on the general economic application of the corresponding technology, in accordance with the trends in its use that formed in the 1940s (Rogachev, 1948a, 1948b; Taraschanskiy, 1948a, 1948b, 1948c). Thus, information about the study by *KhEMP* scientists during the second half of the 1930s of the possibility of creating electromagnetic systems for bubble-free torpedo firing was unavailable not only to historians, but also to the vast majority of specialists in the field of linear electric motors, which is why the problem raised in this article remains today not only unexplored, but generally unknown, which makes this article actuality.

Research Methods.

This study is based on the principles of historicism and objectivity, which made it possible to recreate the real historical picture of the implementation of the project of electromagnetic torpedo tubes at *KhEMP* with maximum reliability. The use of the problem-chronological method made it possible to find out the reasons for the formation of established ways of carrying out experimental work within the framework of this project, and the retrospective one – to show the patterns of this process. Using the chronological method, the appropriate sequence of presentation of the obtained historical information was achieved, and using the methods of logic, analysis and synthesis, the conclusions and statements presented in the article were obtained.

Results.

Based on the top secret orders of the People's Commissariat of Heavy Industry USSR: No. 5s.s. and No. 102s.s. of 1935, as well as No. 6s.s. of 1936, a group of scientific-technical employees of the Bureau of Special Electrical Engineering *KhEMP* under the leadership of G. I. Shturman, in March 1936, began studying the possibility of creating a bubble-free torpedo firing system for submarines, the operation of which would be based on the use of electromagnetic energy (The State Archive of Kharkiv Region [SAKhR], 1936a). This project received the official name "Magnetic Torpedo Pusher" [*MTP*], and at the first stage it involved an analysis of the feasibility of three design principles for its implementation: solenoid, electrodynamic and magnetofugal (SAKhR, 1937a). The solenoid principle provided for an initial asymmetry in the relative position of the solenoids and the torpedo [as a core], which required the presence of a special device that turned off the solenoids at the moment when the torpedo approached the equilibrium magnetic position, since otherwise effect of a braking the torpedo would occur. Thus, the electromagnetic force would not act during the entire movement of the torpedo, but only at the initial moment, during which it would have to be given kinetic energy sufficient to push out, by inertia, a projectile weighing 1,600 kg, with a diameter of 0.533 m and a length of 4.8 m into an environment of increased hydrodynamic resistance at a speed of at least 12 m/s (SAKhR, 1938a). That is, the use of the solenoid principle initially presupposed the installation on submarines of either heavy-duty pulse generators or sections of the same heavy-duty starter-type batteries, which by definition required an increase in the weight and size parameters of submarines: both those already built, those under construction, and those at the design stage.

The electrodynamic principle of launching a torpedo was based on the Biot-Savart-Laplace law, according to which the torpedo would receive the necessary ejection force continuously – from the interaction of the magnetic field of the torpedo tube frame and the electric current passing through the elements of the torpedo, that located in the magnetic field, which, however, provided for the presence in the torpedo tube open current-carrying parts, as well as sliding conductive contacts along the body of the torpedo itself. This point led both to intense corrosion of torpedo tubes and to

the risk of frequent uncontrolled short circuits, as well as to the occurrence of the phenomenon of electrolysis and, as a consequence, intense gas formation, which partially neutralized the original goal of achieving bubble-free torpedo firing (SAKhR, 1937a). At the same time, both the first and second design principles were united by the use of direct current, with the inherent phenomenon of sparking the switching parts of electric machines, which is extremely undesirable for submarines, and in the second option was aggravated by use of low-voltage currents, but of high strength, although such significant generating capacities as in the first option was not required here. In any case, based on the above arguments, the team of authors rejected the solenoid and electrodynamic principles of the design of the proposed torpedo tube, and even at the initial stage in 1936, they finally settled on the principle of magnetofugal action, which probably facilitated by the fact that the immediate supervisor of developers – G. I. Shturman by that time already had his own theoretical developments in the field of designing linear electric machines with magnetofugal action. Thus, the method of electromagnetic launching of torpedoes accepted for study was based on the fact that the torpedo [like a solid squirrel-cage rotor of an asynchronous AC motor] was ejected by a running magnetic field from the active part of the torpedo tube, which was a deployed multiphase stator. Despite the structural complexity of the magnetofugal torpedo tube, its undeniable advantage was that, according to preliminary theoretical calculations, confirmed by static mock-up tests (Fig. 1), this principle could be implemented on existing torpedo tubes and torpedoes without any significant alterations, and therefore did not require replacement of the torpedo arsenal of the *WPRF* of the USSR (SAKhR, 1937a).

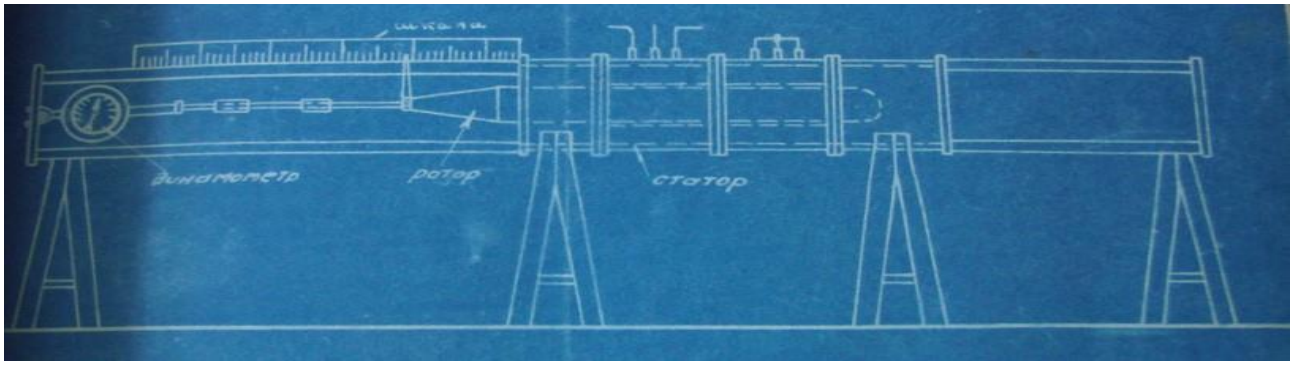

Figure 1. Scheme of an experiment installation for static testing of the possibility of magnetofugal launch of torpedo (SAKhR, 1937a).

Meanwhile, during 1936, political repression began to unfold at *KhEMP* against representatives of the opposition to the Stalinist course of building socialism in the Soviet Union, as a result of which G. I. Shturman (Fig. 2) [as Trotskyist] was accused of "counterrevolutionary sabotage" by the factory Bolsheviks at the beginning of 1936 and was dismissed from the enterprise by the end of that year, and the *MTP* project was headed by his brother L. I. Shturman (SAKhR, 1936b; SAKhR, 1937b). In this

situation, attention is drawn the fact itself that, unlike most similar cases in the USSR in the second half of the 1930s, public accusations of party activists G. I. Shturman were not further developed than as dismissal, when usually those subjected to a similar public accusation were then brought to a criminal court, by decision of which they were either imprisoned or executed, after which their closest relatives were brought to trial [with various consequences]. However, G. I. Shturman [who, of course, like the majority of those repressed by the Soviet totalitarian machine, did not commit any sabotage], unlike many accused of Trotskyism, never denied his commitment to L. D. Trotsky, and moreover, he never abandoned this commitment. However, if usually even those suspected of simply sympathizing with L. D. Trotsky, as well as their relatives, since 1936, criminal repressions fell like an avalanche, G. I. Shturman, having been fired from *KhEMP*, found a permanent job at *KhETI*, where he had previously worked part-time, and from where in 1937 he was transferred to the Ural Industrial Institute.

Figure 2. G.I. Shturman [1903 – 1964] (The Scientific and Technical Library of NTU «KhPI», 2024).

Also, repressions did not affect L. I. Shturman [if not considering as such his exclusion from candidate to Bolshevik Party members], who, after the dismissal of his brother, as already mentioned, headed the work on the *MTP* project, but in a new factory research unit created after January 1937, when *KhEMP* and the Kharkiv Turbogenerator Plant were merged into a single Kharkiv Electromechanical and Turbogenerator Plant *KhETP* (SAKhR, 1936c; Voznesenskiy, 1965). This division, created on the basis of the Machine Laboratory, was called the Special Drives Laboratory [*SDL*], and in it, in addition to L. I. Shturman in group studying the electromagnetic launch of torpedoes included engineers M. G. Sorokin and B. A. Zilbershtein, as well as installation technician L. A. Amolin (SAKhR, 1937a). *SDL* itself instead of G. I. Shturman was headed by E. M. Bogdanov, and structurally

the laboratory became part of the Special Design and Installation Bureau [*SDMB*] of the Technical Department for Design and Installation [*DIT*] *KhETP*, headed by M. G. Waisman. Thus, we have every reason to assume that both for the *MTP* project and for the study of the problems of linear electric machines in general, a qualificative personnel for replacement to the Shturman brothers and announced in 1937 the Trotskyist B. A. Zilbershtein the Soviet government did not have, and it abandoned the criminal repressions practiced in such cases, although apparently a certain unspoken forceful pressure was exerted on these scientists by the authorities, since in subsequent years none of them showed any political activity (SAKhR, 1937c).

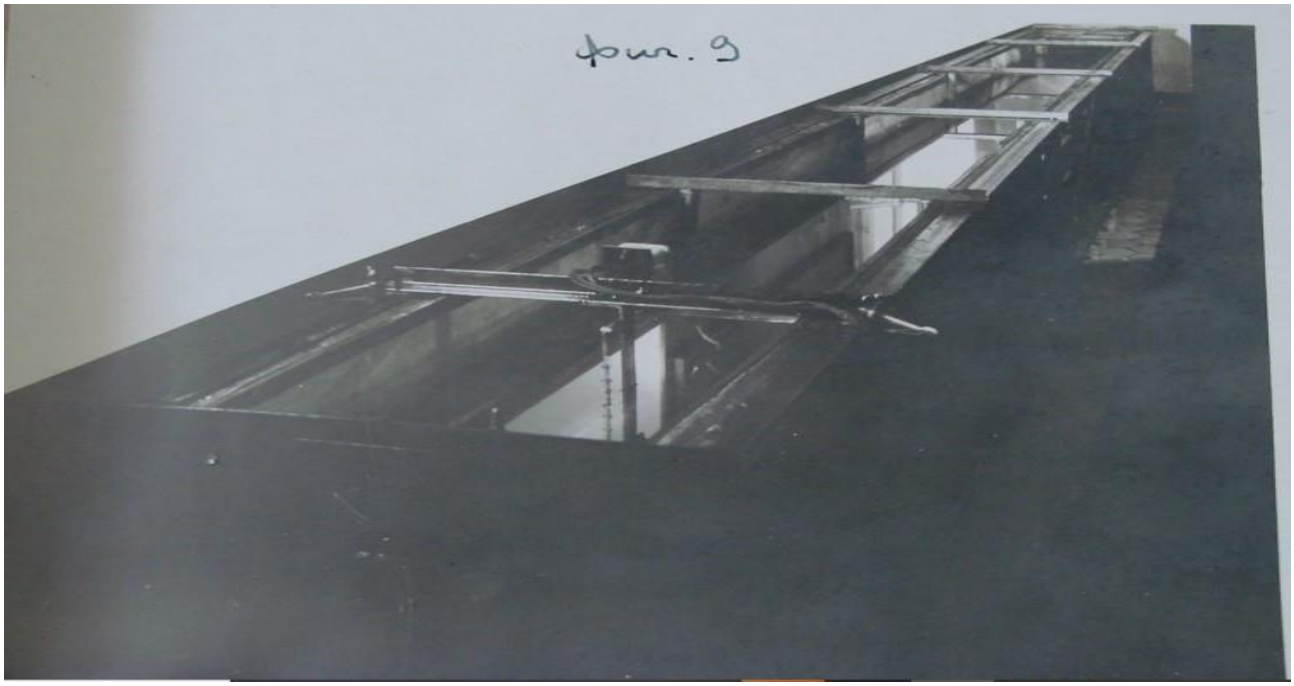

Figure 3. A pool for dynamic testing of a magnetofugal launch of the torpedo from the 1:5 scaled copy 21" torpedo tube in armament with the submarine forces of the *WPRF* USSR (SAKhR, 1937a).

In any case, work on the *MTP* project required its continuation, since the static tests carried out confirmed only the very possibility of using a running magnetic field to push a torpedo out of the torpedo tube, but did not reveal how effective this possibility would be in real conditions, and how it should torpedo launchers should be prepared so that this capability can be implemented on submarines in principle. For this purpose, dynamic testing of a magnetofugal torpedo tube became necessary, however, due to the high cost of the corresponding work on full-real objects with complete uncertainty of the results of these tests, by a meeting of the management: of *KhETP*, the Mine-Torpedo Research Institute [*MTRI*], Leningrad Mechanical Plant No. 103 [manufacturer of torpedo and torpedo tubes], as well as the Armament Directorate of the *WPRF* USSR, it was decided for these dynamic tests to build special stands at *KhETP* for simulating real torpedo firing conditions (SAKhR, 1938a). In

accordance with this decision, in the *SDL* room, to simulate torpedo firing conditions, a special steel pool 8 m long, 0.6 m wide and 0.7 m high was built (Fig. 3), which housed a five-fold reduced working copy of a standard torpedo submarine apparatus with a caliber of 21 inches (Fig. 4), equipped with measuring instruments and special devices that recreate, on an appropriate scale, the loads on the elements of torpedo tubes and torpedoes that occur in real conditions. The number of models to be tested was not initially established, but it was intended to carry out tests until such a result was obtained that would give an unambiguous answer to the advisability of using magnetofugal torpedo tubes, and the first model to be tested was called *MTP-1*. Thus, all tested copies of the torpedo tube and torpedoes had to be equipped with electromechanics that would create the necessary magnetofugal action, and the design of which would be modified based on the results of previous experiments. Changes could also be made to the design and equipment of the test benches themselves if the results of the experiments would be revealed that the simulated conditions turned out to be different from the specified ones or if the installed measuring instruments could not clamp the researched loads parameters.

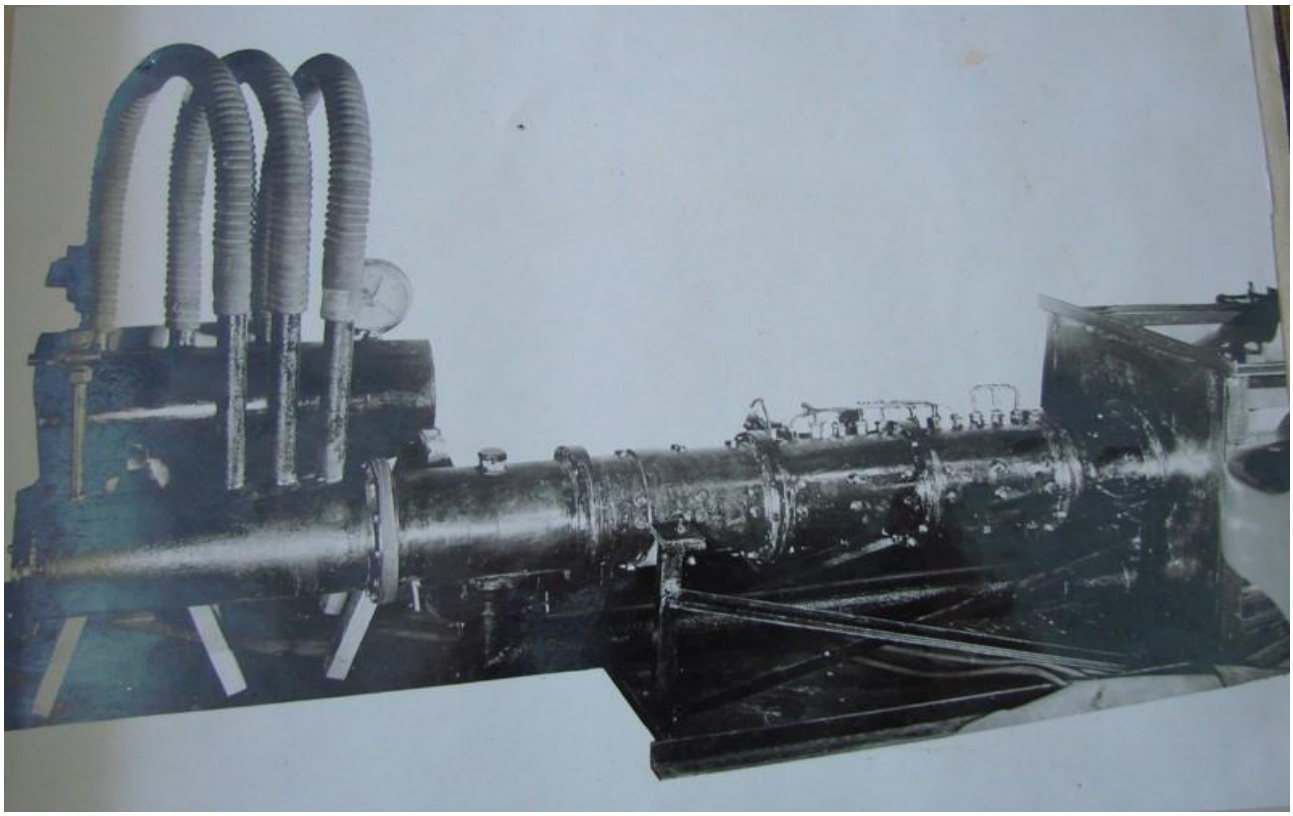

Figure 4. A working copy of a 21" torpedo tube of Soviet submarines on a scale of 1/5 of the original, intended for dynamic testing of magnetofugal launches of torpedoes (SAKhR, 1937a).

The results obtained in 1937 during dynamic tests at the *MTP-1* installation showed that the tactical and technical requirements set by the customer directly for the

launch of torpedoes, in laboratory conditions were achieved (Fig. 5). This was the impetus for the *SDMB DIT KhETP* team to begin designing a six-tube magnetofugal torpedo system, based on the six-tube pneumatic torpedo system used on Soviet submarines. However, the lack of experience in creating torpedo tubes forced Kharkiv designers to turn to specialists from Plant No. 103 and *MTRI* for help in this matter, while insisting to the government on the need to build a full-size prototype, since the installation *MTP-1* did not allow research in the first place , issues of full hydraulic compensation for torpedo launch and optimal design and location of the magnetofugal stator for maintaining stable electrical power and weight balances of submarines (SAKhR, 1937d). Based on the importance of this issue for determining the impact of the use of magnetofugal torpedo tubes on the design of submarines as a whole, both Plant No. 103 and *MTRI* did not refuse *KhETP* the necessary consultations, at the same time not supporting the *SDMB DIT* proposition to build a full-size prototype, and insisting on maintaining the originally adopted tactics of testing. As a result of a short debate, the government made a decision in favor of Plant No. 103 and *MTRI*, as a result of which the work plan of *SDMB DIT KhETP* for 1938 included the continuation of research on the *MTP* project with the construction of new test models on the mechanical basis of the *MTP-1* installation in that quantity , which was necessary to study all those nuances of using a running magnetic field to push out torpedoes, which were of decisive importance for deciding on the feasibility of creating magnetofugal torpedo tubes (SAKhR, 1938b).

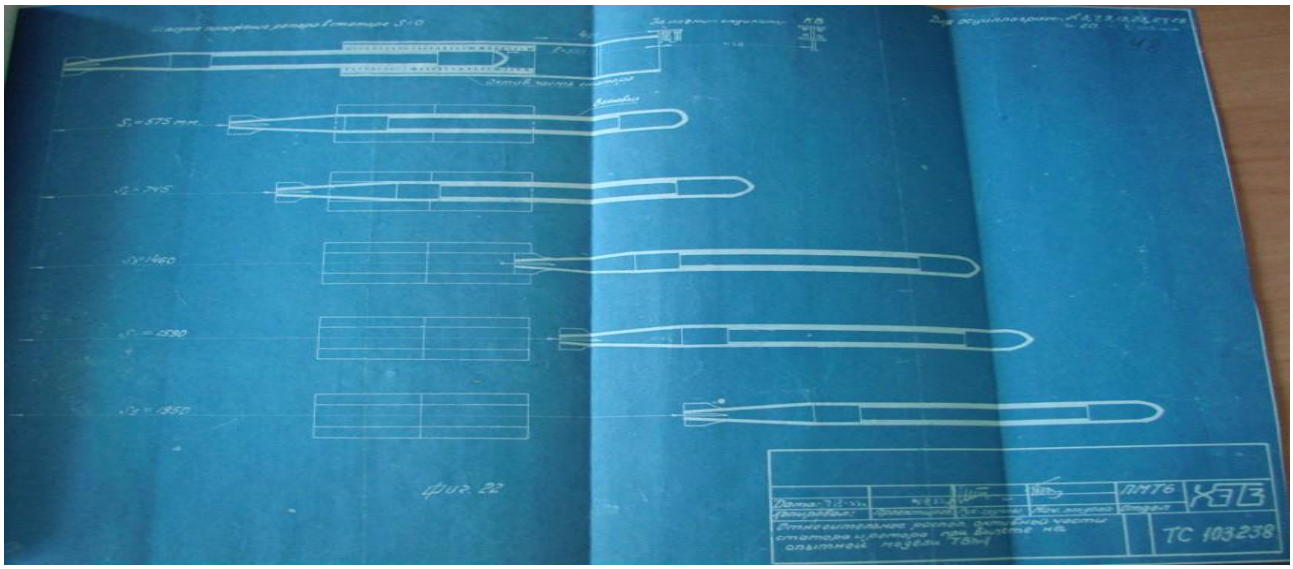

Figure 5. The stroke of a torpedo model on a scale of 1:5, achieved on the *MTP-1* installation (SAKhR, 1937a).

In accordance with the work plan, during 1938 *SDMB DIT KhETP* on the basis of *MTP-1*, 3 more experimental installations for dynamic tests and a separate installation for static tests of the magnetofugal stator were built (Fig. 6), which were all carried out on scale 1:5 to the original. At the same time, before 1938, certain changes occurred in

the research team, which, however, affected not so much the quality as the pace of research on the *MTP* project. So, *SDL*, instead E. M. Bogdanov of defending the need to conduct tests on the *MTP* project on life-size models, was headed employee by *SDMB DIT KhETP* M. L. Sosnov, who was more loyal to the original scheme of conducting experimental work, and B. A. Zilberstein, who also considered the transition to full-scale testing of magnetofugal torpedo tubes premature, was removed from the *SDL* team and promoted to the position of head of the Combat Mechanisms Group, of which *SDL* became a structural unit. That is, in 1938 L. I. Shturman was practically deprived of influence on the organization of work on the *MTP* project as a whole, and remained only the head of mock tests of the possibility of using the magnetofugal method of pushing torpedoes out of submarine torpedo tubes. Thus, all attempts made by L. I. Shturman's to scale up the *MTP* project by involving Plant No. 103 and *MTRI* in it as subcontractors, those manufacturing and testing not mock-ups, but prototypes of magnetofugal torpedo tubes and, thereby, to gain the opportunity for a longer-term existence of the project, were stopped. The latter was necessary for L. I. Shturman for the reason that in the course of research within the framework of the *MTP* project at *KhETP*, he should obtain results that, the benefits of which for implementation this project were not yet entirely clear, however they were very relevant for the theory of linear electric machines, that being developed at *KhETI*, where he also worked at part-time after his brother left for the Urals, but yet with less funding for corresponding research. Now, with the final foothold of only mock-up tests by the *MTP* project, the time frame for research work was significantly compressed, since the rather long stages required to create and refine full-size prototypes was eliminated.

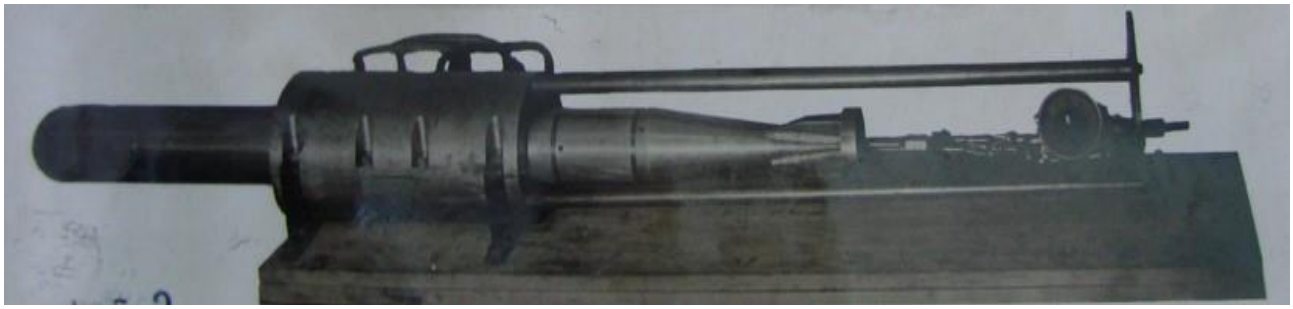

Figure 6. Installation for mock-up static tests of magnetofugal stator designs (SAKhR, 1938c).

Concentrating on mock-up tests, L. I. Shturman and M. G. Sorokin first of all tried to operate the optimal design of a magnetofugal starter on mock-ups, since it was this point that was decisive for solving all the other problems [with hydraulic compensation of torpedo launch, etc.], which were discussed above. It should be noted that scientists, using a new installation for static tests (Fig. 6), as well as on the *MTP-2* dynamic test model, were able to determine the most technologically advanced design of a magnetofugal stator – from a detachable thick-walled pipe with screw

threads on its inner surface, which made a range of options placement of such a stator in the axial direction of the pipe of torpedo tube is wider. That is, from the point of view of meeting the weight and size requirements for submarine torpedo launchers and ease of manufacture, this design was optimal, but its traction characteristics turned out to be worse (Fig. 7) than the laminated design used on the *MTP-1* model. Therefore, to reduce losses of electromagnetic energy in the stator, in the next model *MTP-3* it was milled from the inside by 32 radial grooves 2 mm wide and 20 mm deep, which, however, only slightly increased the efficiency of the design, at least not so much that the total capacity power-plants used to ensure the normal mode of torpedo launch when using a solid stator was both economically and technically justified by the simplicity of its design (SAKhR, 1938c). Thus, in the *MTP-4* model, scientists returned to the laminated types of magnetofugal stator designs as the most rational from the standpoint of minimizing energy consumption for each torpedo launch.

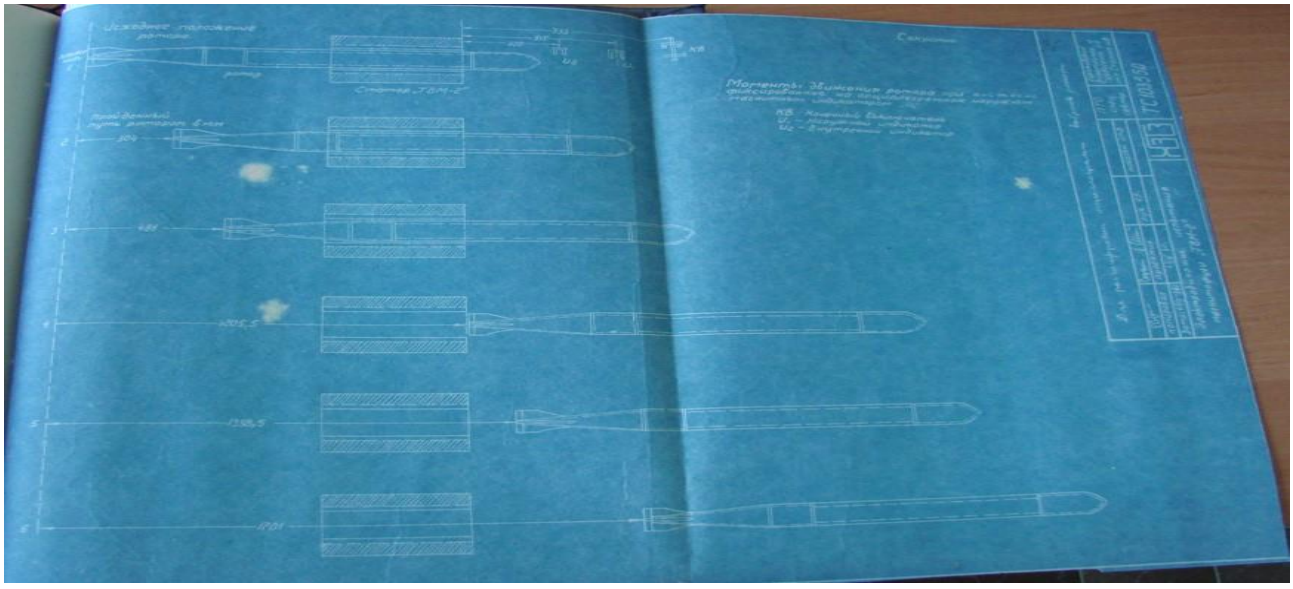

Рисунок 7. The stroke of a torpedo mock-up on a scale of 1:5, achieved on the *MTP-2* installation (SAKhR, 1938c).

By the end of 1938, having testing various versions of laminated stators on the *MTP-4* model, the final design diagram of a magnetofugal torpedo tube with an efficiency equal to that of a pneumatic device had been obtained at *SDL SDMB DIT KhETP*, although the efficiency of the entire electromagnetic torpedo launch system at whole continued to be inferior to the efficiency air system. At the same time, in addition to previously established problems of a non-electrical nature that arise during the process of pushing a torpedo out of a standard torpedo tube using a running magnetic field, already during tests on the *MTP-3* model, the problem of rapid wear of the insulation of current-conductive elements inside the torpedo tube under the influence of variable [water/air] environment they located, as well as at hydraulic pressure greater than 10 atm (SAKhR, 1938a). The types of insulating materials known at that time in the Soviet Union did not guarantee the minimum required by the customer [5-

year] service life of torpedo tubes before their overhaul, even in peacetime conditions, with rare use of torpedo systems for their intended purpose [and therefore without a significant load on current-conductive elements], which was absolutely unacceptable for the *WPRF* when preparing the USSR for a global and long-term armed conflict. And although in the *SDMB DIT KhETP* during the period under review [*regardless of the* MTP *project, according to the relevant resolution of the 2nd conference on ship electrical equipment, held in Kharkiv on February 07–13, 1937 (SAKhR, 1937e)*], intensive work was carried out on the creation of insulating materials with qualities that meet the requirements for the insulation of conductive parts of torpedo tube magnetofuges, their completion had a rather vague prospect both in terms of time and result (SAKhR, 1939). Therefore, as a temporary measure, *SDL* specialists proposed a fairly simple method of mechanically solving this problem – by placing the conductive parts of the magnetofugal stator in a sealed casing made of stainless non-magnetic material [stainless steel, brass, zinc, etc.] (Fig. 8).

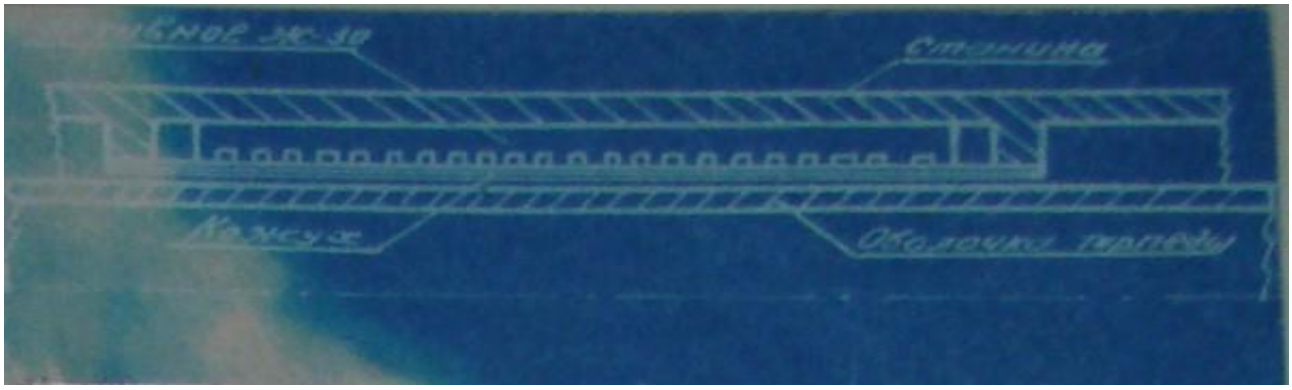

Figure 8. Insulation scheme of the conductive parts of the magnetofugal stator in the torpedo tube pipe, proposed by *SDL SDMB DIT KhETP* (SAKhR, 1938c).

The simplicity of solving the problem of insulating the current-conductive parts of the magnetofugal stator led, however, to an increase in power losses in the magnetofuge and, as a consequence, to the need to increase the power of the installations that provide it with electricity, and therefore their weight and size parameters. Thus, all three options for powering magnetofuges with energy, developed during the re-design of a 6-tube magnetofugal torpedo tube [from two shock generators; from one shock generator with a mechanical energy accumulator [flywheel]; from an accelerating action generator], assumed installation on the submarine of appropriate equipment weighing about 30 tons [and this is not counting the increase in the weight of torpedo tubes], which made the use of this method of launching torpedoes only theoretically possible on operational submarines, and only on squadron and cruising types of them (SAKhR, 1938a). At the same time, dynamic model tests have shown that the electromagnetic launch of a torpedo by itself does not ensure its completely bubble-free exit from the torpedo tube [which determined by the physics of the movement of bodies in an aquatic environment] and for this, the presence

of an air compensation device is still necessary (Owis & Nayfen, 2003; Phan, Nguyen, & Park, 2020). In addition, the use of an electromagnetic launch system required a fairly large number of auxiliary electromechanical devices and controls, and this made such a system not only more cumbersome, but also less reliable than a pneumatic one, which implied simultaneous mandatory use on submarines and the latter as a backup one. That is, arming even large submarines with magnetofugal torpedo tubes presupposed either the creation of new projects for such submarines, or a radical redesign of existing ones, wherein with the very dubious combat effectiveness of electromagnetic torpedo firing. This circumstance served as an argument for the curtailment of the *MTP* project at the end of 1938 and news's about all the work of Kharkiv scientists in the field of linear electric machines before the outbreak of the Soviet-German war in 1941 in historical documents is associated exclusively with their civilian use - in the construction and mining industries.

Discussion.

The short life of the *MTP* project was one of the reasons that the total number of documents accompanying it did not form such a large amount of information about it that would allow obtaining complete information about the work on the project even after a significant period of time and, as a consequence of it, the loss of part of the documentary base. On the other hand, the analysis of other short -term research projects, performed in this time on *KhETP*, shows that the volume of documents accompanying such draft documents also depended on that degree of importance of research results for the Soviet government that it expected from them. Hence, in our case, the insignificant documentary support of the *MTP* project may also indicate an initially skeptical assessment by the military and party-economic leadership of the USSR of the possibility of creating effective electromagnetic systems for bubble-free torpedo firing. Thus, due to the weakness of the historical source base, the motivations given in this article for the scientists who carried out the *MTP* project and the customers regulating their actions are justified not so much by direct relevant documentary evidence, but by the results of an analysis of the historiography of the development of the theory and practice of constructing linear electric machines in Ukraine during 1930s, as well as the empirical knowledge of the author of this article about the traditions of office work relative to research projects established at *KhETP* during this period in a whole. Therefore, in a case if the base of relevant historical sources to be expanded, it may be possible to discover additional motivational factors was established as a result of interactions between customers and performers and that influenced the way of *MTP* project implementation.

Conclusions.

The project of electromagnetic torpedo tubes appeared as a result of a confluence of circumstances when, on the one hand, the Soviet naval forces had a need to arm submarines with bubble-free torpedo firing systems, and on the other hand, the

development of the Ukrainian segment of Soviet electrical machinery reached a level that allowed it to resolve this problem in the specified method. The last point does not allow us to consider the mentioned coincidence of circumstances as accidental, but rather, on the contrary, as a natural result of the measures taken during the 1920s–1930s by the Soviet government to develop scientific support for Ukrainian electrical machinery, as a result of which the achievements of domestic scientists in the field of linear electrical machines made creating electromagnetic torpedo tubes are possible in principle. At the same time, the theoretical possibility of creating electromagnetic systems for bubble-free torpedo firing did not yet mean that it could be implemented in practice, since the physics of launching a torpedo by a submarine in an underwater position has a number of nuances that cannot be resolved using electromagnetism by definition. This was the factor that influenced the Soviet government to limit work on the creation of electromagnetic torpedo tubes to only mock-up studies, the feasibility of what for the fleet was subsequently confirmed by the results of these studies. However, for Ukrainian scientists who were entrusted with carrying out the corresponding scientific project, more important than the practical confirmation of the possibility of electromagnetic launch of a torpedo were the validation and verification of the calculation and design methods they developed for linear electric machines, the improvement of which, based on the results of this particular project, made it possible to make a qualitative leap in the production of linear electric motors. Therefore, the creative team of researchers was interested not only in mock tests, but also in testing full-size prototypes of electromagnetic torpedo tubes, which would make it possible to test methods for calculating and designing linear electric machines with more accurate results, and also would give a greater margin of time for adjusting these methods due to the duration manufacturing cycle of these prototypes. The antagonism of the interests of customers and researchers on the issue of ways to implement the experimental part of the project indicates the skeptical attitude of the government in the second half of the 1930s to the relevance of the issue of developing the theory of linear electric machines. This allows us to consider the creation of linear electric motors for certain categories of equipment for the mining and construction industries mentioned in the historiography of Ukrainian electrical engineering of the studied chronological period as the fruit of the enthusiasm of Ukrainian electrical mechanical engineers rather than the result of a targeted sectoral scientific and technical policy of the Soviet government. Nevertheless, this achievement of domestic specialists in the field of linear electric machines undoubtedly became possible thanks to the use of the results of the work that they carried out as part of the implementation of project of electromagnetic torpedo tubes. And since these results were of fundamental importance for the development of the theory of linear electric machines, despite the revealed impossibility of their use to ensure bubble-free torpedo firing, the corresponding research project can be considered unsuccessful only in this context.

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Робота на Харківському електромеханічному і турбогенераторному заводі над проєктом електромагнітних торпедних апаратів (1936–1938 рр.)

Анотація. *Діяльність учених Харківського електромеханічного і турбогенераторного заводу над проєктом електромагнітних систем безбульбашкової торпедної стрільби впродовж 1936–1938 рр. на сьогодні є новою інформацією як для істориків науки і техніки, так і для спеціалістів у галузі електромашинобудування. Цей проєкт виник внаслідок збігу кількох обставин, одним з яких стала потреба радянського військово-морського підводного флоту напередодні ІІ Світової війни в удосконаленні свого торпедного озброєння системами, що не демаскували б субмарини під час пуску*

торпед з підводної позиції. Іншою обставиною стало те, що Харківський електромеханічний завод з 1934 р. був головним підприємством у СРСР з виготовлення електромеханіки для кораблів усіх класів та для всіх об'єктів берегової оборони, а відповідно його адміністрація і той науково-технічний персонал, котрий на заводі займався оборонною тематикою, були обізнані за вказану проблему. Одночасно, частка співробітників з числа останніх, працюючи за сумісництвом у Харківському електротехнічному інституті, з першої половини 1930-х років поряд з проблематикою ротаційних електромашин активно розробляла напрям електромашин із лінійним рухом ротору, і досягла в цьому суттєвих результатів. Таким чином, до 1936 р. сформувалися умови, коли задовольняння потреби в забезпеченні радянських субмарин системами безбульбашкової стрільби стало теоретично можливим завдяки застосуванню електромагнітного пуску торпед, відповідно до методик, розроблених харківськими науковцями для лінійних електромашин, і з апаратів, оснащення яких виготовлювалося б на Харківському електромеханічному заводі. Проте ця теоретична можливість вимагала практичного підтвердження, для чого й було організовано проєкт «Торпедний виштовхувач магнітний», виконавцями якого стали ті самі спеціалісти, котрі займалися дослідженням лінійних електромашин як на Харківському електромеханічному заводі, так і в Харківському електротехнічному інституті. Метою проєкту стало: вибір можливого варіанту принципового устрою торпедної установки електромагнітної дії і перевірка працездатності побудованої згідно обраного варіанту конструкції за допомогою макетних випробувань. Проведені дослідження показали, що само по собі виштовхування торпеди з торпедного апарату в межах встановлених замовниками проєкту режимів можливо за допомогою біжного магнітного поля, однак електромагнітний пуск торпеди не робить його повністю безбульбашковим, а лише веде до зменшення об'єму утворюваної при пострілі повітряної бульби. При цьому, застосування електромагнітного пуску торпед на існуючих та проєктованих конструкціях радянських субмарин виявилося неможливим через значні зміни в такому випадку масогабаритних характеристик встановлюваного на них електроенергетичного устаткування. Між тим, такий же ступінь зменшення повітряної бульби вже був досягнутий у конструкціях пневматичних торпедних апаратів субмарин типу «Сталинец», спроєктованих за замовленням Радянського Союзу німецькими та голландськими конструкторами, що повністю позбавило проєкт торпедних апаратів електромагнітної дії своєї привабливості, і привело до його закриття. Проте, незважаючи на невдалу результативність цього проєкту в контексті створення системи безбульбашкової торпедної стрільби, його здійснення дозволило харківським ученим валідувати та верифікувати створювані ними методики розрахунків і проєктування лінійних електромашин, а також визначити оптимальні конструкції магнітофугальних статорів, що в наступному було використано

при створенні спеціального електромеханічного обладнання для гірничодобувної та будівельної індустрій.

Ключові слова: *безбульбашкова стрільба; електромагнітний пуск; лінійні електромашини; субмарина*

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Analysis of the application of lasers for counter-UAV purposes

Abstract. *From the dawn of human history, mankind has always made efforts to create more effective tools for combating other creatures, including fellow people. Thus, the utilisation of different species of animals, the creation of new weapons and other means of human progress have always led to new developments, aimed at*

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emulating, replacing or combating these innovations. The development of unmanned aerial vehicles has prompted the need to develop alternative and innovative countermeasures. These methods may range from the usage of interceptor drones to the application of concentrated energy beams. This paper examines the progress and known uses of laser technology in the context of combating unmanned aerial vehicles. In order to deepen and systematize knowledge about the development of laser applications in the military field, a systematic bibliographic analysis of scientific papers and popular publications on the development of both laser technologies and unmanned aerial vehicles over the past century was conducted. The study focused on developments that were built (at least as a prototype) and tested against various unmanned aerial vehicles. The results were then compared with a number of articles that separately focused on the history, prospects, and current issues in the development of laser weapons and unmanned aerial vehicles. At the same time, due to the fact that laser technology is one of the most rapidly and comprehensively developing areas of scientific progress, it was decided to use a periodic classification model, the main criterion of which was the focus of laser technology development on countering unmanned aerial systems. The issue of determining the cause-and-effect relationship that links the development of unmanned aerial vehicle technologies and designs with the shift in the focus of laser weapons development to counteract them was considered. It is noted that, due to the high requirements for human and financial capital, the direction and pace of development of laser weapons depend not only on technological limitations, but also on the vision of military strategy and possible threats at a given time. As a conclusion, a variant of periodization of the history of the development of laser weapons as a means of combating unmanned aerial vehicles was proposed.

Keywords: *laser; laser emission; technological development; laser weaponry; unmanned aerial vehicle; Counter Unmanned Aircraft Systems (C-UAS)*

Introduction.

From the ancient Greeks' wars with the Persian Achaemenid Empire to modern armed conflicts, armed conflict has been an integral part of human history. These conflicts have left their mark on humanity in many ways. One of the dimensions of this impact has been represented by weapons development. Since the first battle between tribes of primitive people, humanity has been striving to create more effective tools to fight other creatures, including other people. In different historical periods, the creation of new, more advanced weapons, as well as the development of methods for their production, gave one party of the conflict a significant advantage on the battlefield and contributed to their victory (Hacker, 1997). The emergence of such innovations on the part of one of the belligerents gave it an indisputable advantage over their opponent. However, the creation and use of innovative weapons has always triggered the emergence of new developments in both weapons and techniques designed to combat these weapons in a qualitative and cost-effective manner. This phenomenon is sometimes called an “arms race”. There are many developments of weapons that are

considered to be milestones: from bronze swords and Macedonian sarissas to tanks, combat aircraft and nuclear weapons. However, the scientific and historical community has paid less attention to the methods of countering these weapons that have been developed throughout history. There are several explanations for this, ranging from the fact that countermeasures were often as much of a development milestone as their predecessor; and the fact that these developments were often defeated through the use of tactics, strategy and cunning. For example, during the Battle of Isandlwana (1879), Zulu forces, armed mainly with spears and leather shields, defeated the British army, armed with breech-loading rifles, machine guns and artillery, through trickery and skilful strategy (Beckett, 2023). However, in general, history shows that technological superiority provides a dramatic advantage. An extreme example of such an advantage occured during the next battle of the Anglo-Zulu War – the defence of the hospital in Rorke's Drift, where only 140 British soldiers stopped and repelled the attack of 4000 Zulus, armed not only with traditional spears but also with captured British weapons. The first use of tanks during the World War I did not change the course of the war immediately; however, it did manage to cause a certain amount of panic in the ranks of the Reichswehr command, which in turn launched programmes to both build their own tanks and create weapons specifically designed to combat tanks. These weapons became known as anti-tank rifles. In general, the development of tanks and combat aircraft are good modern examples of such an arms race and methods of countering them, since with the advancement of these types of weapons to a new level, the development of methods of countering these updated weapons would commence immediately (Salminen, 1992). Thus, the first tanks of the World War I, named so because of their visual resemblance to cisterns (which was used by British counterintelligence to create a legend that the project itself was not intended to create armoured vehicles, but to create a mechanised tank for the needs of the Entente armies (Fuller, 1920), turned into medium and heavy tanks of the World War II, and then into the main battle tanks of the Cold War. At the same time, anti-tank rifles have evolved into anti-tank guns, and subsequently into anti-tank missile systems (ATGM’s).

Over the last 30 years, we can observe a transition to a new round of such an "arms race" (Salminen, 1992; Hacker, 1997). The development of the latest stealth technologies, the development and use of the first hypersonic weapons; the increasing use of the Internet and space satellites for tracking of enemy actions as well as coordination of own units (GPS, Starlink, etc.), along with other innovations, provide a new set of challenges for weapons designers.

One of these weapon developments are unmanned aerial vehicles. With the overall development of various technologies, due to a variety of factors, a new ‘round’ of UAV development has taken place (Fuhrmann & Horowitz, 2017; Babak et al., 2021; Ajakwe, Kim, & Lee, 2023) These factors include:

a. Advances in materials science, including the development of new durable carbon fibre composites, as well as non-metallic composite materials, both of which have significantly reduced aircraft weight and increased payload.

b. Development of computer technology (miniaturisation of processors and other controller boards as well as an increase in their computing power) through the development of the semiconductor industry and IT technologies.
c. The development of design and theoretical calculation tools is directly related to the growth of the computer industry. The widespread adoption of computer software (CAD programs and mathematical modelling packages) makes it possible to quickly create structures of more complex shapes and more efficiently calculate any number of models required to confirm their effectiveness.
d. The development of the battery industry, namely the development of small-sized, high-capacity Li-ion batteries, has reduced their weight and dimensions by a factor of several times.

At the same time, the number of areas and types of work that can be performed with UAVs is growing rapidly every day. However, these also pose security risks, especially when used for espionage, smuggling, or military purposes. As a result, advanced anti-drone technologies have been developed to counter UAV threats. Military UAVs pose significant threats to various objects and infrastructure (Kim, Choi, & Kwon, 2024), as their capabilities expand from surveillance to direct attack roles (Liu, Zhang, L., Wang, Meng, & Zhang, B., 2024). Here are some key targets military UAVs can threaten and countermeasures to mitigate their impact:

1. Critical Infrastructure. UAVs can attack power plants (Mohsan, Khan, Noor, Ullah, & Alsharif, 2022), oil refineries (Chamola, Pavan, Aayush, Naren, Navneet, & Mohsen, 2021), water treatment facilities, and communication hubs. A successful attack could cause widespread outages, disrupt essential services, or create environmental hazards.

2. Military Bases and Personnel (Kratky, Minařík, Šustr, & Ivan, 2020). UAVs can be used for reconnaissance or launching missile strikes against troops, equipment, and military installations. They can carry bombs, missiles, or act as kamikaze drones, directly targeting high-value military assets.

3. Government Buildings. UAVs can be deployed for espionage, capturing sensitive information, or even direct attacks on key government sites such as command centers, embassies, or defense ministries.

4. Transportation Infrastructure. UAVs pose threats to airports, ports, bridges, and highways. Attacks on these facilities can paralyze logistics, hinder troop movements, and disrupt supply chains.

5. Nuclear Facilities. UAVs can be used to attack nuclear power plants or weapons facilities, risking catastrophic consequences like radiation leaks or the destruction of nuclear materials.

6. Civilian Population and Public Events. UAVs can target densely populated areas or major public events, resulting in mass casualties and creating widespread panic, especially in cases of terror attacks.

7. Industrial and Economic Targets (Lykou, Moustakas, & Gritzalis, 2020). UAVs can disrupt factories, financial centers, or major corporations, causing economic instability by damaging production lines, data centers, or financial infrastructure.

8. Naval and Maritime Assets. Drones can threaten ships, ports, or offshore oil rigs, using surveillance to monitor naval movements or deploying explosives to cause physical damage.

As UAV technology advances, so too must the tactics and technologies designed to combat them. However, to understand them, we first must understand their development cycle throughout history.

The first real-world application of this type of weapon is generally considered to be German developments from the World War II, namely the V-1 projectile aircraft (Palik & Nagy, 2019), as well as the US Operation "Aphrodite" plane-bombs (Boyne, 2010). Afterwards, UAVs became an integral part of the arsenal of countries around the globe, performing reconnaissance and auxiliary tasks (such as target aircraft), and since the early 2000s, strike missions. At the same time, the rather large size of this generation of unmanned aerial vehicles made them vulnerable to traditional air defence methods, and therefore did not require the development of special countermeasures. Nevertheless, the events of the last decade have shown a rapid paradigm shift in this regard. Smaller combat drones are becoming an increasingly integral part of the modern battlefield. At the same time, the skilful use of Bayraktar TB-2 UAVs during the Azerbaijani-Armenian conflict in 2020 and at the beginning of the Russian-Ukrainian war in 2022 showed that classical methods of using air defence systems were ineffective against these vehicles. However, due to their rather massive size, traditional air defence equipment was still able to fight this class of drones, so over time, methods of fighting these UAVs were developed, and due to the high rate of losses, Bayraktars were transferred to the Black Sea maritime patrol duties.However, the main technological breakthrough in the field of combat UAVs was the use of smaller UAVs such as the Sha'ed, Orlan, and later - even more miniaturised drones such as the DJI Mavic as well as various FPV drones. Here, it is worth noting that there are currently several classifications of UAVs used for military purposes. Two classifications are mainly used: the NATO classification (STANAG 4670), shown in Table 1, and the Pentagon classification (DOD-USRM-2013), shown in Table 2.

Their size made the use of existing air defence systems virtually impossible, forcing both sides of the conflict to adapt and develop methods to counter drones of this size. The Israeli-Palestinian conflict of 2024 deserves special attention, during which Israeli air defence systems were able to overcome waves of Iranian attack drones by using multi-echelon air defence systems such as the Patriot and Iron Dome. However, while the cost of one Iranian attack drone is 50 thousand dollars, the cost of a Petriot interceptor missile is 4 million dollars. It is interesting to note that this issue has been on the agenda of the Israeli military for some time, as the first documented and proven use of laser weapons as an interceptor of flying objects (UAVs and missiles) was recorded during the same conflict.

Table 1. UAV classification according to NATO standards (NATO, 2019).

Class	Category	Normal employment	Normal operating altitude	Normal mission radius	Primary supported commander
Class III (> 600 kg)	Strike/ Combat	Strategic/ National	Up to 20000 m	Unlimited (BLOS)	Theater
	HALE	Strategic/ National	Up to 20000 m	Unlimited (BLOS)	Theater
	MALE	Operational/ Theatre	Up to 14000 m	Unlimited (BLOS)	Joint Task Force
Class II (150—600 kg)	Tactical	Tactical Formation	Up to 5500 m	200 km (LOS)	Brigade
Class I (<150 kg)	Small (>15 kg)	Tactical Unit	Up to 1500 m	Up to 50 km (LOS)	Batallion, regiment
	Mini (<15 kg)	Tactical Subunit (manual or hand launch)	Up to 900 m	Up to 25 km (LOS)	Company, platoon, squad
	Micro (<66 J)	Tactical Subunit (manual or hand launch)	Up to 60 m	Up to 5 km (LOS)	Platoon, squad

Table 2. US DOD classification of UAVs (Department of Defense, 2013).

Class	Size	Maximum gross takeoff weight	Normal Operating altitude	Airspeed
1	Small	under 9 kg	<300 m	<190 kph
2	Medium	9.5 – 25 kg	<1000 m	<460 kph
3	Large	up to 600 kg	<6000 m	<460 kph
4	Larger	over 600 kg	<6000 m	Any airspeed
5	Largest	over 600 kg	>6000 м	Any airspeed

Modern countermeasures to mitigate UAV threats are extremely varied and can be divided into several categories (Ajakwe, Kim, & Lee, 2023; Shaohui et. al., 2023; Liu, Zhang, L., Wang, Meng, & Zhang, B., 2024):

1. Electronic warfare. Electronic warfare systems operate by disrupting or blocking communication between the operator and the UAV or interfering with GPS navigation. The main methods of electronic warfare include:

1.a. Jamming. Systems that emit signals that jam or interrupt the drone's control, disabling it. This is one of the most common methods for neutralizing commercial and military UAVs.

1.b. Spoofing. A technology that transmits fake GPS or radio signals to a drone, fooling its navigation systems and forcing it to change course or land.

1.c. Communication jamming. Used to cut off communication between a UAV and its operator, making the drone uncontrollable and often leading to a crash.

2. Kinetic destruction systems. These systems involve physical damage or destruction of UAVs using conventional or specialized weapons:

2.a. Surface-to-Air Missile systems. Used to destroy drones at long distances. For example, Patriot or S-400 systems can intercept drones at high altitude or range.

2.b. Anti-aircraft guns: specialized artillery systems, such as CIWS or ZSU-23-4 Shilka systems, that can effectively destroy low-flying drones with rapid-fire cannons.

2.c. Combat interceptor drones: specially equipped drones that can shoot down or intercept other UAVs in the air by striking or physically engaging them.

By combining these defensive measures, nations and organizations can effectively counter the threats posed by military UAVs, ensuring the protection of both critical infrastructure and civilian populations.

Recently, the interest in the use of laser systems to combat UAVs has grown significantly, as evidenced by a large amount of information from various sources, such as news, official statements, expert comments, as well as scientific research and technical reports. The use of the latest technologies to combat these threats, namely small-sized drones and, in the future, drone swarms, is one of the most pressing issues in modern armaments development. The main developments focus on technologies such as the use of electromagnetic weapons of directed action, as well as the use of laser radiation. The use of laser radiation as a weapon has been one of the fundamental issues for weapons scientists since the 1970s (Hecht, 2010), but due to the development of laser technologies, the creation of lasers capable of fighting aircraft at distances comparable to the destruction distances of traditional (artillery and missile) anti-aircraft systems has only become close to being a reality in recent years. The main advantages of laser weapons are the high speed of the laser beam (travelling at the speed of light, since the laser is a directed stream of light), the low cost per shot, measured in units of dollars per shot, and the fact that laser radiation can completely destroy its target, not just disable its electronics, as is the case with electromagnetic weapons (Cheng, 2006; Lykou, Moustakas, & Gritzalis, 2020).

The development of science and technology has profoundly transformed modern society, driving progress in nearly every aspect of life. Innovations in fields such as manufacturing (Zavdoveev et al., 2022; Halchuk et al., 2023; Shevchenko et al., 2024; Stoyan, et al., 2024), processing of materials (Voinarovych et al., 2017; Balitskii, et al.,

2022; Demchenko et al., 2022; Pliuhin, Tsegelnyk, Plankovskyy, Aksonov, & Kombarov, 2023) have significantly improved the quality of life and expanded human capabilities. One such groundbreaking advancement is the development of laser technology, which has had a wide array of applications, ranging from medicine and telecommunications to industrial manufacturing and scientific research. Lasers have revolutionized numerous industries due to their precision and versatility. In medicine, lasers are used for delicate surgeries, vision correction, and even cancer treatments. In communication, fiber optic networks powered by laser technology have enabled high-speed internet and global connectivity. Industrial applications include cutting, welding, additive manufacturing (3D printing), and others, which have enhanced production efficiency and accuracy (Goncharuk, Zhuk, Kaglyak, Dzhemelinskyi, & Lesyk, 2018; Shelyagin et al., 2018; Bernatskyi, Sydorets, Berdnikova, Krivtsun, & Chinakhov, 2020; Berdnikova et al., 2021). Lasers also play a vital role in scientific research, enabling high-resolution imaging and experiments at the quantum level.

While science and technology have brought immense benefits, their development also introduces significant challenges and ethical dilemmas. One of the most concerning issues is the use of advanced technologies, including lasers, for military purposes. High-energy laser systems are increasingly being developed as weapons capable of targeting drones, missiles, and even satellites with unparalleled precision. This raises the risk of escalating arms races and the proliferation of destructive capabilities, potentially destabilizing global security.

The development of science and technology, particularly laser and related innovations, exemplifies humanity's potential to solve complex problems and improve lives (Bernatskyi & Khaskin, 2021; Lyubomir, Edmunds, & Risham Singh, 2021; Tsybulenko, 2022). However, it also highlights the need for careful consideration of the ethical, social, and environmental implications of these advancements, ensuring that progress serves as a force for good rather than harm.

The relevance of this paper is argued by the need to consider the historical stages of creation, implementation, first applications, review of the reasons for the rapid development and prospects for the use of lasers to combat UAVs.

The purpose of this study is to identify the patterns of interaction between scientific progress and its integration into military affairs through a multifaceted analysis of the processes of development, testing and adoption of laser technologies by countries around the world as a countermeasure to the development and spread of the use of unmanned aerial vehicles. This analysis focuses on the development of laser technologies in the context of countering unmanned aerial vehicles. With this in mind, the article will focus on the use of lasers as a countermeasure to UAVs, as well as on the development of UAVs and laser weapons in armaments in chronological order.

Research Methods.

In order to study the history and the current state of development of laser technologies for countering UAVs, a bibliometric and literature review of scientific

papers published over the past 10 years was conducted. The dynamics of the scientific community's interest in this topic was also analysed by analysing the scientometric databases Google Scolar and Scopus, as well as Google and Microsoft search engines. Bing!' for queries related to the terms "C-UAS laser", "anti-drone laser", etc. The total number of references for each query in different databases over the past 10 years was compared; the dynamics of changes in the number of scientific papers by year; and the countries of authors of articles with dynamics by year.

Research in this area can be divided into several main areas:

a. announcements and popular science articles in the press (Abott, 2023; Rtx.Com, 2023) – – in general, such articles simply confirm the fact of one of the stages of development or testing of weapons systems (Abott, 2023; O'Rourke, 2024), but they often contain a small amount of technical information that does not appear in other sources;
b. various publicly available reports of parliaments, ministries of defence and other government agencies of different countries are broadly analytical in nature with sufficient references to scientific review and scientific and practical articles (O'Rourke, 2024);
c. scientific review articles (Chamola, Pavan, Aayush, Naren, Navneet, & Mohsen, 2021), as well as scientific (Kim, Choi, & Kwon, 2024; Mohsan, Khan, Noor, Ullah, & Alsharif, 2022) (theoretical, experimental and combined, containing both theoretical and experimental components) articles devoted to the development of individual components of such complexes (Lyu & Zhan, 2022).

The Research and its Results.

To determine the extent to which this topic has been studied in the modern scientific community, a bibliometric analysis of scientometric databases over the past 10 years was conducted.

Table 3. Papers on C-UAS, published in scientometric bases over the last 10 years.

Keywords	Scopus	Google Scholar
Laser Counter Drone	21	17500
Laser C-UAS	6	802
Laser Anti-drone	8	990
Laser anti UAV	44	16500

It is necessary to emphasise the small number of articles on this topic in rigorously peer-reviewed scientometric databases. This can be explained by the closed nature of data in many countries, in which a large number of works on the development of laser anti-drone weapons are being carried out (as evidenced by practical results in the form of prototypes of laser systems), as well as the overwhelming majority of works, presented by the Chinese scientific community. This alone demonstrates the relevance of this topic and the importance of its proper study in different contexts.

Despite the numerous advantages of laser systems for UAV countermeasures, such as high accuracy and speed of response, they also have important limitations.

The main advantages of laser anti-UAV systems include:

1. Speed of action. Lasers operate at the speed of light, which makes them an almost instantaneous means of defeating targets. As soon as a drone is detected and brought into view, the system can immediately activate the laser beam to neutralize it. This is especially important when dealing with high-speed or maneuverable UAVs.

2. High accuracy. The lasers of an anti-UAV system are usually equipped with target detection and tracking systems that can accurately target critical drone components such as the engine, electronics, or cameras. This makes it possible to quickly disable the drone without causing its complete physical destruction. Accuracy is also important to avoid collateral damage in areas with civilian infrastructure or on a battlefield with close proximity to your own units.

3. Unlimited number of shots. Laser weapons do not require physical ammunition such as missiles or bullets. This means that it can be used continuously as long as there is power supply. This autonomy makes laser systems cost-effective in prolonged conflicts or in situations with a large number of attacking drones.

4. Minimization of collateral damage. Laser engagement systems are highly accurate and can operate at certain distances without risking surrounding infrastructure or people. This makes them ideal for use in densely populated areas or when protecting critical facilities such as airports, power plants, or military bases.

5. Mobile platforms. Many laser systems can be installed on mobile platforms such as cars, ships, or even airplanes. This allows for rapid deployment of the laser system in different environments and provides high maneuverability. For example, military lasers are already being integrated into vehicles to protect against drone attacks on the battlefield.

Laser-based anti-UAV systems are gaining popularity as an innovative means of neutralizing drones in various military and civilian situations. Due to their high accuracy, rapid response time, and lack of ammunition requirements, lasers have the potential to become a key component of air defense systems in the near future. Technological developments in this area continue to improve these systems, expanding their capabilities for use in real-world combat situations.

Laser anti-UAV systems have significant advantages, such as high accuracy, instant response, and no need for ammunition. However, like any other technology, they have a number of disadvantages that affect their effectiveness and application in real-world conditions.

The main disadvantages of laser anti-UAV systems:

1. High power requirements. Laser systems require a significant amount of energy to operate efficiently. The laser power must be sufficient to quickly heat up and damage the materials from which the UAVs are made. This means that laser systems require a reliable power supply, which can be challenging for mobile platforms or for extended operations in remote areas.

2. Limited range. Although lasers can operate over long distances, their effectiveness decreases with distance due to beam energy dissipation. The further away the target is, the more energy is lost due to atmospheric factors. In real combat conditions, especially at long distances, this can significantly reduce the effectiveness of lasers.

3. Vulnerability to weather conditions. Laser radiation is very sensitive to weather conditions. Rain, fog, snow, dust, or even extreme heat can scatter or absorb some of the laser beam energy, making the system less efficient. This is a serious limitation for using lasers in difficult weather conditions or in certain climatic zones.

4. Reflection and absorption of materials. The materials from which UAVs are made can have reflective or absorptive properties, which reduces the efficiency of the laser. For example, metal surfaces or special coatings can partially reflect laser radiation, making it difficult to destroy the drone. In addition, heat-resistant materials may require more power or longer laser exposure times to damage them.

5. Cooling of the laser system. High-power laser operation generates a large amount of heat, so the system needs a reliable cooling system to maintain optimal temperature. This adds complexity to the design and can limit the amount of continuous laser operation. Inadequate cooling can lead to overheating and reduced system efficiency or even damage.

6. High cost of development and implementation. Laser systems are an emerging technology that requires significant investment in research, development, and manufacturing. Although they can reduce ammunition costs in the long run, the initial costs of developing laser systems are high. This may limit the widespread adoption of such systems, especially for countries with limited defense budgets.

7. Ability to counter lasers. Over time, methods of countering laser systems are evolving. For example, the use of drones with reflective surfaces or special coatings can make it more difficult to destroy them with lasers. In addition, there is a growing likelihood that UAVs will be made of materials resistant to high temperatures or with low thermal conductivity, which will make them more difficult to damage with a laser.

8. Limitations in multi-target operations. Although lasers have a fast response and can destroy targets almost instantly, there are certain limitations to the simultaneous destruction of multiple objects. A laser beam can only focus on one target at a given time, which creates a problem with simultaneous attacks by a large number of drones (flock attacks), when several UAVs attack an object at the same time.

High energy requirements, dependence on weather conditions, vulnerability to special materials and coatings, and high implementation costs are key drawbacks that require further improvement and research. However, the development of technology and engineering solutions can gradually reduce these shortcomings and make lasers more effective in real-world combat.

In this context, research on the development of a methodology for determining the impact of laser radiation parameters on the destruction of materials from which UAV parts are made is becoming increasingly relevant.

Lasers can be used for interdiction of UAVs in many ways: from using laser radiation as an alternative to radio waves to detect drones at long distances (utilizing the LIDAR principle), using a laser beam to guide a more traditional kinetic or explosive munition, to direct laser interaction with the drones themselves. In terms of direct engagement, laser radiation can interact with its target in many ways. The simplest is to blind the sensors, as it does not require great amounts of laser radiation energy to disable cameras and infrared targeting heads. However, there is still a chance that the enemy drone will reach its target with the help of redundant secondary control systems.

When directly engaging a drone, there are a large number of variables and problems associated with the principles of laser propagation in the atmosphere: from atmospheric aberration to thermal blooming and airborne defocus effects. Weather conditions also play a significant role in determining the required laser power.

It should also be noted that the type of material used to make a UAV plays a major role in its ability to be affected by laser emission. For example, a plastic UAV requires several times less energy to destroy than a UAV, made out of metal. At the same time, there are various options for the results of the interaction between laser radiation and individual parts of unmanned aerial vehicles.

The development of laser weapons has a number of problems and challenges that are directly related to the conditions associated with the design and the environment in which they operate (Garcia & Herz, 2016; Zabunov & Mardirossian, 2020; Tsybulenko, 2022; Yang, Wang, Chen, & Yan, 2024). It is evident that the design and characteristics of the laser directly determine its effectiveness against certain materials at certain distances; the calculation of optimal parameters for combating different UAV types at different distances is one of the most pressing tasks in the development of laser weapons. At the same time, much depends on the design conditions of the laser system: mobile, and even more so, portable systems have significantly more restrictions on their characteristics, as well as a radically different approach to use. At the same time, the environment, in which a particular laser system is used, dictates its own conditions, which is why, for example, for marine applications of lasers, there is a complex problem of the specifics of using laser weapons in marine conditions, since for proper operation it is necessary not only to meet the conditions present in any atmosphere (mass concentration, humidity and wind speed), but also marine issues in the form of a different composition of sea water and their vapours; problems of splashing and oscillations generated by waves; the problem of operation in the environment At the same time, for land-based laser applications, there are similar complex problems associated with the greater prevalence of dust, soil, diverse flora and fauna, as well as weather factors that cannot be reproduced in marine conditions.

The development of powerful lasers emitting invisible infrared rays led to a number of impressive technological demonstrations, especially in the United States and the former Soviet Union in the 1970s (Hecht, 2010). For example, the first case of UAVs being shot down by laser radiation is considered to be the MIRACL (Mid-

Infrared Advanced Chemical Laser), which was tested in 1978 as part of the US Navy's Joint Program, successfully intercepting and destroying a BQM-34 Vandal unmanned aerial vehicle in flight (Appell, 1997). Since then, the United States and the Soviet Union have conducted various efforts to destroy missiles or supersonic reconnaissance drones in flight. The PRC joined this 'race' to develop laser weapons in the mid-1980s, although due to limited access to Chinese documentation, it is currently impossible to determine the exact date (Qiwan, Zhixiang, & Chuanfu, 1998; Cheng, 2006; Bernatskyi & Sokolovskyi, 2022). Similar developments took place in the United Kingdom, which not only developed a laser shipboard system for blinding aircraft pilots under the 'Raker' and 'Shingle' codenames, but also deployed a ship with a prototype of this system in the flotilla that participated in the Falklands conflict in 1982 (Garcia & Herz, 2016; Zohuri, 2016, p. 45; Lyubomir, Edmunds, & Risham Singh, 2021). However, it is worth noting that there is no verified data on the use of this weapon during the hostilities against Argentinian forces.

At the same time, technological advances have led to the deepening and development of unmanned aerial vehicles in various directions – from the USSR's turbojet reconnaissance drones (such as the Tu-141) to barraging drones such as the american RQ-1\2, which used a small turboprop engine (Figure 1).

Figure 1. Tu-141 – a typical unmanned aerial vehicle from the end of the Cold War (Rogoway, 2022).

However, the completion of the first working laser designs coincided with the beginning of dramatic changes in the vision of the armed conflicts' future. With the end of the Cold War and the collapse of the USSR, laser weapons development began to be re-profiled, and in some ways has continued in these countries and their successors to this day.

In the modern sense, ‘anti-drone’ laser weapons began to develop in the early 2010s, after the introduction of small UAVs (DJI Enterprise, n. d.), shown in Fig. 2, by armies and illegal armed groups as reconnaissance vehicles. Moreover, there is evidence that most developed countries are interested in this topic for various reasons, from airport security to military operations. Thus, tracking the years of the first publicly known developments of laser weapons allows us to conclude that the development of a laser system requires years and expertise in optics and physics of interaction of concentrated energy flows. The first laser to be developed and tested against modern unmanned aerial vehicles is the United States' Navy AN/SEQ-3 LaWS, which began development in 2010 and was first installed on a naval installation in 2014 (Zabunov & Mardirossian, 2020). This system is currently being upgraded to the AN/SEQ-4 ODIN (O'Rourke, 2024), which will specialise in protecting ships from unmanned aerial systems.

Figure 2. A typical modern UAV, also known as a ‘drone’ (pictured – DJI Mavic 3 Enterprise) (DJI Enterprise, n. d.).

Two other systems have been developed at approximately the same time: the Chinese “Silent Hunter” with a power of 10 and later 30 kW (Lyu & Zhan, 2022; Gruszczak & Kaempf, 2023), and the French High Energy Laser for Multiple Applications (HELMA-P) with a power of 5 kW see Fig. 3 (Michau & Védrenne, 2024): both were presented in 2017 and are currently among the available offers on the market. It should be noted that they are fundamentally similar, as these lasers are among the first examples of modern fibre lasers being used to combat UAVs.

The next generation of anti-UAV laser systems, designed to counter UAV threats, is a family of Raytheon HELWS laser systems (Sanyal, Bevington, & Brigham, 2017; Lyu & Zhan, 2020, 2022; Rtx.Com, 2023). This family of lasers, designed to be used as a mobile installation and protect against short-range aerial threats for both the US Air Force in the form of the 10-kilowatt Raytheon H4 (Fig. 4), as well as a 15-kilowatt laser system on a British Wolfhound, developed in 2021 duringed Ministry of Defence's Land Demonstrator programme (Rtx.Com, 2023).

Figure 3. The HELMA-P laser system (Michau & Védrenne, 2024).

Figure 4. American anti-UAV laser system Raytheon H4 (Rtx.Com, n. d.).

It could be considered that Raytheon UK is a continuation of the success of previous U.S. investment, since a total of eight high-energy laser weapons have been delivered to the U.S. military (Grigoraş & Muşat, 2024). Over the years of testing and usage, these systems are claimed to have defeated more than 400 targets over 25,000 operational hours (Lyu & Zhan, 2020; Rtx.Com, n. d.).

One of the most developed systems at the moment is the American DE M-SHORAD, which currently exists in a number of designs. All variants of this system use solid-state fibre lasers with a power of 25 to 50 kW and are planned to be used by the US Army on the basis of the Stryker armoured personnel carrier in the coming years. During tests in 2022, a variant of this system from Raytheon (Fig. 5) successfully shot down a Class 3 UAV (Rtx.Com, n. d.).

Figure 5. Raytheon DE M-SHORAD air-defense system on trials (Rtx.Com, n. d.).

At the same time, the system from Leonardo (Figure 6) has proven itself as a combined air defence system that uses a 25 kW fiber laser to destroy UAVs at a distance of more than 2 km.

Figure 6. Leonardo DE C-UAS air-defense system on trials (Leonardo US Inc., 2024).

One of the most closely monitored laser systems is the Israeli Iron Beam (Ross, 2023; Gruszczak & Kaempf, 2023; Neice & Wostenberg, 2024), which began development in 2010 and is due to be commissioned in October 2025. It is considered the culmination of 15 years of work on this system. Unconfirmed reports indicate that this system has already been used during the current Israeli-Palestinian conflict, which would make it the only "battle-proven" system (Neice & Wostenberg, 2024).

These and other indicators make it possible to understand that the creation of a laser system for destruction of UAVs requires a large expenditure of human resources and finances. For example, the production of the AN/SEQ-3 prototype cost the US $40 million, and the programme to upgrade it to the AN/SEQ-4 level costs the US Navy $1.1 billion in the first year alone. At the same time, the US Army's multi-year programme to develop a combined ground laser system based on existing equipment that would be capable of engaging a variety of targets, including UAVs, is estimated to cost about $1.3 billion (O'Rourke, 2024).

Discussion.

From the analysis of papers that study the history and prospects of laser weapons, it can be noted that most articles positively consider the prospects of using laser weapons to combat unmanned aerial vehicles. For example, Steinwal (2021) notes in his work that *"Unmanned aerial vehicles (UAV:s) have become an increasing threat in both civilian and military arenas. …The criminal world has quickly realized how UAV:s can be used to smuggle weapons or drugs, for example. Militarily, UAV:s are established for reconnaissance, fire control and electronic warfare operations etc. Laser-guided weapons from a UAV, is an example of a widely used system for precision operations during later conflicts… The laser can be used as a support sensor to others like radar or IR to detect end recognise and track the UAV and it can dazzle and destroy its optical sensors. A laser may also be used to sense the atmospheric attenuation and turbulence in slant paths, which are critical to the performance of a high power laser weapon aimed to destroy the UAV."* It is difficult to disagree with this point of view, as the statistics provided by Lykou, Moustakas, & Gritzalis (2020) and Kudzai (2021) indicate a large increase in the usage of UAVs in no-fly zones, while the experience of modern conflicts suggests that the issue of combating UAVs is becoming critical for the international community.

However, when considering the sources that examined the development of laser technologies from a more historical perspective (Hecht, 2010;), it can be concluded that in the past, most authors considered laser weapons as 'promising weapons of the next generations'. However, more recent articles (Ahmed, Mohsin, Ali, 2021; Ajakwe, Kim, & Lee, 2023; Gruszczak & Kaempf, 2023) indicate that the use of lasers to counter UAVs in a military environment may occur in the next 5–10 years. This point of view is confirmed by the large number of laser anti-UAV systems that have been developed in the last decade and are already undergoing military trials (such as Iron Beam and DE M-SHORAD) (Bernatskyi & Sokolovskyi, 2022; Hengyu, Xingwen,

Xinyi, & Yu, 2024; He et al., 2024). This difference in perspective is attributed to the authors' view of slower development of laser technologies, especially fibre and diode lasers, which can provide high-quality (single-mode) laser radiation of sufficient power with relatively small installation sizes.

At the same time, it should be noted that the development of laser weapons with the primary function of countering unmanned aerial vehicles is directly related to the development of UAVs (Sanyal, Bevington, & Brigham, 2017; Lyubomir, Edmunds, & Risham Singh, 2021; Ross, 2023; Yang, Wang, Chen, & Yan, 2024) and their proliferation (Fuhrmann & Horowitz, 2017)). In his work, Fuhrmann & Horowitz (2017) notes that due to technological advances, UAVs are expected to become one of the most influential and rapidly developing weapon types. In the current context, it is hard to disagree with this point of view. In modern conflicts, individual companies use dozens of drones per day, whilst kamikaze strike drones are often used instead of bombers and bombs. Therefore, it is important to understand how the development of laser weapons and unmanned aerial vehicles has affected the trajectory of their development.

Based on this, the following scheme for periodising the focus of laser technology development for combating UAVs is proposed:

1. Development of lasers, where the counter-UAS aspect was considered a secondary task, used to test lasers before testing installations in accordance with their primary task of engaging cruise (and ballistic) missiles sharing the same altitude and/or speed range. This period was characteristic of the Cold War and ended with the curtailment of these laser weapons development programmes in the mid-1990s and early 2000s.
2. The development of universal laser systems - this process was associated with a change in the vision of warfare and current threats of the time, which focused on the fight against irregular forces (threats of terrorism, piracy, etc.). UAVs of the time were also developing in this direction, and therefore, despite the decrease in speed, size, and visibility, classical air defence measures have proven to be quite effective in countering such drones. For this reason, a mainly anti-drone approach to the development of laser weapons was not adopted. This period begins in the late 1990s and ends in the early to mid-2010s.
3. A sharp change in focus of the laser weapon development has occured in the mid-2010s, which can be contributed on both the widespread use of drones and UAVs, which began to rapidly shrink in size due to the use of more modern materials in their construction (carbon, aramid honeycomb, various composites, etc.), on top of the reduction in weight and size of their batteries. At the same time, the market for fibre lasers in that period has developed rapidly, with several manufacturing facilities being established in all around the world. This, among other factors, led to reduction in the cost of manufacturing fibre lasers by a magnitude of several times, allowing for their widespread usage during development of laser systems to counter UAVs. The use of

miniaturised UAVs by ISIS, as well as their large-scale use in conflicts starting from 2016–2018, has forced the scientific community to quickly look for methods of specialised counteraction to small UAVs. In this regard, laser radiation is poised to be one of the most promising areas for the possible development of methods to counter such vehicles due to the multiple possibilities of direct interaction with the UAV itself (including its possible destruction), as well as the low cost of a shot.

Conclusions.

As a result of the analysis of the available information on the development of laser weapons in the context of counteracting the widespread use of unmanned aerial vehicles and the development of their designs, the following periodization principle for concentrating efforts aimed at developing laser weapons to combat UAVs was proposed: the period when laser weapons were used against UAVs on an experimental basis; the period when the fight against UAVs was considered one of the secondary tasks, which was established by the general focus on the fight against the irregular enemy; and a period of focus on countering UAVs due to their proliferation and miniaturization. It was observed that the change in the main focus of laser weapons development was driven not only by technological advances in laser technology, but also by general technological developments in many fields, from materials science to IT, as well as by the military-geopolitical situation and military planning "vision of the upcoming war."

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Conflicts of interest.

The authors declare no conflict of interest.

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Аналіз застосування лазерів для боротьби з БПЛА

Анотація. *З самого початку людської історії, людство завжди прикладало зусилля до створення більш ефективних інструментів боротьби з іншими істотами, включаючи й інших людей. Таким чином, створення і використання нових видів тварин, створення нового озброєння та інші методи прогресу людства завжди спонукало до нових розробок, спрямованих на емуляцію, заміну або для боротьби з даними новинками. Розвиток безпілотних літальних апаратів створив необхідність у розробці альтернативних та новітніх методів протидії. Ці методи можуть бути різними, від використання дронів-перехоплювачів, до використання концентрованих потоків енергії. Дана робота присвячена вивченню прогресу та відомих використань лазерних технологій у*

контексті боротьби з безпілотними літальними апаратами. Для поглиблення та систематизації знань про розвиток застосувань лазерів у військовій галузі, було проведено систематизований бібліографічний аналіз наукових робіт та науково-популярних публікацій, щодо напрямку розвитку як лазерних технологій, так і безпілотних літальних апаратів на протязі останнього сторіччя. Дослідження фокусувалось на розробках, котрі були фактично реалізовані та випробовувались проти різноманітних безпілотних літальних апаратів. Після цього, його результати було порівняно з рядом статей, котрі окремо фокусувались на історії, перспективах та нагальних питаннях розвитку лазерного озброєння та безпілотних літальних апаратів. При цьому, завдяки тому, що лазерні технології є одним з найбільш стрімко та всебічно розвиваючихся напрямків наукового прогресу, було вирішено використати періодичну модель класифікації, головним критерієм якої був фокус розробок лазерних технологій на протидію безпілотних літальних апаратам. Було розглянуто питання визначення причинно-наслідкового зв'язку, котрий пов'язує розвиток технологій та конструкцій безпілотників з зміщенням фокусу розробки лазерного озброєння на протидію ним. Відзначено, що через високі потреби в людському та фінансовому капіталі, напрямок та темпи розвитку лазерного озброєння залежать не тільки від технологічних обмежень, але й від бачення військової стратегії та можливих загроз в той чи інший момент часу. В результаті було запропоновано варіант періодизації історії розвитку лазерного озброєння як засобу боротьби з безпілотними літальними апаратами.

Ключові слова: *лазер; лазерне випромінювання; розвиток техніки та технологій; лазерна зброя; безпілотний літальний апарат; протидія безпілотним авіаційним системам*

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History of the evolution of cinema in the context of considering the stages of development of science and technology. The first steps to the birth of cinema

Abstract. *Historiographic works on the history of cinema play an important role in preserving knowledge about the development of this art form. They not only document the key stages of the evolution of cinema, but also provide an opportunity to analyze it as a cultural phenomenon that is closely intertwined with the history of mankind. Historiographic works on the history of cinema cover the study of the development of cinema as an art, a means of communication and an industry. They reflect various aspects of its formation: socio-cultural influences, technological breakthroughs, genre transformations and the role of cinema in a historical context. However, a thorough analysis of historiographic sources on the study of the history of the evolution of cinema in the context of considering the stages of the development of science and technology has not been carried out before. The aim of the study is to investigate the state, completeness and reliability of the study of the history of the development of cinema in the context of considering the stages of the development of science and technology, based on the analysis of historiographic sources, the achievements of predecessors, and modern methodology. The objective of this article is to analyze historiographical sources that consider the magic lantern, the camera obscura, and the shadow play as key precursors to cinema. The magic lantern, the camera obscura, and the shadow play were key milestones in the development of cinema, as they developed techniques for manipulating light and shadow, creating the illusion of movement, and projecting images. They became important precursors to cinema, providing the conceptual and technical foundations that allowed cinematic technologies as we know them today to emerge. All three devices actively used the manipulation of light and shadow to create visual effects that became the basis for cinema. Each of these devices allowed for technical innovations in the use of lighting, projections, and images that were later adapted in cinematic technologies such as projectors and motion pictures. All of these technologies helped popularize the idea of using optical effects and media for a mass audience, which was important for the emergence of cinema as an industry. Historiographical works devoted to the magic lantern, the camera obscura, and the shadow play focus on the study of these inventions as important precursors to cinema. They laid the foundations of visual art that uses the play of light and shadow, and influenced the development of technologies for creating the illusion of movement.*

Keywords: *birth of cinema; visual effects; magic lantern; camera obscura; shadow play; historiography*

Introduction.

The development of cinema has always been closely linked to the progress of science and technology, since it was technical innovations that created the foundations

for the emergence and evolution of this art. For example, research into human vision, in particular the persistence effect (a residual image on the retina), became the basis for the creation of devices capable of reproducing movement, such as movie cameras and projection devices (Usai, 1996, p. 21; Galifret, 2006; Utterson, 2020). In the second half of the 19th century, the first devices for recording and demonstrating movement were invented, such as Thomas Edison's kinetoscope and the Lumière brothers' cinematograph, which undoubtedly became a technical breakthrough for its time.

The development of optics and precision mechanics allowed the creation of new, more precise optical-mechanical systems and lenses. Thus, the improvement of optical lenses made it possible to shoot clearer and higher-quality images. And the creation of mechanisms for the continuous movement of film made it possible to shoot and demonstrate films without stopping (Betancourt, 2020, p. 27).

Research in the field of acoustics and electroacoustics made it possible to record and synchronize sound with images, which made it possible to introduce sound into cinema. The emergence of sound systems, such as the phonograph and technologies for optical recording of sound on film, made this possible (Zappe, 2020; Dienstfrey, 2024; Slowik, 2024).

The development of chemical science, namely the study of color pigments and reactions, provided the possibility of obtaining color recordings on film (Technicolor, Kodachrome systems), which contributed to the emergence of color cinema (Brown, Street, & Watkins, 2019; Thompson, 2019; Lipton, 2021).

The development of computers and digital cameras opened a new era in cinema and allowed the abandonment of film, which significantly simplified the process of shooting and editing. Computer equipment and technology became the leaders of the digital revolution in the film industry (Alforova, Marchenko, Kot, Medvedieva, & Moussienko, 2021; Hatchuel, & Vienne-Guerrin, 2021; Dun, et al., 2022). Modern software for 3D modeling and compositing created a new dimension of visual aesthetics.

Progress in science and technology also influenced the subject of cinema. For example, science fiction (films like *"2001: A Space Odyssey"* or *"Interstellar"*) show ideas about space, robots and the future, based on modern scientific theories.

Thus, cinema has always developed in close connection with scientific discoveries and technological achievements, which allowed for the improvement of both the technical component and artistic possibilities. Therefore, these aspects have always been in the field of view of historians of science and technology.

Soon after the emergence of cinema, historiographical works on the history of cinema appeared, which sought to record and systematize the achievements of this new art form. In the early stages of the historiography of cinema, these were rather descriptive chronicles. The first works, for example, articles in newspapers and magazines of the late 19th and early 20th centuries, documented the development of

cinema as an invention. These materials focused on technical innovations, such as the use of the kinetoscope or the improvement of film projectors.

In the 1910s, cinema began to be considered not only as a technical achievement, but also as an art form, which contributed to the formation of theoretical approaches. Researchers and critics such as Louis Delluc (Delluc, 1990; Bernabei, 2018; Calvo, 2021; Matti, 2022) and Ricardo Urgoiti (Alonso, 2023; Reyes, 2023; Arce, 2024) began to analyze its artistic potential. Louis Delluc is one of the first film theorists to introduce the concept of "cinematic art".

In the period between World Wars I and II, works appeared that explore the impact of cinema on culture and society. For example, the works of Siegfried Kracauer considered cinema as a social mirror that reflects the collective consciousness of a certain era (Kracauer, 2019).

In the middle of the 20th century, the historiography of cinema moved from individual articles to large-scale systematic studies, which opened the era of systematization of the history of cinema. Researchers began to study the impact of cinema as an industry on society. They considered the role of large film studios, censorship, economic and political factors.

In particular, thorough chronological works stand out. Georges Sadoul wrote one of the first global histories of cinema (*"Histoire générale du cinéma"* multi-volume work, 1946–1954), which covered key periods in the development of cinema. In it, Georges Sadoul focused on technical achievements and aesthetic transformations. In another thorough chronological work, Lewis Jacobs ("*The Rise of the American Film: A Critical History*", 1939) examines the development of Hollywood as the center of world cinema (Stadel, 2014; Slugan, & Terrone, 2021).

At the same time, the studies of that time are characterized by an institutional approach. Thus, André Bazin in his work *("Qu'est-ce que le cinéma?",* 1958) focuses on the analysis of the aesthetics and philosophy of cinema. Douglas Gomery ("*The Hollywood Studio System"*, 2017) considers the study of Hollywood as an industrial system.

Studies began to appear that examined specific genres, such as science fiction, westerns, and film noir, which allowed for a better understanding of the evolution of forms and themes in film.

Cinema began to be studied as a means of reflecting social change, ideologies, and cultural identity. For example, Siegfried Kracauer (*"From Caligari to Hitler: A psychological history of the German film"*) analyzed the influence of German cinema of the 1920s on the formation of Nazi ideology (Deaville, 2019; Henkel, 2022; Ponten, 2023). Sergei Eisenstein's work on montage theory became the basis for the analysis of propaganda cinema (Belodubrovskaya, 2018; Santolin & Rigo, 2019; Bulgakowa, 2022; Román Vidal, 2023).

In the second half of the 20th century, interest in cinema outside of Hollywood grew. Studies of European auteur cinema (Jean-Luc Godard, Federico Fellini, Ingmar Bergman) and analysis of cinema from Asian, Latin American, and African countries

(Ritwik Kumar Ghatak, Satyajit Ray, Ossama Mohammed) reached a new level. There is growing interest in studying National Film Schools, particularly regional features of cinema, such as Soviet cinema, the French New Wave, and Italian neorealism.

Since the second half of the 20th century and in the 21st century, the historiography of cinema has become more multifaceted, introducing new approaches. In particular, researchers focus on cultural and sociological analysis when studying the impact of cinema on society and the relationship between cinema and politics, ideology, and social change. Modern researchers analyze the transition of cinema to digital formats, the impact of streaming platforms and new technologies such as VR and AR. Interest in digital technologies, the globalization of cinema, and transmedia narratives is being explored. More and more attention is paid to such aspects of film history as: the role of women in cinema; informal film movements; cinema from countries that have long remained outside global analysis, etc. The works of modern film historians such as Thomas Elsaesser (2004) are devoted to the analysis of cinema in the context of media history; Kristin Thompson, David Bordwell and Jeff Smith (*"Film History: An Introduction"*) to a comprehensive study of the history of cinema.

Many issues remain debatable. For example, the question of what to consider the "beginning of cinema" (Eadweard Muybridge, Thomas Edison or the Lumière brothers). Researchers also consider the role of genre cinema in artistic development in different ways (commerce vs. auteur art).

Historiographic works on the history of cinema play an important role in preserving knowledge about the development of this art form. They not only document the key stages of the evolution of cinema, but also provide an opportunity to analyze it as a cultural phenomenon closely intertwined with the history of mankind. Historiographic works on the history of cinema cover the study of the development of cinema as an art, a means of communication and an industry. They reflect various aspects of its formation: socio-cultural influences, technological breakthroughs, genre transformations and the role of cinema in a historical context. However, a thorough analysis of historiographic sources on the study of the history of the evolution of cinema in the context of considering the stages of the development of science and technology has not been carried out before.

The aim of the study is to investigate the state, completeness and reliability of the study of the history of the development of cinema in the context of considering the stages of the development of science and technology, based on the analysis of historiographic sources, the achievements of predecessors, and modern methodology.

The objective of this article is to analyze historiographic sources that consider the magic lantern, the camera obscura, and the shadow theater as key predecessors of cinema.

Methods of Research.

The study of historiographic works on the history of cinema requires a comprehensive approach, which determines the interdisciplinary nature of this article.

To analyze the evolution of historiographic works in time sequence, the chronological method was used. To do this, we studied how approaches to the analysis of cinema changed in different historical periods.

In order to identify differences in the interpretation of the history of cinema depending on the cultural or regional context, a comparative method was used.

To study works devoted to a specific topic or aspect of cinema, a thematic analysis was used. The goal was to identify how a certain topic is revealed in different contexts and research traditions.

The method of source analysis was used to study the source base on which historiographic works are based. It consisted in analyzing the materials used: archival documents, films, memoirs, technical descriptions and assessing the reliability and representativeness of the sources. This allowed to determine how the selected sources influence the interpretation of film history.

To study the key themes, concepts and categories used in the texts, the method of content analysis was used. This allowed to identify dominant trends, stereotypes or gaps in the study of the history of cinema.

Methodological analysis was also used. It allowed to understand how the methodological choice affects the results of the study and to assess the advantages and limitations of each approach. The research data showed how the methodologies of film analysis changed: from descriptive to structural-semiotic or media archaeological approaches.

The interdisciplinary approach used consisted in combining methods from other sciences (sociology, cultural studies, technical sciences) (Strelko, et al., 2019; Gutnyk, Sklyar, Radohuz, Volosnikova, & Tverytnykova, 2021; Yatskiv, 2022). It was used in order to reveal the relationship of cinema with the wider cultural and technological context.

To analyze historiographic works through the personalities of the authors, the biographical method was used (Pylypchuk & Strelko, 2020; Tverytnykova, Radohuz, & Gutnyk, 2020; Pylypchuk, O. Ya., Strelko, O. H., & Pylypchuk, O. O., 2021; Faust & Németh, 2024;). The study of the influence of historians' personal beliefs and experiences on their work has allowed to reveal the subjective dimension in the interpretation of history.

Thus, the integrated approach used, combining several methods, has allowed to understand historiographical works on the history of cinema more deeply, their strengths and limitations, and to reveal new perspectives in the study of this field.

Results and Discussion.

The first step towards cinema was taken in the 5th century BC, when the *camera obscura* was created. In addition, *shadow theater (shadow play)* appeared even earlier in China and Japan (see Figure 1), and the principle of creating an image using a narrow hole was known even in antiquity. In the 17th century, another important device for projecting images appeared – the "*magic lantern*". The emergence of these three

techniques is a significant stage in the history of the development of cinema at the stage of its inception.

Researchers note that the common factors that unite these devices are the following:

Manipulation of light and shadows. All three devices actively used manipulation of light and shadows to create visual effects that became the basis for cinematography. In cinematography, the use of light and shadows is fundamental to the formation of an image.

Figure 1. Luanzhou Shadow Play (Sun et al., 2024).

Illusion of motion. Each of these devices created or conveyed the idea of the illusion of motion, which is the main feature of cinematography. The magic lantern and the shadow play made it possible to create images that moved or changed, which is key to the development of cinema.

Technical innovations. Each of these devices allowed for technical innovations in the use of lighting, projections, and images, which were later adapted in cinematic technologies such as projectors and motion pictures.

Popularization of the idea of media and optical effects. All of these technologies helped popularize the idea of using optical effects and media for a mass audience, which was important for the emergence of cinema as an industry.

Development of optical concepts and technologies. These devices became important stages in the development of optics and technologies that allowed for the manipulation of images. The development of photography and cinematography is closely linked to the technologies of projection and recording of images, which were the basis of the magic lantern, the camera obscura, and the shadow play.

Historiographical works on the magic lantern, the camera obscura, and the shadow play focus on examining these inventions as important precursors to cinema. They laid the foundations for visual art using the play of light and shadow, and influenced the development of technologies for creating the illusion of movement.

The "magic lantern" for projecting images onto a vertical screen became widely known in the 17th century. In its simplest form, it was a box with a magnifying tube and a lamp inside. Behind this lamp was a reflector, and between the tube and the box there was a gap where a frame drawn in ink was placed (see Figure 2). The images were static. In their works, Georges Sadoul, Eric Barnouw, Laurent Mannoni, Erkki Huhtamo, and Mervyn Heard analyze the technical improvements to the magic lantern that contributed to the popularity of this device in the 18th and 19th centuries. Historians saw the magic lantern as a prototype of the modern projector, which influenced the emergence of cinema.

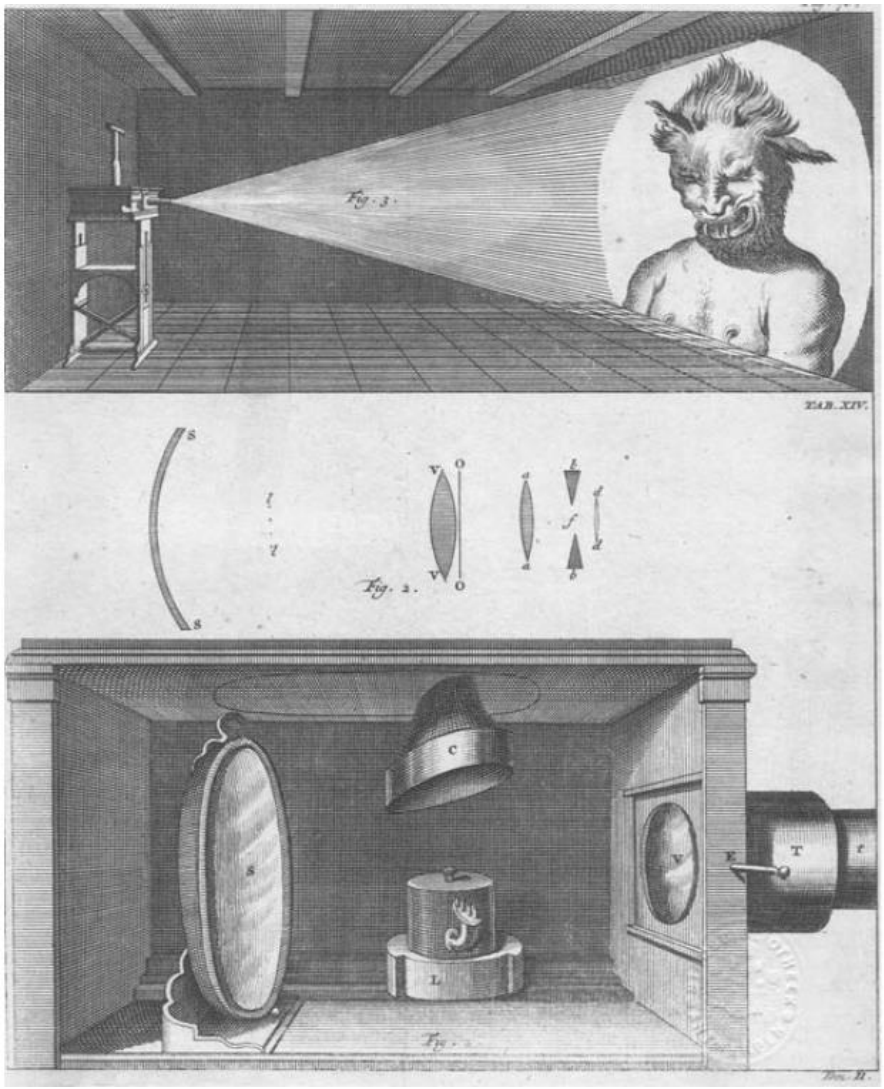

Figure 2. Even's Gravesande's illustration of a magic lantern (1721) (Vermeir, 2005).

Georges Sadoul, a famous French film historian, in his works on the history of cinema, in particular in the fundamental book *"Histoire générale du cinéma"* (1946), mentions the magic lantern as an important predecessor of cinema. He examines this device in the context of the development of visual technologies that preceded the invention of cinema. Georges Sadoul considers the magic lantern to be one of the most important stages in the development of visual entertainment technology. He emphasizes that this device was not only a technical achievement, but also a way to introduce a wide audience to optical effects. This made it a prototype of the cinematic show. Sadoul emphasizes that although the magic lantern could not create real movement, its appearance laid the foundation for subsequent developments that allowed for the imitation of movement in images (through the change of slides or mechanical devices). In his research, Sadoul turns to the phenomenon of phantasmagoria, which was popular in the 18th and 19th centuries. He indicates that such shows were the first experience of collective "cinematic" perception by the audience. Thus, the "magic lantern" created a new format of entertainment, which was perceived as a miracle of the time. Sadoul mentions the contributions of European scientists and inventors, such as Christiaan Huygens, who created the first magic lantern in the 17th century, and Étienne-Gaspard Robertson, who perfected a device for phantasmagoria. Sadoul sees the magic lantern as part of a long journey in the development of the visual arts, including the camera obscura, the shadow theatre, panoramas and dioramas. These inventions, he believes, formed the aesthetic and technical basis for the emergence of cinema. For Georges Sadoul, the magic lantern is not just a technical device, but a key part of history that explains how humanity gradually arrived at the creation of cinema. He sees in the magic lantern not only the technical basis of cinema, but also the first manifestation of mass visual art, which taught the viewer to enjoy stories through images.

Although Eric Barnouw did not focus exclusively on the magic lantern, it is considered in his comprehensive studies of media and film history. His book *"The Magician and the Cinema"* (1981) explores the relationship between early visual media, particularly the magic lantern, and cinema. Barnouw emphasized the role of the magic lantern in combining education and entertainment, and that the device was a precursor to cinematic techniques such as the use of light, projection, and sequential images to convey narratives. Barnouw emphasizes the "magical" nature of the device, its ability to evoke a sense of wonder and fascination in the audience. He connects this to humanity's general attraction to illusion and the desire to bring images to life. Examining the use of the magic lantern in phantasmagoria of the 18th and 19th centuries, Barnouw analyzes its role in shaping ideas about the supernatural, death, and fear. Phantasmagoria, according to Barnouw, was a kind of prototype of the cinematic art, which also often plays on emotions and experiences. Barnouw notes that the magic lantern was the first device that created the possibility of projecting images onto a large screen for an audience, which is the main idea of cinema. Although the lantern did not create real movement, additional mechanisms, such as interchangeable slides or

moving components, made it possible to simulate dynamics. Barnouw sees the magic lantern as an important link between traditional visual arts, such as shadow theater, and technological innovations that led to the emergence of cinema. He emphasizes that the magic lantern laid the foundations not only for the technical, but also for the cultural perception of the ideas of cinema: collective viewing, the use of light to create illusions and the involvement of the audience in the story. Eric Barnouw, like his contemporaries, explores the magic lantern not only as a technical invention, but as a phenomenon that reflects cultural and social notions of reality, illusion, and art. His work is an important contribution to understanding how devices like the magic lantern formed the basis for modern cinema and visual culture in general.

In his book *"Le Grand Art de la Lumière et de L'ombre, Archéologie du Cinema"* (1994), Laurent Mannoni analyzes in detail the role of the magic lantern as one of the key devices that preceded the emergence of cinema. He emphasizes that the magic lantern was not only a technical invention, but also a cultural phenomenon that greatly influenced the development of visual art and the popularization of knowledge. Mannoni considers the magic lantern as a revolutionary device that used the possibilities of light and optics to create images that could be projected onto large surfaces. He analyzes the evolution of the technique, including the use of color slides, moving elements and mechanisms to create the illusion of movement. The magic lantern was a tool for educational demonstrations in fields such as astronomy, physics and biology. Mannoni notes that scientific lectures, accompanied by projections, helped to visualize complex phenomena and make them understandable to a wide audience. The book describes how the magic lantern was used in entertainment performances, religious ceremonies, and even political propaganda. Particular attention is paid to the phenomenon of phantasmagoria, when the magic lantern was used to create the illusion of ghosts and supernatural images. Mannoni argues that the magic lantern laid the foundations of cinematic language: the use of light, projection, editing, and movement. He sees the magic lantern as part of a broader process of development of optical entertainment that culminated in the emergence of cinema. Mannoni's book is important for understanding the magic lantern as part of the history of not only technology but also culture. He connects the device with the evolution of ideas in science, art, and society that paved the way for the emergence of modern cinema.

In *"Illusions in Motion: Media Archaeology of the Moving Panorama and Related Spectacles"*, Erkki Huhtamo examines the magic lantern in the context of media archaeology, viewing it as an important stage in the development of visual technologies that preceded cinema. Huhtamo does not analyze the magic lantern in isolation, but as part of a broader phenomenon – the culture of moving images that existed long before the invention of cinema. He emphasizes that the magic lantern was part of a series of innovations, such as panoramas, dioramas, and other optical shows. Huhtamo applies the method of media archaeology to study how the magic lantern not only functioned as a device, but also interacted with the social, cultural, and economic contexts of its time. He explores how the magic lantern was integrated into various spheres of life –

from entertainment to education. Like Laurent Mannoni, Erkki Huhtamo notes the use of the magic lantern in educational and scientific demonstrations. He pays particular attention to how this contributed to the popularization of knowledge among audiences who did not have access to traditional education. His book gives examples of lectures demonstrating natural phenomena such as volcanic eruptions or solar eclipses. Huhtamo describes in detail how the magic lantern created visual effects that were innovative for the time. The use of color slides, moving elements and narratives formed a multifaceted audiovisual experience. The author considers how the magic lantern influenced the formation of new types of audiences. Visitors to such shows learned to perceive visual narratives, which became important for the future of cinema. Erkki Huhtamo's *"Illusions in Motion: Media Archaeology of the Moving Panorama and Related Spectacles"* is one of the most thorough works in media archaeology, which not only explores the magic lantern as a technology, but also analyzes its role in a broader historical context. Huhtamo emphasizes the importance of the magic lantern as a cultural phenomenon that changed the perception of the possibilities of visual storytelling, ultimately leading to the emergence of cinema.

In *"Phantasmagoria: The Secret History of the Magic Lantern"*, Mervyn Heard (2006) explores the history of the magic lantern, focusing on its use for illusion, entertainment, and audience manipulation. He details both the technical and cultural aspects of the device, focusing on its role in the phenomenon of phantasmagoria. Heard explains how the magic lantern was used in phantasmagoria shows – spectacled performances that created the illusion of ghosts and the supernatural. He examines in detail the productions of such shows in the 18th and 19th centuries, including the work of Étienne-Gaspard Robertson, who improved the projection technique by adding moving slides, changing the size of the image, and other effects. Heard emphasizes the technical aspects of the magic lantern, such as the use of special lenses, multi-layered slides, and moving mechanisms to create the illusion of movement. He also describes how projections could be made onto smoke or translucent screens, which enhanced the "realness" of the images. Mervyn Heard's book examines how the magic lantern was used to create frightening images and embody ideas about death, ghosts and the afterlife. Heard emphasizes that phantasmagoria became popular because it satisfied the audience's need for entertainment that evoked strong emotions. Although the main focus of Mervyn Heard's book is on the entertainment function, Heard also mentions the use of the magic lantern in scientific demonstrations and educational lectures. The author draws parallels between the magic lantern and cinema, noting that the technologies and methods used in projections laid the foundations for future cinema. He argues that the magic lantern educated an audience who learned to perceive stories through visual images. The book "Phantasmagoria" is unique in its genre, as it does not simply describe the magic lantern, but also explores its cultural impact. Mervyn Heard shows how this device was used to manipulate emotions, spread ideas and form new types of entertainment that became the predecessors of cinema. This work is an

important contribution to understanding the role of the magic lantern in the context of media, culture and history.

A camera obscura is an optical device that projected an image of the outside world onto a surface inside a dark room through a small hole (see Figure 3). The idea of a camera obscura is known from antiquity (Aristotle), but practical application developed in the 15th-16th centuries. The term "camera obscura" itself arose in the late 15th century, and the corresponding experiments were carried out by Leonardo da Vinci. The first accurate and complete description of a camera obscura is found in one of Leonardo da Vinci's unpublished works. Venturi, in his work *"Essai sur les ouvrages physico-mathématiques de Leonardo de Vinci"* (published in 1797 in Paris), cites relevant excerpts from Leonardo's work. The medieval Arab scientist Ibn al-Haytham (Alhazen) is considered the first to describe in detail the principles of the camera obscura in his work *"Book of Optics"* in the 10th–11th centuries (Ros, García, Moreno, Romagnoli, & Sebben, 2019; Boudrioua, Chergui, & Rashed, 2020; Maftouni, 2024). He used this device to demonstrate the laws of refraction of light and to study the structure of the visual system. Many film scholars, such as Georges Sadoul, Eric Barnouw, Laurent Mannoni, and even André Bazin, analyze the camera obscura as a fundamental element in understanding visual culture. Film historians see the camera obscura not simply as a technical device, but as a cultural and scientific phenomenon that prepared the ground for the emergence of cinema as an art and technology. Jonathan Crary explores how the camera obscura shaped the visual practices of modernity. Philosopher Michel Foucault sees the camera obscura as a metaphor for the perception of reality and the influence of technology on the formation of worldviews.

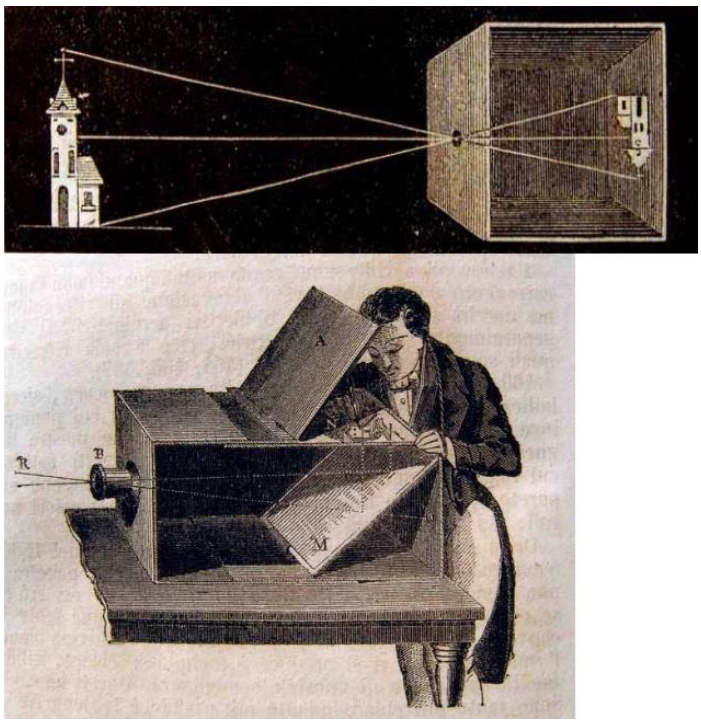

Figure 3. The Camera Obscura (Camuffo, 2011).

Georges Sadoul in his works, in particular in *"Histoire générale du cinéma"* (1946), considers the camera obscura as one of the key stages in the development of image display technologies that preceded the invention of cinema. Sadoul pays attention to its technical and cultural aspects, as well as its influence on aesthetics and the development of fine arts. The camera obscura in the works of Georges Sadoul is considered as a scientific instrument. Sadoul emphasizes that the camera obscura was invented and used for scientific research in the field of optics and the study of the nature of light. It allowed to study the mechanisms of imaging, refraction of light and perspective. Its principle of operation, based on the projection of an image through a small hole in a dark room, became the basis for further technological developments. The camera obscura, according to Sadoul, became an important tool for Renaissance artists, in particular for Leonardo da Vinci. It helped to create realistic images and study perspective, which later became the basis of cinematic framing. Sadoul sees the camera obscura as a precursor to cinema, as it demonstrated the possibility of capturing reality through an optical process. Its technical principle (image projection) was adapted in later inventions such as the magic lantern, photography, and later cinema. Sadoul emphasizes that the camera obscura symbolizes man's desire to "capture" reality and reproduce it in the form of an accurate image. This desire became a key motive for the development of cinema, which he calls the "artificial eye". Sadoul concludes that the camera obscura has a key historical significance, since it became an important stage in technological progress, in particular through its influence on the development of optics and image mechanics. The camera obscura not only prepared the ground for the creation of cinema, but also formed the first ideas about the principles of perception of moving images. Georges Sadoul sees the camera obscura not only as a technical invention, but also as an important cultural and scientific phenomenon that laid the foundations for modern technology and visual art. Its use in science, art, and culture created a solid foundation for the emergence of cinema, which, according to Sadoul, was a logical continuation of this tradition.

Eric Barnouw, in his book "*The Magician and the Cinema*" (1981), draws attention to the camera obscura as an important tool in the development of visual technology and as one of the stages of evolution that led to the invention of cinema. Barnouw examines the camera obscura in the context of its technical, philosophical and cultural significance, emphasizing its impact on the perception of images and the development of media. Barnouw describes the camera obscura as a fundamental invention, as a device that allowed for the creation of accurate projections of reality. Its action, based on the use of natural laws of light and shadow, became the basis for the development of more complex optical technologies, including photography and cinema. Barnouw notes that the camera obscura gave users the first experience of observing "reality", which was transformed into a projection. This became key to understanding the principles of cinema, where the moving image is based on a similar concept of reflecting the real world. Eric Barnouw highlights the role of the camera obscura in art: artists used it to create realistic paintings, and scientists used it to study

the laws of optics and perspective. These applications influenced the technical and aesthetic evolution of images. Barnouw draws attention to how the camera obscura symbolizes the connection between reality and its illusory reproduction. This philosophical aspect became the basis of cinema, where viewers are immersed in the illusion of movement based on real images. Eric Barnouw considers the camera obscura not only as a technical device, but also as a socio-cultural phenomenon. It was popular not only among scientists and artists, but also as entertainment that inspired new ideas in the visual arts. Eric Barnouw emphasizes the role of the camera obscura in the context of media history. Barnouw emphasizes that the camera obscura became the first tool for creating a collective experience of "image contemplation". It allowed not only to see the world in a new perspective, but also to understand it through technical mediation, which is an important feature of cinema. Barnouw sees the camera obscura as a defining stage in the development of media technology and culture. Its impact on artistic reproduction, scientific research and entertainment made this device an important precursor to cinema. For Eric Barnouw, the camera obscura is the beginning of a long history of human interaction with optics, light and images, which ultimately led to the emergence of modern cinema.

Laurent Mannoni (1994), a leading historian of optical technology and author of the seminal work *"Le Grand Art de la Lumière et de L'ombre, Archéologie du Cinema"*, has devoted considerable attention to the camera obscura, considering it a key element in the long history of visual innovation that led to the invention of cinema. Mannoni analyzes this device not only as a technical achievement, but also as a cultural and philosophical phenomenon. Laurent Mannoni describes the camera obscura as the oldest device that allows to recreate reality using the natural principles of light. He emphasizes its versatility and long-standing use in science, art and education. The book states that this invention became the basis for all future devices that work on the principles of image projection. The camera obscura was crucial for Renaissance artists, helping to create accurate images through the knowledge of perspective. At the same time, it was used by scientists to study the properties of light and form an understanding of optical laws. Mannoni emphasizes that the camera obscura symbolized the human desire to understand and "reflect" the world. It became a means of meditation on reality, a way of comprehending the connection between nature, light and man. In the work, he mentions the camera obscura as an example of the first "visual machine", which made it possible to see the world within a frame, similar to a modern cinematographic frame. Laurent Mannoni considers the camera obscura as a precursor to cinema, because it forms an idea of the importance of light in creating an image. And also, because the camera obscura introduces the concept of observing the world through an "artificial window", which later became the basis of cinema. In his book, Laurent Mannoni traces in detail the path from the camera obscura to the magic lantern, photography and cinema, demonstrating how this device contributed to technical and cultural development. For Laurent Mannoni, the camera obscura is not just a technical device, but an epochal invention that has had a huge impact on the development of

visual culture, science and art. Its role in creating optical illusions and shaping a new way of perceiving the world became the basis for the emergence of cinema, which preserves its legacy in its technical and philosophical principles.

André Bazin, a famous film theorist, in his works, in particular in *"Qu'est-ce que le cinéma?"*(1958), analyzes the camera obscura as a conceptual precursor to cinema. Although he does not pay as much technical attention to it as other historians, Bazin uses it as a philosophical symbol for understanding the nature of the image and cinematic realism. Bazin sees the camera obscura as the first step in man's quest for "an objective reflection of reality". According to him, this device embodies the idea of an image that is created automatically, without the intervention of the artist or subjective interpretation. For André Bazin, the camera obscura illustrates the principle of photographic imaging, where reality is conveyed through light, rather than through human intervention. He sees the camera obscura as a tool that reflects reality as it is, without stylization. This correlates with his concept of cinema as a means of "imprinting reality". The camera obscura laid the foundations for the perception of the image as something objective and authentic, which became key to cinematic aesthetics. André Bazin emphasizes the role of light in the creation of images. In the camera obscura, light acts as a "natural artist", forming a picture of the external world. This idea is close to his theory of photography and cinema as "inventions of nature" that serve humanity. For André Bazin, the camera obscura also symbolizes the importance of the "frame" as a means of highlighting a fragment of reality. This is related to the concept of the cinematic frame, which organizes and structures the world for the observer. The camera obscura is, according to Bazin, one of the key stages in human history, when man began to make sense of and document visible reality through technology. It became part of the evolution that eventually led to the creation of cinema as the culmination of these efforts. For André Bazin, the camera obscura is the philosophical and conceptual precursor of cinema. It symbolizes the human desire for objectivity and authenticity in the depiction of the world. Its role in creating an image through light laid the foundations for the theory of cinematic realism, which became central to André Bazin's work and significant for cinema in general.

Jonathan Crary (1992), a renowned cultural and media historian, devotes considerable attention to the camera obscura in his book *"Techniques of the Observer: On Vision and Modernity in the Nineteenth Century"*, considering it not only as a technical device, but also as a key metaphor for understanding changes in perception and philosophical concepts of vision. Crary considers the camera obscura as the dominant model of vision in the 17th and 18th centuries, when it symbolized the idea of objectivity and the detached observer. This device embodied the ideal of a distant, unbiased view of the world, where the observer is outside the events he sees. The camera obscura, according to Crary, was not only an optical device, but also a philosophical metaphor of the Enlightenment era, emphasizing the importance of rational contemplation and the separation of the subject (observer) from the object (reality). Jonathan Crary argues that by the 19th century, the camera obscura as a model

of vision had entered a crisis. The emergence of new technologies such as the stereoscope, together with scientific and cultural changes, led to a rethinking of the role of the observer. He argues that the camera obscura no longer corresponded to new concepts of perception, which emphasized the subjectivity and mobility of the gaze. Crary sees the camera obscura as a precursor to new visual technologies, but at the same time emphasizes that its significance goes beyond its technical impact. It was a conceptual stage in the development of ideas about the way in which humans interact with reality through vision. Crary describes the transition from the static, isolated model of observation symbolized by the camera obscura to the more dynamic and interactive forms of vision that emerged with the development of modern media. For Jonathan Crary, the camera obscura is not only a technical device, but also an important intellectual and cultural symbol. It represents a historical stage in the development of ideas about vision, perception, and knowledge. Crary shows how changing models of observation reflect broader transformations in philosophy, science, and culture that ultimately influenced the evolution of visual media.

Michel Foucault, a renowned philosopher and cultural theorist, although he did not directly study the camera obscura as an optical device, uses it as a metaphor in his work *"L'archéologie du Savoir"* (1969) and other works. He interprets the camera obscura as part of his analysis of power, knowledge, and the ways in which observation and control are organized. Like the camera obscura, which records the world through a limited "frame", power in society structures reality through observation and discipline. In his concept of the disciplinary society, Foucault describes how institutions such as schools, hospitals, and prisons organize space and observation, creating a "visibility of reality". In this sense, the camera obscura is an early example of how technology influenced the formation of knowledge. The camera obscura, which produces an inverted image, is for Foucault a metaphor for how knowledge is often constructed in a distorted, indirect form. This is particularly relevant for the analysis of discourses that he explores in his works. In the context of his critique of the Enlightenment, Michel Foucault sees the camera obscura as a metaphor for the dominant model of knowledge at the time: objective, static, and centralized. He points out the limitations of this approach in the modern era, when knowledge becomes more dynamic and relative. Michel Foucault is often compared to ideas about the camera obscura when he describes the panopticon (an architectural model of a prison that allows centralized surveillance). Both concepts refer to the organization of space where the observer has complete control over what is visible. Michel Foucault does not analyze the camera obscura as a specific invention, but uses it as a philosophical symbol to analyze the structure of knowledge and power. The camera obscura is for him an example of how technology affects the way reality is constructed, creating not only an image of the world, but also a way of understanding and controlling it. The camera obscura in Foucault is a conceptual tool that reflects key aspects of his theory of knowledge and power. Just as the camera obscura determines what the observer sees, so institutional structures determine how society perceives reality. This metaphor helps

to reveal the connection between technology, culture, and the formation of discourses in different historical eras.

Shadow theater, as an ancient art form known in China, India, and other Asian countries since ancient times, spread to Europe in the 18th and 19th centuries (Won & Lee, 2016; Demchenko, et al., 2022; Johnson & Lim, 2022). Shadow theatre: discovering human motion from a sequence of silhouettes. ACM Transactions on Graphics (TOG), 35(4), 1-12.). Its essence is the use of figures that create shadows on a screen with the help of light. Studies of shadow theater often focus on its ritual and cultural aspects, especially in Asian traditions (for example, Indonesian wayang kulit). European versions of shadow theater, such as the performances created by Jean-Eugène Robert-Houdin, are studied as forms of popular entertainment. In works on the history of cinema, shadow theater is analyzed as an early form of visual narrative that influenced the development of editing and lighting techniques. It also attracts the attention of many film historians as a precursor to moving images.

Tom Gunning, a renowned film historian and theorist, sees shadow theatre as an important precursor to cinema, helping to understand early forms of visual spectacle and the role of the viewer in their perception (Gunning, 2009; Gunning, 2017; El Bouayadi, 2023). Although Gunning focuses more on the concept of "attraction cinema", shadow theatre fits into his broader analysis of the development of media and technologies that use light and movement. In his research, Tom Gunning emphasizes that shadow theatre is an example of an "attraction" – a spectacle aimed at visual experience and emotional impact, rather than just narrative. Like early cinema, shadow theatre focused more on creating an immersive visual effect. Shadow theatre demonstrated the ability to manipulate light and form to create optical illusions, which formed the basis of many cinematic techniques, such as the use of light and shadow contrasts, silhouettes and spatial composition. Gunning draws attention to the interactivity of shadow theatre: the viewer became a participant in the spectacle, actively interpreting what he saw. This principle resonates with his concept of early cinema, which invited the audience to directly experience the attraction. Tom Gunning emphasizes that shadow theatre, like phantasmagoria, combined staticity with movement. This created a sense of magic and movement, which later became defining for cinema. Shadow theatre, like early cinema, was a form of "attractions" that focused on visual effect. The development of light and shadow techniques influenced expressionist cinema and the use of optical effects in films. Shadow theatre in Tom Gunning's concept is seen as an important part of the evolution of visual culture, which laid the foundation for cinema as an art of movement and light.

Georges Sadoul considered shadow theatre to be one of the oldest ways of manipulating light and images (1946), creating the illusion of movement, similar to what cinema does. He noted that this art form had much in common with later cinematic techniques, in particular in the way it created visual effects through light and shadow. Sadoul emphasized that shadow theatre developed through the use of various optical technologies, which eventually found their continuation in cinema. One such

tool was the magic lantern, which used light to project moving images similar to those in shadow theatre. Georges Sadoul also noted the aesthetic influence of shadow theatre on the development of visual art. According to him, through the manipulation of light, shadow theatres taught viewers to perceive moving images in a special way. This became the basis for the formation of cinematic traditions, where light and shadow were of great importance in creating atmosphere. Sadoul drew attention to the popularity of shadow theatre in various cultures, from Asia to Europe. He believed that shadow theatre was an important element of folk culture, used for entertainment, education, and religious and mythological narratives. For Georges Sadoul, shadow theatre was an important stage in the development of visual art, which laid the foundation for cinema. He highly valued the technical and artistic innovations of this art form, in particular the use of light, shadow and optical devices, which influenced the development of cinematic practices. Shadow theatre became one of the key elements in the great history of the visual arts that preceded the invention of cinema.

Zenon Walter Pylyshyn, a Canadian cognitive scientist and philosopher of Ukrainian origin, has paid particular attention to the development of early forms of visual art, such as shadow theatre (O'Brien & Opie, 1999; Schröder, 1999; Matthen, 2024). He has analyzed these art forms as important stages on the path to the development of cinema and as part of a broader cultural tradition of optical illusions. Pylyshyn sees shadow theatre as an important part of the evolution of visual technology that preceded cinema. Shadow theatre used the illusion of movement and the creation of images through light and shadow, which became the basis for later cinematic techniques. Zenon Pylyshyn addresses the aesthetic and cultural aspects of shadow theatre, emphasizing its role in folk traditions and popular forms of entertainment, as well as in religious and educational contexts. Pylyshyn emphasizes how this art form has developed and adapted in different cultures around the world. Zenon Pylyshyn also explores the connection between shadow play and other optical devices, such as the magic lantern, and how this contributed to the development of optics and the manipulation of light and images. Shadow play, along with other technologies, became part of the experiments that led to the emergence of cinema. Zenon Pylyshyn was one of those who actively studied the role of optical illusions in the context of cinematic art. He emphasized the importance of early forms of manipulation of light and image in the development of cinema. Shadow play was one of these important stages in this process, where optical devices were used to create effects resembling movement and changes in form. Zenon Pylyshyn considered shadow play as one of the precursors of cinema and an important element in the development of optical effects and manipulation of images. He emphasized how this art form influenced the aesthetics and techniques that later became part of cinema.

The magic lantern, the camera obscura, and the shadow play are considered to be part of the visual culture of their eras, influencing people's understanding of images and their movement. These devices served as means of telling stories, creating the first forms of visual storytelling that became the basis of cinema. Researchers such as

Thomas Elsaesser (2004), using a media archaeological approach, include these devices in the broader context of the evolution of media that preceded cinema.

The magic lantern, the camera obscura, and the shadow play are key precursors of cinema. Historiographical works emphasize their technical, cultural, and artistic impact, viewing these devices as stages in the development of visual media that combined science, art, and technology into a single process that led to the creation of cinema.

Conclusions.

The magic lantern, the camera obscura, and the shadow play can be considered key precursors to cinema, as these devices and art forms played an important role in the development of technologies and concepts that became the basis for the emergence of cinema. The magic lantern, the camera obscura, and the shadow play were key milestones in the development of cinema, as they developed techniques for manipulating light and shadows, creating the illusion of movement, and projecting images. They were important precursors to cinema, providing the conceptual and technical foundations that allowed cinematic technologies as we know them today to emerge.

The magic lantern, the camera obscura, and the shadow play not only laid the foundations for cinema, but also contributed to the development of important scientific and technical concepts. They were milestones in the development of optics, projection technologies, and helped popularize scientific ideas among the public. These devices have become important tools in the fields of media, communications, and the study and development of the physics of light and images, making them significant milestones in the history of science and technology.

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Історія еволюції кінематографу в контексті розгляду етапів розвитку науки і техніки. Перші кроки до зародження кінематографа

Анотація. *Історіографічні праці з історії кінематографа відіграють важливу роль у збереженні знань про розвиток цього виду мистецтва. Вони не лише документують ключові етапи еволюції кіно, але й надають можливість аналізувати його як культурний феномен, що тісно переплітається з історією людства. Історіографічні праці з історії кінематографа охоплюють дослідження розвитку кіно як мистецтва, засобу комунікації та індустрії. Вони відображають різні аспекти його становлення: соціокультурні впливи, технологічні прориви, жанрові трансформації та роль кіно в історичному контексті. Але ґрунтовний аналіз історіографічних джерел, щодо вивчення історії еволюції кінематографу в контексті розгляду етапів розвитку науки і техніки раніше не проводився. Мета дослідження полягає у тому, щоб на основі аналізу історіографічних джерел, здобутків попередників, сучасної методології дослідити стан, повноту й достовірність вивчення історії розвитку кінематографу в контексті розгляду етапів розвитку науки і техніки. Завданням даної статті є аналіз історіографічних джерел, які розглядають магічний ліхтар, камера-обскура та театр тіней як ключові попередники кінематографа. Магічний ліхтар, камера-обскура та театр тіней стали основними етапами у розвитку кінематографії, оскільки вони розвивали техніки маніпуляції світлом і тінями, створення ілюзії руху та проекції зображень. Вони стали важливими попередниками кінематографії, надаючи концептуальні та технічні засади, що дозволили виникнути кінематографічним технологіям, як ми їх знаємо сьогодні. Усі три пристрої активно використовували маніпуляції зі світлом і тінями для створення візуальних ефектів, що стали основою для кінематографії. Кожен з цих пристроїв дозволяв здійснювати технічні інновації у використанні освітлення, проекцій та зображень, що згодом були адаптовані в кінематографічних технологіях, таких як проектори та кінокамери. Всі ці технології допомогли популяризувати ідеї використання оптичних ефектів і медіа для масової аудиторії, що було важливим для становлення кінематографії як індустрії. Історіографічні праці, присвячені магічному ліхтарю, камері-*

обскура і театру тіней, зосереджуються на дослідженні цих винаходів як важливих попередників кінематографа. Вони заклали основи візуального мистецтва, що використовує гру світла і тіні, та вплинули на розвиток технологій створення ілюзії руху.

Ключові слова: *зародження кінематографу; візуальні ефекти; магічний ліхтар; камера-обскура; театр тіней; історіографія*

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Academician of the All-Ukrainian Academy of Sciences Petro Mykhaylovych Suprunenko: Life and activity

Abstract. *The article updates the most significant information about the outstanding scientist-mechanic and railwayman of the first third of the 20th century Academician of the All-Ukrainian Academy of Sciences Petro Mykhaylovych Suprunenko (1893–1938). It is proven that his activities in the field of railway development are a significant contribution to the development of world science and technology. The main scientific works of the scientist and engineer are devoted to important problems of transport mechanics. He paid special attention to locomotive and wagon construction (he was a wagon designer). Wagons were built on the basis of a large amount of experimental material, which at one time received significant public resonance and scientific and technical recognition. It is emphasized that P. M. Suprunenko was one of the first railway engineers who proposed a scientific analysis of the interaction of the track with the rolling stock of railways. The article notes that today P. M. Suprunenko is mentioned very little, only fragments of his biography are described, only some of his scientific works are characterized. In the Institute of Transport Mechanics of the All-Ukrainian Academy of Sciences headed by him, the following research was successfully developed under his leadership: methodological problems of transport mechanics were highlighted in order to comprehensively solve the tasks of modernization of the railway industry; research of non-stationary dynamic processes of interaction of rolling stock (train) with the track system (especially the study of the resonance phenomenon); research of the theory of calculations of locomotive traction on railway tracks in order to optimize elements of*

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transport mechanics and increase their efficiency, etc. The article describes in detail each of these areas of research by P. M. Suprunenko. In general, his research focused on problems of railway transport. In the field of train traction theory, P. M. Suprunenko created a number of new methods for graphical integration of differential equations of train motion, paid significant attention to improving existing ones and creating new devices designed to measure the characteristics of various processes occurring in rolling stock and tracks. The scientist's achievements in the initial period of railway transport construction in Ukraine, especially on the South-Western Railways, are confirmed. The article shows that the role of P. M. Suprunenko was in his scientific work as an "idea generator" and a leading theorist in combination with engineering activities.

Keywords: *history of railway transport in Ukraine; problems of transport mechanics; track management; mobile railway warehouse; victims of Stalinism*

Introduction.

Petro Mykhaylovych Suprunenko, graduate of the Kyiv Polytechnic Institute, later head of the department of this Institute, actively worked in the field of transport mechanics, railway transport (locomotive and wagon construction). In particular, he was a designer of wagons and a teacher. But the name and scientific achievements of Petro Suprunenko are almost forgotten today. Despite the current growth of scientific interest in the personalities of Ukrainian railway engineers, the personality of Petro Suprunenko, who made a discovery of international significance in the field of experimental research on the dynamics of a four-axle wagon, is not often mentioned in scientific publications. In the context of the modern struggle of the Ukrainian people for independence, the introduction into scientific circulation of the biography of one of the active railway engineers, who made a significant contribution to the development of transport mechanics, is extremely relevant.

Analysis of Research and Publications.

In modern newspaper and magazine publications, and individual scientific works, only fragments of the biography and individual areas of scientific activity of Petro Suprunenko are mentioned. Thus, S. M. Pankova in her article “Institute of Transport Mechanics of the Academy of Sciences of the Ukrainian SSR: History and Fate” (1991) restores, based on documentary sources, one of the unknown pages of the activities of the All-Ukrainian Academy of Sciences (AUAS) *(Ukrainian Academy of Sciences, from 1918 to 1921; All-Ukrainian Academy of Sciences, from 1921 to 1936; Academy of Sciences of the UkrSSR from 1936 to 1991; Academy of Sciences of Ukraine from 1991 to 1993; National Academy of Sciences of Ukraine, since 1994)* – the Institute of Transport Mechanics and the fate of its employees (Pankova, 1991, pp. 94–100). This institute, under the leadership of Academician P. M. Suprunenko, solved complex technical issues, mainly in the field of railway transport. P. M. Suprunenko and his subordinate Institute focused much attention on the issues of traction, track and

operation. The fate of the scientific Institute, the names of scientists, including P. M. Suprunenko, is one of the pages of the past of the All-Ukrainian Academy of Sciences. The employees of the Museum of the History of Kyiv managed to restore it. They display the Institute's materials in the Museum at an exhibition in memory of the victims of mass repressions. They reflect the situation that developed in pre-war science, during the years of the so-called "cult of personality of J. V. Stalin." These facts indicate that not only individuals, but also entire scientific institutions must be rehabilitated.

Lyubov Sukhoterina, a modern historian of science and technology from Odessa, emphasizes the terrible pages of the history of the Ukrainian people. In her article "The Fate of Petro Mykhaylovych Suprunenko – as an Example of the Fate of a Ukrainian Scientist in the Conditions of Stalinist Totalitarianism" (2001), she objectively examined the pages of the history of P. M. Suprunenko's activities, which were silenced and forgotten for a long time (Sukhoterina, 2001, pp. 71–75). The author of the article concludes that the fate of the prominent Ukrainian Academician P. M. Suprunenko indicates that the terror unleashed by the then totalitarian system against the best representatives of Ukrainian science stopped for many years and decades the development of certain areas of technical sciences, and railway transport in particular.

Modern historians of science and technology also wrote about P. M. Suprunenko (Vlasenko, 2007; Lokun, 2007; Azarova, 2015).

The purpose of the article is to reveal the role and contribution of P. Suprunenko to the development of railway transport as an outstanding scientist and engineer, public and educational figure at the beginning of the 20th century. Among the key tasks is the analysis of the subject matter and content of his engineering publications.

Research Methods.

The research methodology is based on the principles of historicism, objectivity and systematicity. With their help, it was possible to clarify the conditions in which the views were formed and the public and educational activities of P. M. Suprunenko were implemented. Analytical, synthetic, logical, retrospective, historical and biographical and other general scientific methods were also applied. They made it possible to determine the areas of activity of the scientist and engineer, to analyze the content of part of his creative heritage.

The principle of historicism made it possible to consider the formation of the scientific heritage as a historical final process that took place in time, in specific conditions and circumstances. After all, the principle of historicism is always applied to the consideration of phenomena that have a beginning and an end, and also studies the connection between certain phenomena in space and time in the context of the development of a single and gradual world-historical process.

The principle of scientificity contributed to the elucidation of the cause-and-effect relationship between the phenomena and processes of the studied period in the context

of the development of historical events and facts. After all, it is the principle of scientificity that makes it possible to familiarize contemporaries with the events of the past, and also shows the prospects for the development of science.

Currently, the figure, activities, and creative legacy of P. Suprunenko remain little known. A comprehensive study of his life and achievements has not yet been carried out, and most of his works remain out of scientific circulation.

Results and Discussion.

Petro Mykhaylovych Suprunenko was born in Kremenchuk on June 18, 1893. In 1919, he graduated from the Mechanical Department of the Kyiv Polytechnic Institute. He began his career at the South-Western Railways in the technical department of the traction service. His professional activities were diverse. He held the following positions: design technician, design engineer, head of the technical group and department. He gained extensive experience as a railway transport engineer. At the same time, he did not shy away from pedagogical work - from the 1920s to the mid-1930s he worked as a teacher at the Kyiv Polytechnic Institute, the Kyiv Institute of National Economy, and also at the Kyiv Railway Institute. Petro Mykhaylovych grew from assistant to professor. In the same years, he was the head of the department of steam locomotives and wagons at the Kyiv Polytechnic Institute.

Simultaneously with teaching at various universities, in 1926 P. M. Suprunenko began working in the transport section of the Institute of Transport Mechanics of the All-Ukrainian Academy of Sciences. After receiving the title of professor in 1929, he became the head of the Cabinet of Transport Mechanics (CTM) at this academic institute. In 1934, he was elected as an Academician of the All-Ukrainian Academy of Sciences. In 1934, the CTM, thanks to his efforts, was transformed into the Institute of Transport Mechanics of All-Ukrainian Academy of Sciences (ITM). Petro Mykhaylovych held the position of director of this institute until his arrest and liquidation of the institute in 1937. P. M. Suprunenko was convicted on unfounded charges and died in the camps in 1938. His brilliant engineering and scientific activities were achieved by special abilities, good education, which he received at the Kyiv Polytechnic Institute, and rich practical experience.

In 1924, 5 years after graduating from the university, P. M. Suprunenko published a monograph in Kyiv, which he defended as a dissertation on the topic “Theory of oscillations of the super-spring parts of steam locomotives in connection with smoothness of movement, safety of movement and pressure of wheels on rails”. In his dissertation, Petro Mykhaylovych highlighted the issues of the influence of various factors on the movement of a steam locomotive, impacts and collisions at the joints of rails, and investigated the features of the movement of a steam locomotive on curved tracks. He also calculated the forces that arise due to inertia forces in parts of the steam distribution mechanism during the movement of the steam locomotive.

In 1926, P. M. Suprunenko published a textbook "Traction Calculations". This textbook was actively used by both students and railway engineers and technicians for

the purpose of practical calculations and design work. This textbook was so relevant that 6 years later, in 1932, it was published a second time under the title "General Theory of Train Traction". Finally, in 1934, P. M. Suprunenko published his fundamental monograph "Harmonic Oscillations of Railway Rolling Stock". This monograph was recommended as a textbook for students of higher technical educational institutions of railway transport.

The vast majority of research was conducted by P. M. Suprunenko himself, or by teams of employees of the ITM with his direct participation and under his scientific and organizational leadership. We characterize five of his main areas of research.

The study of methodological problems of transport mechanics is relevant to the entire spectrum of problems that were faced by scientific and technical workers in the industry at that time in connection with the gigantic plans for the modernization and industrialization of the national economy. The main factors and results of these studies, in our opinion, were: the objective conviction of the technical management and the public in the need for large material and intellectual investments in the field of scientific research and engineering education in the transport industry in general; the development of the engineering systems in the transport industry in general (Suprunenko, 1933). Without such an approach, which was developed by many scientists, including Academician P. M. Suprunenko, the impressive successes of transport, in particular railway transport, which the civilized world achieved in the last decades of the 20th century would not have been possible!

Research in the *second direction* should include theoretical analysis and experimental modeling of locomotive oscillations under resonance conditions, development of theoretical models of oscillations of the last cars in the train and their impact on the track system. These processes led to mechanical failures in the systems of locomotive mechanisms and cars (tanks, platforms) and had a detrimental effect on the condition of rails and other elements of the track system. In turn, this led to catastrophic consequences - ruptures of gas pipelines in locomotive water heaters with subsequent explosion of the boiler and the death of the locomotive crew.

In the second case, the violation of the condition of the rails, which was caused by the increased amplitudes of vibrations of the last cars of the train, especially in the state of resonance, could lead to ruptures of both the rails themselves, joints, sleeper reinforcements, and an increase in the interrail distances, which, in turn, led to derailments of trains and accidents with great material losses and numerous human casualties. It is obvious that the results of such studies were the spectra of the frequencies of resonant vibrations and their dependence on the structure of trains, the loading of individual cars, the methods and order of their coupling, the technical condition and profile of the railways, the speed of movement, temperature, weather, and other factors.

All this, as we can see, on the one hand, was aimed at increasing the reliability and safety of traffic, developing practical recommendations regarding train formation, loading of individual wagons, traffic regimes on individual railway sections, etc. On

the other hand, such development of objective methods for examining the condition of trains, tracks, transportation organization, analysis of traffic regimes, causes of accidents and disasters deprived the party-bureaucratic leadership of the voluntarist lever of pressure on technical workers to force them to carry out unrealistic, adventurous transportation plans, poorly (but quickly!) build new tracks, go beyond the permissible parameters of operation of rolling stock and railway equipment. Often, it did not allow these workers to be unjustifiably accused of sabotage in cases of accidents, while making it possible to conduct a more or less objective investigation of the circumstances of the case. Obviously, this political factor in an issue that at first glance appears to be entirely theoretical technical and engineering research had to be taken into account when assessing the work of the ITM and understanding why such a terrible fate befell its director and employees.

The third area of research occupies a large place, in terms of volume and importance, in the works of the CTM in general and P. M. Suprunenko in particular. The results of works in this area were published in two of his monographs, recommended as textbooks for the ITM and students of higher education institutions of railway transport. A detailed analysis of these studies is yet to be done. While giving a superficial analysis of these studies, it should be noted that the steam locomotives, used at that time as locomotives, had a very low efficiency factor (several percent!), which limited their power and traction capabilities. The increase in the power of steam locomotives did not lead to an increase in this factor. In the conditions of a massive increase in the volume of transportation, this factor was transformed from a purely technical one into a technical and economic one, determining, to a large extent, the cost price and deciding the rate of growth of the volume of transportation. In this regard, any attempts to increase the efficiency factor of steam locomotives had, at that time, great importance not only technical, but also economical, and in the conditions of a state-planned economy - also political. This includes studies that intersect with the second direction, namely the interaction of train rolling stock, primarily steam locomotives, with the track system, and in fact, with railway rails. In such interaction, the most important factor is the resistance force, which varies depending on the condition of the track, wheel treads, friction coefficients of wheels and rails, as well as the temperature of the external environment, which within the geographical boundaries of the USSR fluctuated in the range of 100–120 °C at different times of the year. On the other hand, this interaction also determines the force of adhesion of the locomotive to the track and, as a result, the traction force. Failure to take this factor into account led to large errors in traction calculations and, as a result, significant losses of fuel and train control efficiency. Coefficients of adhesion and friction also have a large impact on the quality of brakes, on which traffic safety directly depends.

Research in the *fourth direction* was largely aimed at improving the efficiency of energy use, which was obtained from burning coal (or other fuel) in the furnace of a steam locomotive. Combustion was very inefficient. Therefore, it was necessary to use expensive high-calorie coal, which led to an increase in the cost of transportation, took

away valuable raw materials from metallurgical and chemical industries, and increased the load on coal mines. The solution to this important national economical problem lay in the development of new schemes and modes of burning low-calorie coal in furnaces and increasing the efficiency of generation and use of heat and steam in water heaters of steam locomotives. The increase in the power of steam locomotives required an increase in pressure in the boilers, and this, in turn, affected the quality of heat transfer and steam generation. There were possible situations of overheating and damage to the pipelines in the boilers and, as a result, a locomotive accident, or even a train disaster. As we can see, P. M. Suprunenko's research in this area was aimed not only at increasing the efficiency of transport mechanics, but also to a certain extent - at increasing the safety of rolling stock operation and railway transportation in general. Solving these problems required the development of new approaches to thermodynamic calculations and modeling of combustion and heat transfer processes in complex systems of steam locomotive heat exchangers.

A very important approach to solving the problems of the transport industry, which dominated the works of the CTM and personally by P. M. Suprunenko, found its reflection in research in the *fifth direction* - optimization of the processes of managing the creation (formation) of trains, development of train schedules, reduction of car downtime and reduction of transportation costs.

It is obvious that from today's perspective these works seem too primitive and simple, but one must take into account the time of their implementation. The New Economic Policy ("NEP"), which in the late 1920s was suspended in favor of accelerated industrialization, collectivization, and the Cultural Revolution, clearly demonstrated the role of complex organizational and economic factors in increasing labor efficiency. But the times of "Stakhanov" methods in production and "Lysenko" in science were already coming... Soon all these "bourgeois-nationalist economical methods" would become arguments in the indictments... The time of the defeat of Soviet science was coming, and it began with Ukraine, with its outstanding scientists and leading creative collectives.

Thus, summarizing the results of this brief analysis, we can determine that:

- The Transport Mechanics Department, for a fairly long time of its existence (approximately 8 years), was engaged in solving *urgent problems* of transport, primarily railway transport, both in Ukraine and in the USSR in general. These problems did arise in practice, but within the limits and by the forces of the technical services of individual railways they could not be solved, they required general theoretical and experimental in-depth research, mathematical modeling and physical and technical simulation with the involvement of highly qualified scientific personnel. The creation of this structure within the Institute of Transport Mechanics of the All-Ukrainian Academy of Science provided the opportunity to focus specifically on the tasks of researching the dynamics of transport mechanics, which corresponded to the specifics of the scientific topic and the degree of complexity of the research;

- The staff of the CTM proved their scientific qualifications by solving complex scientific and technical tasks. The appointment of Professor P. M. Suprunenko as the head, and then as the director was not accidental, it was a recognition not only of the fact of his numerous scientific achievements, but also of the fact that he was at that time a leading scientist - a leader in the field of applied mechanics.;
- Scientific research at CTM focused on the problems of ensuring the reliability, safety and efficiency of railway transport - the main, as at that time (and still!), type of transportation in the former USSR. These directions were justified not only by the state of affairs at that time, but also by the trends in the development of the USSR economy, foreseen by the five-year industrialization plans;
- The role of P. M. Suprunenko was in his scientific work as an "idea generator" and leading theorist combined with engineering creativity. Personal creative abilities, good fundamental education and practical experience, as evidenced by his brilliant engineering and scientific career, helped him in creative growth and brought good results to the scientific team;
- The CTM (as well as the Institute of Transport Mechanics) was closely connected with the system of research, design and construction organizations and educational institutions. Thus, the first scientific conference on the dynamics and interaction of track and rolling stock, held in January 1935, was attended by representatives of 30 organizations from different regions of the USSR, with which the ITM maintained scientific relations. This fact determines the leading role of the Institute at that time in the field of the dynamics of transport mechanics and other issues.

Comparing the results of the presented analysis of the scientific directions of CTM (ITM) with the above-mentioned systemic factors of the development of science in transport mechanics, we come to the conclusion that there is a certain convergence of the requirements for the development of technical sciences in the field of transport engineering and operation with the directions of scientific research conducted in the Cabinet and Institute of Transport Mechanics of the All-Ukrainian Academy of Science under the leadership of Academician P. M. Suprunenko. According to the authors, this fact objectively confirms the usefulness and correctness of the creation and existence of this scientific structure precisely within the All-Ukrainian Academy of Science at that "critical" time, which can be characterized as a preparatory period for the transition to the system of the so-called "departmental science" (Yarema, 2007; Altenbach, Bogdanov, Bulat, Guz, & Nazarenko, 2023; Dunayevska & Yevtukhov, 2023; Starostenko & Kobolev, 2023).

The following question deserves the answer: why was the ITM team, led by the director, chosen as a victim of terror? Why was it necessary to destroy the structure itself and erase the fact of the existence of CTM (ITM) from the history of science? According to the authors, there could be several reasons for this. We have already talked about some of them earlier, and we can emphasize once again that there were no objective scientific reasons for the liquidation of ITM. Most likely, the reasons were

of a political nature - the fight against the so-called "Ukrainian nationalism", standard (in the wake of mass terror against the intelligentsia) accusations of "espionage and sabotage", "sabotage", etc., which covered up the actual reasons - the introduction of a command-and-administrative system of "departmental science" and the destruction of "inconvenient" scientists and organizations under the slogan "No man - no problem!"

In this regard, a second question arises – is it good or not to have “departmental science” and how should it relate to “academic” science? Again, systematically considering this issue, we can conclude that the existence of these two organizational “levels of abstraction” in the system of research, production and management of new knowledge is useful. The history of the development of science in the world, as well as in the USSR, has proven the correctness of this thesis. The problem lies in a different context – these “levels” should not dominate one over the other, not compete, but complement each other, having complementary, but still different tasks. Violation of this principle leads to negative consequences not only in a purely ambitious-personal, scientific-cognitive, or even economic sense, but also in a general civilizational context (as the bitter experience of the Soviet model of science convincingly proved!), which also became obvious at the turn of the millennium. The Soviet Union, as a civilizational geopolitical system, did not lose the "cold" war, the arms race, or even the economic competition. The chance to take a place in the ranks of world leaders in scientific and technological progress, appropriate to the material, financial and intellectual resources of the country and society, the achievements and traditions of Russian, Ukrainian and other scientific schools, and an accelerated transition to the civilizational phase of the information society was lost. To a large extent, the reason for this lies in the totalitarian form of the command-bureaucratic system, which also prevailed in Soviet science in the 1930s, and the consequences of which have not yet been eliminated.

The third question that arises when studying the life path and scientific heritage of P. M. Suprunenko relates to the socio-political and moral-ethical sphere and can be formulated as follows. How free is a scientist, engineer, technician from the obligations of participation in the socio-political life of his society, how free is he to stand aside from the so-called "politics"? The example of Academician Suprunenko shows that this is possible up to certain limits. Within the framework of authoritarian, totalitarian, and even quasi-democratic societies, a scientist, without losing his dignity as an intellectual, objectively cannot avoid such participation. A more or less talented, gifted and educated person has a heightened sense of justice, dignity and his own worldview, sets a bad (from the point of view of the totalitarian system) example for other members of society, is “inconvenient” and poses a threat. Even if a person is not engaged in “politics”, the latter will “engage” in it. Therefore, in the conditions of an information society, when the intelligentsia becomes not a “layer”, but a full-fledged productive force, the protection of freedom of creativity, personal, scientific dignity and other moral and ethical values of every person, especially artists of science, culture, education, had to become a serious priority of the state.

At the end of the article, we consider it appropriate to outline *some ways of further research into this problem.* First, a systematic analysis of P. M. Suprunenko's methods is needed when modeling and developing practical calculation methods (synthesis, analysis and design) of a transport mechanical system. Second, a detailed analysis of the specific results of each scientific work is needed. Special attention should be paid to assessing the place occupied by his works at the time, the role and influence of the results obtained on the further development of applied dynamics of transport mechanics. Third, it is necessary to investigate the scientific and ideological environment in which the scientist and engineer lived and worked, the legacy of which scientists he adopted and who continued his work, what fate befell his students and followers, what response Suprunenko's ideas found among scientists at the time, and how relevant they are in the present day.

Conclusions.

In science (fortunately rather than unfortunately!) history is made by individuals. They, as embryos – "centers of crystallization" create around themselves human structures, so to speak, of the "collective mind" of like-minded people, where a certain scientific ideology, or even a bright idea, finds its embodiment in life with the subsequent birth of an island, or even a continent, of new knowledge in the turbulent ocean of human intellect. This is, in fact, the sphere of human life where the infamous slogan "There are no irreplaceable people!" does not work. It is therefore not surprising that the destruction (physical, moral, spiritual or ideological – it makes no difference!) of such "centers" instead of pure and strong crystals leads to the rise of amorphous intellectual "mush". And this, in turn, does not allow creating a strong human resource base of high-quality scientists, thereby ensuring a high level of research, development of relevant systems and technologies, destroys practical connections with industry, etc., just as the refusal of long-term investments in domestic science and the pursuit of so-called "fast money" lead to copying and application by industry and business structures of foreign technologies and further deepen the crisis in science and, in general, the intellectual sphere of the country. The circle closes, the country falls out of the ranks of highly developed countries and slides to the margins of the world economy and culture. The question of science may not even arise at all... Obviously, such a path is unacceptable for the largest country in Europe! Ukraine is a country with highly developed heavy industry, agriculture, transport infrastructure (built, by the way, with hard work, on the bones and blood of its people!) and large natural resources. As an example, we can only say that it has the world's largest reserves of iron ore, manganese, lithium, gallium, large reserves of coal, granites, etc. All this determines a certain "doom" of Ukraine for the development of the metallurgical, chemical, mining, machine-building, transport industries, it must be a center of large freight and passenger transportation, which is impossible without a developed modern transport infrastructure. In turn, all this puts before scientists and engineers of Ukraine important

and honorable tasks of further development of science and technology in the field of railway and other types of transport.

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Академік Всеукраїнської академії наук Петро Михайлович Супруненко: Життя та діяльність

Анотація. *У статті актуалізовано найбільш значні відомості про видатного вченого-механіка і залізничника першої третини XX ст., академіка Всеукраїнської академії наук Петра Михайловича Супруненка (1893–1938). Доведено, що його діяльність у сфері розвитку залізничної справи є вагомим внеском у розвиток світової науки і техніки. Основні наукові праці вченого та інженера присвячені важливим проблемам транспортної механіки. Особлива увага приділялася ним паровозному і вагонному будівництву (був конструктором вагонів). Будувалися вагони на основі великої кількості експериментального матеріалу, які у свій час отримали значний суспільний резонанс і науково-технічне визнання. Наголошено, що П. М. Супруненко був одним з перших інженерів-залізничників, хто запропонував науковий аналіз взаємодії колії з рухомим складом залізниць. У статті зазначається, що сьогодні про П. М. Супруненка згадують дуже мало, описуються лише фрагменти його біографії, характеризуються тільки окремі його наукові праці. В очолюваному ним Інституті транспортної механіки Всеукраїнської академії наук за його керівництва успішно розвивалися наступні дослідження: висвітлювалися методологічні проблеми транспортної механіки з метою комплексного розв'язання завдань модернізації залізничної галузі; дослідження нестаціонарних динамічних процесів взаємодії рухомого складу (поїзда) з системою колії (особливо вивчення явища резонансу); дослідження теорії розрахунків тяги локомотивів на залізничних коліях з метою оптимізації елементів транспортної механіки та підвищення їх ефективності тощо. У статті детально характеризується кожен з цих напрямів досліджень П. М. Супруненка. Загалом його дослідження сконцентрувалися на проблемах залізничного транспорту. У галузі теорії тяги поїздів П. М. Супруненко створив низку нових методів графічного інтегрування диференціальних рівнянь руху поїздів, приділяв значну увагу вдосконаленню існуючих та створенню нових приладів, призначених для вимірювання характеристик різних процесів, що протікають в рухомому складі та колії. Підтверджено доробок вченого у початковому періоді будівництва залізничного транспорту в Україні, особливо на Південно–Західних залізницях. У статті показано, що роль П. М. Супруненка полягала в його науковій праці як «генератора ідей» та провідного теоретика в поєднанні з інженерною діяльністю.*

Ключові слова: *історія залізничного транспорта України; проблеми транспортної механіки; колійне господарство; рухомий залізничний склад; жертви сталінізму*

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