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Motivational factors and methodological principles of forming the goal of scientific research

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Choosing the goal of scientific research for a scientist (or group of scientists) is a special action, on which the real contribution to the relevant field depends. Objective. In order to understand how to make the right choice, we retrospectively assessed the historical experience of forming the most effective scientific projects at the Sytenko Institute of Spine and Joint Pathology National Academy of Medical Sciences of Ukraine. Methods. The material for the study was dissertations, monographs and articles of the institute's employees, which are in the library of the institution since the first years of its foundation. Results. During the period of the institute's existence, three most important scientific and practical achievements can be distinguished: obtaining fundamental knowledge about the laws of bone tissue regeneration; substantiation and development of transplantation methods for replacing bone defects; diagnostics and treatment of spinal pathology. Conclusions. The definition of a potentially effective scientific goal occurs in the mind of a person (scientist) who is endowed with a sense of curiosity and is capable of theoretical thinking. The main drivers of the correct choice are the presence of a problem and the level of knowledge and character traits of the individual. The priority option for a scientific and medical institution is the goal of a strategic direction, which involves obtaining fundamental knowledge about the biological processes involved in the pathogenesis of various lesions and diseases. For its implementation, it is necessary to build a complex of separate interconnected theoretical, experimental and applied works, in which the goal and objectives are also determined, but of the second (lower) order.

Вибір мети наукового дослідження для вченого (або групи) це особлива дія, від якої залежить реальний внесок у відповідну галузь. Мета. Ретроспективно проаналізувати зародження та формування найбільш ефективних (значущих) наукових проєктів ДУ «Інститут патології хребта та суглобів ім. проф. М. І. Ситенка НАМН України». Методи. Матеріалом для дослідження були дисертаційні роботи, монографії та статті співробітників Інституту, які знаходяться в бібліотечному фонді установи починаючи з перших років її заснування. Результати. За період існування Інституту можна виділити три найбільш важливих науково-практичних досягнення: отримання фундаментальних знань про закономірності регенерації кісткової тканини; обґрунтування та розробки методик трансплантації для заміщення кісткових дефектів; діагностика та лікування патології хребта. Висновки. Визначення потенційно дієвої наукової мети відбувається у свідомості особи (ученого), яка наділена почуттям допитливості та здатна до теоретичного мислення. Основними рушіями правильного вибору є наявність проблеми та рівень знань і риси характеру особистості. Пріоритетним варіантом для науково-медичної установи є мета стратегічного спрямування, яка передбачає отримання фундаментальних знань про біологічні процеси, що задіяні в патогенезі різних уражень і захворювань. Для її реалізації необхідно побудувати комплекс окремих взаємно пов'язаних теоретично-експериментальних і прикладних робіт, в яких також визначити мету та цілі, але другого (нижчого) порядку. Ключові слова. Мета, наукова робота, історія, регенерація.

Keywords. Goal, scientific work, history, regeneration

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Introduction

In contemporary scientific and methodological medical publications, authors primarily focus on the principles and procedures of conducting research once its objective has already been defined [1, 2]. However, the determination of the research objective itself remains of primary importance. There are works in which authors attempt to systematize and classify research objectives according to different criteria [3, 4]. In reality, the choice of a research goal is a crucial decision for a scientist, determining whether the work will merely result in the attainment of an academic degree or, in addition, make a meaningful contribution to the field. The key question is how to select a research objective that can be effectively implemented in practice and gain recognition within society.

Scientific activity in Ukraine is predominantly carried out by institutions belonging to the state research infrastructure [5]. A significant proportion of these are state subordinated institutions that independently define their research topics within the scope of their respective specialties or fields. Effective approaches to this process can be identified through the study and analysis of historical scientific experience. In particular, the origins and development of several research projects can be retrospectively examined based on the experience of the staff of the State Institution "Professor M. I. Sytenko Institute of Spine and Joint Pathology of the National Academy of Medical Sciences of Ukraine" (the Institute), one of the leading centers of Ukrainian medical science with more than 100 years of history.

Aim: to retrospectively analyze the emergence and development of the most effective (significant) scientific projects of the Institute.

Materials and Methods

The study material included dissertations, monographs, and articles authored by Institute staff, available in the institutional library collection since the early years of its foundation.

The first three authors of this article have worked at the Institute for more than half a century, participated in the implementation of scientific ideas and projects into clinical practice, and had the opportunity to observe their real outcomes. We have witnessed the emergence of a wide range of research directions, from fundamental to applied studies, varying in scale and in their impact on scientific thinking and on changes in the basic principles of treatment methods.

In addition, we draw upon our long-term experience in peer review (including dissertations, scientific articles, and planned research projects in the specialty of orthopedics and traumatology). This provides a basis for a retrospective assessment of the effectiveness of the selected research directions.

Results and Discussion

Over the entire period of the Institute's existence, three major scientific and practical achievements can be identified based on the scope, depth, and significance of the research.

The first is the acquisition of fundamental knowledge on the patterns of bone tissue regeneration. Since its early years (the Institute was founded in 1907 by decision of the Congress of Mining Industry Owners as the "Medical-Mechanical Institute", with tasks including the assessment of working capacity in individuals with musculoskeletal injuries and their treatment), it focused on the management of fractures, which required an understanding of the healing process. The first director of the Institute, Professor K. F. Wegner, actively introduced fracture treatment using skeletal traction, which necessarily involved early joint mobilization of the injured limb as an alternative to plaster immobilization. He observed that early movement of the limb stimulated the process of bone regenerate formation [6].

The subsequent head of the Institute, M. I. Sytenko, continued to actively investigate regeneration in the context of the treatment methods available at that time. In 1924, he defended his doctoral dissertation, "On Free Bone Grafting in Pseudarthrosis" [7]. In his keynote report at the IV All-Ukrainian Congress of Surgeons in 1930, "Basic Principles of Conservative and Surgical Treatment of Long Bone Fractures", we find a particularly insightful statement that remains relevant today: "It would be ideal if we could achieve precise anatomical alignment when correcting fragment displacement. However, this is not always possible, and fortunately, it is not always necessary… There is a certain minimum of anatomical and mechanical conditions required for restoring proper form, as well as normal statics and dynamics of the locomotor system…" During this period (1927–1935), following the advice of Professor M. I. Sytenko, I. L. Zaychenko began experimental studies on rabbits investigating the course of regeneration after diaphyseal fractures, which later formed the basis of a monograph [8, 9].

However, particular attention should be given to two fundamental scientific works. The first is the doctoral dissertation of M. P. Novachenko and the corresponding monograph entitled "Vascularization of Transplanted Bone", published in 1946 [10].

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This was an experimental study conducted on 132 dogs, in which the fibula was removed (using both subperiosteal and supraperiosteal techniques) and immediately reimplanted into the same site. The work provided a detailed morphological and histological description of vascularization and regenerative processes occurring along the bone surface. The main conclusion was that the transplanted bone is capable of engraftment; however, new bone formation and remodeling occur predominantly along the surface of the graft, while its deeper portions remain unchanged for a long period. As will be shown later, this became a cornerstone of clinical bone grafting.

The second equally important work is that of V. O. Marks, "Healing of Closed Bone Fractures in Humans and Experimental Animals", defended as a doctoral dissertation in 1949 [11]. In this study, the process of bone regenerate formation was examined and described at the cellular level in a comparative manner across animals of different evolutionary levels (amphibians, reptiles, birds, mammals) as well as in humans. It should be noted that 1,040 experimental animals were used. V. O. Marks demonstrated that the lower the evolutionary level of the animal, the greater the proportion of chondroid tissue formed within the regenerate. One of the key conclusions of this work stated: "The prevailing view that the development of chondroid tissue in fractures in mammals, including humans, is a sign of impaired callus formation is not supported by my findings". Here, the author referred to the opinion of foreign researchers who, during the Second World War, applied intramedullary osteosynthesis for diaphyseal fractures and considered the presence of cartilage between fragments to be an abnormal phenomenon. The results of this study provided a comprehensive understanding of the morphological formation of bone regenerate after diaphyseal fractures in animals under conditions without fragment fixation. Regarding fracture healing in humans, it was presented based on clinical, radiological, and histological data from 56 patients. The dissertation did not address the phenomenon of non-union. A monograph based on this research was published in 1961 [12].

Subsequently, the study of bone regeneration was continued by O. O. Korzh, E. Ya. Pankov, and A. M. Belous, who began to investigate this process at the level of self-organization and regulation [13]. They recognized that a major problem arises in cases where continuous bone regenerate formation does not occur, and that understanding abnormal regeneration requires clarification of the mechanisms of growth and transformation of newly formed tissues. In 1961, O. O. Korzh defended his doctoral dissertation "Heterotopic Post-Traumatic Ossifications: A Clinical, Morphological, and Experimental Study", in which he elucidated the mechanism of bone formation in ectopic locations. It was established that the primary factor preceding ossification in non-typical sites is hemorrhage into these tissues [14].

It is useful to consider what scientific objectives guided these researchers and what motivated their work. The dissertations in question do not explicitly state a formulated aim; however, this does not imply its absence, as it is reflected in the titles of the works and their results. The implicit objective was to identify the morphological patterns of bone regenerate formation after fracture, together with clarification of its physiological and pathophysiological mechanisms. Such a level of objective is characteristic of fundamental scientific research, the achievement of which requires a long time span and often involves several generations of scientists. It is not known when such an objective will be fully achieved, as the path toward it is complex and non-linear.

More than half a century has passed since the works of V. O. Marks and O. O. Korzh were written. During this time, new clinical experience in fracture management, both positive and negative, has accumulated, and new scientific data have emerged regarding biologically active factors released from platelets following hemorrhage. Currently, research in this field continues at the Institute, with successors advancing toward the original goal set by their predecessors. In contemporary studies by O. K. Popsuyshapka, V. O. Lytvyshko, and V. V. Hryhorieva [15–17], it has been shown that bone formation after fracture occurs due to the presence of fibrin, on which vascular endothelial growth factor and transforming growth factor-β are adsorbed. These factors direct vascular growth, which is essential for osteogenic differentiation of newly formed cells. A direct trigger for primary angiogenic osteogenesis is the internal tension of fibrin fibers generated by functional loading of the injured limb. Thus, the observations made by earlier researchers have received a modern scientific explanation.

Understanding how bone forms after a fracture is the scientific foundation of the specialty "Orthopedics and Traumatology" and underpins all applied developments, including fixation methods, implant design, and treatment techniques. Each of these is also defined by a specific scientific objective, which is of a more applied nature, with a lower level of abstraction and a more predictable outcome. The development of fracture healing theory is closely linked to

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clinical practice in fracture management. It should be grounded in clinical results and, in turn, influence strategic decisions regarding the implementation of new treatment methods.

At present, we are witnessing rapid progress in the development of various fixation devices for fragment stabilization. These devices are technically and technologically advanced, improving tissue compatibility, increasing the mechanical reliability of fragment fixation, and facilitating surgical procedures. However, there is also a less favorable aspect to this development. The orthopedic implant industry, having become a powerful and highly profitable sector, tends to exert an ideological influence on treatment strategies, prioritizing commercial objectives as its primary goal (here, the term "goal" is used appropriately, as this intent is clearly defined). Despite these seemingly progressive advances, a certain proportion of fractures still fail to heal, as demonstrated by authoritative publications based on retrospective independent multicenter studies [18].

A practical question increasingly faced by the modern world is the extent to which scientific opinion can be used to generate commercial benefit, particularly in the production of medical devices. Manufacturers are interested in selectively "scientific" results that help promote their products in the medical market under the banner of scientific progress. This phenomenon has been discussed by prominent researchers of socio-economic processes. In this context, we refer to an article by Henry Miller (2017), a fellow at the Hoover Institution at Stanford University (a public policy think tank located at Stanford, founded in 1919 as a library dedicated to the First World War and later expanded into a major research center engaged in policy and economic analysis, archival preservation, and endowed by private donations), entitled "Knowledge is Power, But Fake Science is Dangerous" [19]. We cite the most meaningful statement: "The beauty of the scientific method is that it protects us from propaganda and bias, helping us understand where truth lies". He calls for reliance on fundamental knowledge that explains the underlying mechanisms of observed phenomena as a basis for informed administrative decision-making.

Thus, both today and in the future, scientific developments in traumatology should primarily be based on fundamental research into bone regeneration in order to reduce the incidence of non-union. If this principle is neglected and emphasis is placed mainly on the technical sophistication of modern devices driven by convenience for end users (both surgeons and patients), such practice may gradually shift medical treatment toward a commercial domain under the guise of scientific activity. To prevent this, it is necessary to define scientific objectives in a methodologically sound manner.

Another significant scientific achievement that emerged from the understanding of bone regeneration was the development and justification of transplantation techniques for the reconstruction of bone defects, primarily following resection of skeletal tumors.

Several research laboratories and clinical departments of the Institute successfully and persistently worked on this problem. Studies addressed donor site harvesting, graft preparation and preservation, storage techniques, immunological aspects of donor–recipient interaction, and the morphology of bone remodeling, particularly in large grafts. In 1967, R. R. Talyshynsky defended his doctoral dissertation "Homoplasty of Large Bone and Joint Defects" [20]. This work also represented a breakthrough in the surgical treatment of skeletal tumors. Based on these studies, Professor O. O. Korzh, as part of a team of authors, was awarded the State Prize of the former USSR in 1977.

Today, many years later, patients still return to the Institute for follow-up examinations or to obtain medical records, including individuals in whom bone segments were transplanted and limb function preserved more than 25 years ago. With the benefit of hindsight, it becomes clear that the scientific objectives formulated by O. O. Korzh, R. R. Talyshynsky, Yu. P. Delevsky, and others carried a substantial risk of unfavorable outcomes.

A scientific objective is, by definition, a motivated intention. This raises the question of what drove researchers to pursue objectives of such complexity and magnitude. Motivation may be intrinsic, arising from personal needs and intellectual curiosity, or extrinsic, shaped by external incentives such as rewards. In the case of these achievements, the primary source of motivation was an internal need to acquire new knowledge. According to Plato's philosophy, truth cannot be established solely on the basis of observation and sensory perception; it requires the capacity for theoretical reasoning, which is closely linked to human curiosity [21]. Not all individuals possess this quality. The natural curiosity of a scientist is therefore a fundamental and often underestimated driver of scientific progress.

At the Institute, there was an informal tradition of identifying physicians who demonstrated a "scientific instinct" and a strong desire for knowledge; such individuals were actively encouraged to join the Institute. They often left established positions and stable

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living conditions in pursuit of a scientific goal. One could compile a long list of researchers who followed this path, none of whom later regretted their decision.

In addition to individual abilities, the formation of a researcher's scientific objective is strongly influenced by the environment in which they work. The Institute has always included a number of authoritative figures who served as professional role models and exemplars of high ethical standards. An atmosphere of continuous scientific discussion and debate within clinical practice, together with healthy competition among colleagues, shaped scientific thinking and strengthened the researcher's development.

In this context, it is important to mention the origin of another scientific project that emerged in the early 1960s and whose development was witnessed by the authors of this article. At that time, the Institute had become a leading center of traumatology and orthopedics in the former USSR, and its leading scientists began to develop a new area of the specialty, namely spine surgery. In 1963, while serving as an associate professor at the Department of Traumatology and Orthopedics of the Kharkiv Institute for Advanced Medical Training, O. O. Korzh performed, for the first time in the world, a cantilever-type spinal fusion using an allograft [22]. This marked the first step in the study of spinal pathology, which had previously been obscured by the large number of patients diagnosed with so-called "radiculitis" in neurological wards.

At the same time, a young chief physician of a bone tuberculosis sanatorium in the Belarusian Polissia region, motivated by the desire to improve the treatment of tuberculous spondylitis, was searching for an opportunity to learn surgical techniques for managing this condition. The fact that Mykola Khvysiuk met O. O. Korzh in 1961 was not coincidental, but rather a motivated convergence of two purpose-driven individuals that led to the formulation of a shared scientific objective. For Khvysiuk, this goal was so important that he relocated to Kharkiv with his family to study and work there, sacrificing domestic comfort. This project was successfully realized, as is well known today. The Kharkiv school of spine surgery is widely recognized far beyond Ukraine.

Such examples demonstrate that the sources of major and significant scientific projects are often individual personalities.

They acted as a catalyst, after which the scientific community recognized the relevance and prospects of this direction, leading to the emergence of subsequent scientific works (dissertations) focused on specific questions within the project. Notably, these studies were conducted without any dedicated or additional funding sources.

The effectiveness of these scientific projects was also linked to the fact that their foundation was based on a systems approach already at the stage of defining the research objective. Even before W. R. Ashby published his seminal work "An Introduction to Cybernetics" (1959), in which systems theory was first formally articulated [23], our predecessors already understood the importance of carefully selecting the object of research and, in essence, applied the methodological principles of a systems approach. They defined the object of study as the process of regeneration of load-bearing tissues in a living organism following traumatic injury, which is fundamental to orthopedics and traumatology. A particularly illustrative example of this systems-based thinking is the doctoral dissertation of V. O. Marks, mentioned above. It led to the establishment of fundamental regularities of bone tissue morphogenesis, which had formed throughout phylogenesis and operate both in ontogenesis and during fracture healing. Knowledge of the laws governing bone formation is essential for the scientific justification of methods for reconstructing bone defects of various origins, which has become a highly relevant area today. This line of research should be further developed from the perspective of understanding bone regeneration as a biological system with intrinsic self-regulatory mechanisms. The scientific data on bone regeneration generated at the Institute provides a basis for system-level modelling of this process in conditions where bone tissue formation is induced within a defect site.

Finally, we would like to address another important issue: which term better reflects the researcher's intention, "meta" or "tsil"? In Ukrainian scientific publications, particularly in our field, both variants are used. Is there a difference between them? The former is used exclusively in the Ukrainian language and denotes "that toward which someone strives; a pre-set task or intention." A "tsil" is that which one aims at in a literal sense, or, in a figurative sense, the achievement of a goal [24]. In science, it is often the case that one assumes one outcome but discovers another. A "tsil" is always singular: it is either achieved or not. Therefore, this term is more appropriate for describing tasks of a more concrete, narrowly defined level, such as describing a specific phenomenon or performing statistical analysis. In contrast, "meta" more accurately reflects the essence of scientific intention, which inherently includes uncertainty regarding the final outcome, and may involve a com-

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plex, long-term path to its achievement. This fully corresponds to the nature of scientific inquiry and is therefore more suitable for use in medical scientific terminology.

Conclusions

Based on the experience of the State Institution "Professor M.I. Sytenko Institute of Spine and Joint Pathology of the National Academy of Medical Sciences of Ukraine", several methodological principles for defining the objectives of prospective scientific research can be formulated:

1. The definition of a potentially effective scientific objective arises in the mind of an individual researcher endowed with curiosity and the capacity for theoretical thinking, who is confronted with a professionally relevant problem. The main driving forces behind correct goal selection are the presence of a problem, the level of knowledge, and the researcher's personal traits. The objective emerges in the researcher's consciousness together with a plan for its realization, which constitutes the essence of effective scientific planning.

2. The priority for a medical research institution should be a strategically oriented objective aimed at obtaining fundamental knowledge about biological processes involved in the pathogenesis of various injuries and diseases that have a regular, system-like nature and can be regarded as self-regulating systems. Achieving such an objective requires a long-term perspective. Its realization involves a complex of interconnected theoretical, experimental, and applied studies, each of which also has its own subordinate objectives.

3. When selecting a research objective, it is necessary to identify and clearly define the object of study as a biological system with its elements, interactions, and functional purpose.

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

Prospects for further research. The study of research objectives in other fields of orthopedics and traumatology.

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