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Letter to the Editor

The Engineering Biology Problems Book: Bridging the gap between biomedicine and engineering

Ilya. D. Klabukov[1,2,*], Denis S. Baranovskii[1]

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ABSTRACT

Progress in the biological sciences requires advanced approaches to biological education. The current well-established paradigm rarely uses engineering design to solve biological problems. Engineering biology is a novel science field and academic discipline that focuses on the engineering of living objects using biological techniques. We believe that the integration of engineering components into biological education together with a wide application of engineering methods can provide considerable benefits to the education system. We developed the ``**Engineering Biology Problems Book**'' to bridge the gap between biology, medicine, and engineering.

Key words: biological education, biomedicine, design, engineering biology, problems book, synthetic biology

[1]*National Medical Research Radiological Center; Koroleva st. 4, 249036 Obninsk, Russia*

[2]*Obninsk Institute for Nuclear Power Engineering, National Research Nuclear University MEPhI; Studgorodok 1, 249039 Obninsk, Russia*

Correspondence

Ilya. D. Klabukov, National Medical Research Radiological Center; Koroleva st. 4, 249036 Obninsk, Russia

Obninsk Institute for Nuclear Power Engineering, National Research Nuclear University MEPhI; Studgorodok 1, 249039 Obninsk, Russia

Email: ilya.klabukov@gmail.com

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INTRODUCTION

Progress in the biological sciences requires the integration of advanced educational approaches. Although traditional biology teaching methods provide sufficient knowledge of fundamental concepts to meet the requirements of biotechnological companies and research institutes, the current limited paradigm of biological methodology does not stimulate creative thinking, which is necessary for the development of innovative scientific ideas.

Engineering biology is a promising new field that focuses on the engineering of living objects using various biological techniques. As an applied science, engineering biology can achieve biological progress through innovative approaches, while as an academic discipline, it surpasses traditional biological education and stimulates scientific creativity. We suggest that bridging the gap between biological and engineering education is vital for revolutionizing the field of biological sciences. In 2015, the "Biology is Technology" initiative was initiated by officials of the Defense Advanced Research Projects Agency (DARPA) as a strategy to redesign the approach to biological engineering[1,2]. DARPA's program managers are responsible for the development of new biological programs that are based primarily on engineering concepts[1].

Despite the proliferation of classic teaching books (*i.e.*, John Wilson and Tim Hunt's "Molecular Biology of the Cell: Problems Book"[3] and Joseph Feher's "Quantitative Human Physiology"[4]), there are minimal references to essential engineering methods and approaches[5].

What is the difference between biological and engineering education? To understand this gap, we developed a simple comparison chart (**Table 1**).

The majority of attempts at engineering biology programs have had limited success. The NASA initiative of 2009 that aimed to establish a Singularity University to promote scientific creativity was never fully implemented[6]. Similarly, the latest initiative of 2015–2019 by Representative Eddie Bernice Johnson to amend an educational landscape with engineering biology principles was never implemented in practice[7]. The Living Foundries program has the potential to provide the next step of a multilevel hierarchical approach for biological machines[8]. However, no significant advancements have been identified from either the Massachusetts Institute of Technology or Boston University. The bottom-up approach for engineering methods in biology has proved unsuccessful; therefore, we decided to contribute to the development of engineering biology.

We prepared the "Engineering Biology Problems Book" to bridge the gap between biology and engineering. This book was first published in the Russian language; however, a draft English version was created by a collaborative international effort during the International Genetically Engineered Machine (iGEM) Competition in 2021[9].

"The Engineering Biology Problems Book" was inspired by the book series "The Feynman Lectures

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Table 1: Fundamental Differences Between Biological and Engineering Education

	Biology	Medicine	Engineering
Calculations	Bioinformatics only	Pharmacokinetics and models for applied software	In all fields
Logic	Limited		Full, exception of only a few sections of algebra
Engineering design	For specific domains only (for example, for drugs and devices)		Overall
Answer options in classic teaching books	Mono- and multi-variance with the limited versions of correct answer.		Multi-variances. The correct answer depends on the approach to solving the problem.
Scope of problems	Specific problems of the biological/medical field		Engineering is applied to solve problems in different fields of science and technology: from homework tasks to global issues

on Physics" by the Nobel laureate and physicist Professor Richard Feynman, who provided simple and creative formulations for physics problems. Professor Feynman stated that "There is plenty of room at the bottom" and invited his followers into the new nanoworld [10]. As authors of "The Engineering Biology Problems Book", we believe that engineering biology represents a new kind of physics for the 21st century.

"The Engineering Biology Problems Book" (hereafter, "Problems book") contains seven chapters and more than 300 problems relating to engineering biology. This book helps to develop scientific creativity by allowing readers to create engineering solutions for problems in fields such as the *Design of living machines*, *Engineering of human body*, *Enhancements of the human performance*, and *Design of the living objects that do not yet exist.* The Problems book does not presume that only one correct answer exists for each problem but instead provides multiple possible solutions. The essence of the Problems book is to give the reader a space for creative engineering with the aim of capturing new ideas.

Certain engineering solutions used in technical devices naturally exist in living organisms. The bioengineering approach allows creative interventions in the molecular basis of life, which can pave the way for new biotechnological inventions based on "living machines" and the formation of novel biological parts for the human body. Bioengineering approaches have wide clinical outlooks for preventive medicine. The following example of a multivariance problem included in the Problems book is presented to illustrate this approach.

> ***Born as an Electrician*** . *The human body is a complex electric conductor surrounded by an imperfect dielectric - the human skin layer. Breakdown of the stratum corneum of the skin is possible if the intensity of the electric field that occurs in it exceeds its breakdown voltage, equal, as experiments show, to 500-2000 V/mm. The European Union's standard voltage of approximately 200 V always causes a breakdown of the outer layer of the skin. Every year, approximately 30 thousand people in the world die because of electrical injuries. Which gene overexpression in epithelial cells could significantly reduce this number, increasing human resistance to electric shocks?*
>
> *The Engineering Biology Problems Book*

The unity of biology and engineering can enhance both of these fields through advancements such as the prediction of intermolecular interactions, exploration of deep space, and treatment of global environmental problems. Given that even the basic principles of living object design have not yet been fully established, the Problems book has been formatted to include stimulating tasks to help readers develop a variety of original solutions using engineering approaches

that bridge the gap between the fields of biology and engineering.

We believe that many scientific and educational challenges can be solved through international collaborations. The prominent collaboration in the field of engineering biology is that of the iGEM community. The annual iGEM Competition is an excellent exposition for framing and solving engineering problems in biology. "The Engineering Biology Problems Book" was created to evoke discussions of compelling problems in this field and unite scientists from all parts of the world.

ABBREVIATIONS

None.

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AUTHOR'S CONTRIBUTIONS

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The authors declare that they have no competing interests.

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