Improving the scientific cycle

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Received: June 17, 2023; Accepted: June 18, 2023; Published Online: June 21, 2023; https://doi.org/10.59717/j.xinn-life.2023.100002

Citation: Zhang H. and Zhu J.-K. (2023). Improving the scientific cycle. The Innovation Life 1(1), 100002.

Welcome to this inaugural issue of *The Innovation Life* (*TIL*). We are excited to introduce this sister journal of *The Innovation*, dedicated to presenting cutting-edge innovative research in life sciences. TIL is initiated by the same group of early career researchers who started *The Innovation* and recognized the need for a publishing platform that better serves scientists. *TIL* is committed to bringing forth articles covering all areas of life sciences, from molecular mechanisms underpinning cellular processes to organisms' ecological interactions, and from theoretical innovation to interdisciplinary technologies.

The global community of life sciences researchers has seen steady growth since World War II. Meanwhile, the production of research papers has increased each year. The PubMed database hosted a staggering 1.77 million titles published in 2022 alone, which marks a more than three-fold rise from two decades ago. Unquestionably, this substantial increase in published works is partly an outcome of increased funding and an expanded researcher base. Yet, it is also a reflection of the significant focus of funding bodies and academic institutions on quantitative output, for example, the number of publications.[1] However, concerns exist that the advancement of research fields is not keeping pace with the increase in the number of publications.[2] What can we do to help make scientific research more efficacious?

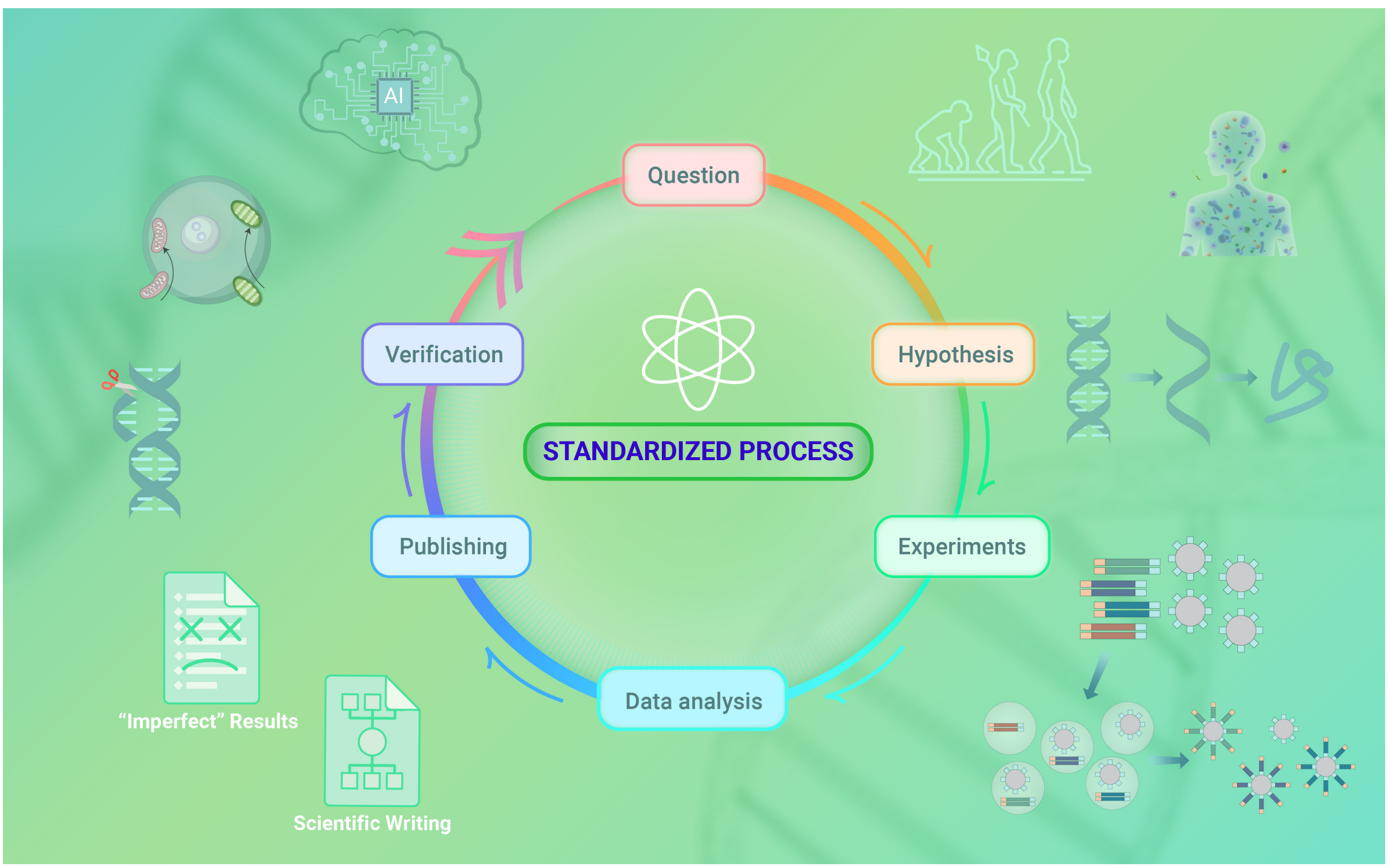

Figure 1. The scientific method cycle can be improved through standardized process.

Scientific research follows an iterative process comprising stages such as "identifying a problem, hypothesis formation, hypothesis testing/experiments, data analysis, and result reporting" (Figure 1). We begin by observing a phenomenon and identifying a problem or an unanswered question, often necessitating the verification of previous research findings. Subsequently, we develop a hypothesis, and design and carry out experiments to test it, and then analyze the experimental data. Lastly, we document and publish the findings, providing the foundation for the next round of hypothesis generation and problem solving. Through this iterative process, scientists build upon previous work, advance the field, and expand our knowledge. Just as any cycle functioning optimally only with harmonious interplay among its various stages, the scientific cycle is no exception. Solely increasing the number of publications is not necessarily helpful for advancing science. In order to help make scientific research more efficacious, we propose to take the following factors into account when considering papers for publication in *TIL*.

STANDARDIZED PROCESS AND MORE RIGOROUS TECHNOLOGIES

As biological science evolves into an increasingly collaborative, interdisciplinary, and data-rich discipline, it is imperative to develop an infrastructure to standardize individual stages of the scientific cycle, redefining the way to document research, analyze data, and report results. Although this target might have been considered unattainable given the exceptional diversity of scientific projects, it is becoming increasingly plausible in the present digital era where the majority of research data either exist in a digital format or can be easily digitized. Isolated attempts of developing standardized tools have been reported across various fields of life sciences, but these tools have yet to gain widespread adoption among scientists. Biologists can learn from data scientists, who already developed interactive notebooks (such as Jupyter), version control/collaboration tools (like GitHub), and an array of other publicly available utilities. Establishing such infrastructure calls for a collective effort from all science stakeholders, including funding agencies, researchers, and academic journals. We envision that such a system can promote transparency and reproducibility. Reproducibility - the ability of other scientists to confirm reported findings - has been a subject of concern for many in the scientific community (see Ref. 3 for examples in preclinical cancer biology). Insufficient reproducibility can lead to inefficient utilization of limited research resources and hinder genuine scientific discoveries.

Addressing key scientific questions requires the application of appropriate technologies. As we continue to untangle the intricacies of living organisms, the ability to separate genuine signals from background noise, and to differentiate primary drivers from secondary effects, becomes crucial. For example, molecular biology research often involves the identification of protein interactions and measuring gene expression levels. Considering the high protein concentration within cells, around 200 mg per milliliter, it is anticipated that numerous protein interactions exist. The real question lies in identifying the key interactions for a specific cellular process and deciphering how the exceedingly intricate system is orchestrated. Traditional techniques like Western blotting and Northern blotting yield largely qualitative results and are thus prone to errors during the quantitative interpretation of the results. On the other hand, technologies such as high throughput sequencing and mass spectrometry, are rich in data with more controls and less biased, and thus more robust, often enabling comprehensive analyses that provide a holistic view of the system under investigation. We therefore encourage the adoption of standardized process in our research and ask that conclusions in *TIL* papers be based on data from more rigorous technologies.

"IMPERFECT" RESULTS

The notion of "perfect" is inherently subjective. In this context, we use the term "imperfect" results to refer to those that do not align with popular trends, and results that might be negative or not as groundbreaking as one might expect. These outcomes are parts and parcels of the scientific exploration process. Publishing negative results can mitigate resource wastage by preventing repeated attempts at similar experiments. Moreover, these results, once published, may provoke new lines of inquiry when viewed through different perspectives. Similarly, findings that might lack the sheen of "novelty" can still contribute significantly to the existing body of knowledge, especially when the related scientific question is important. Verification is an integral component of the scientific cycle (Figure 1). It is through this process of continual testing and retesting that science maintains its ground and objectivity. Yet, projects geared towards verification (of important questions) are often difficult to get funded, and their results, regardless of outcomes, may not resonate with editors or reviewers. This bias towards not publishing "imperfect" results skews our understanding in favor of positive or successful outcomes, ultimately painting an incomplete and sometimes misleading portrait of the real scientific landscape. In considering papers for TIL, we believe that "imperfect" results should be allowed.

HELP WITH SCIENTIFIC WRITING

There is an increasing trend of publications originating from developing countries, thereby steadily narrowing the global inequality in publications of biological science.[4] However, for researchers who use English as a second language, the rigors of scientific writing can be disproportionately time-consuming and resource intensive. This valuable time and resources could be better allocated to advancing the other stages of the scientific research cycle. We strongly encourage editors and reviewers of international journals to factor in language disparities when assessing submissions from these regions. Concurrently, researchers can seek assistance from language editing services, although commercial services available to these researchers often come with very significant costs. On the bright side, an array of artificial intelligence-powered tools are now available to assist with grammar and language editing. Such tools are rapidly evolving and can help streamline the writing process, making it more efficient and less costly. Since our goal is to ensure that valuable scientific findings are disseminated effectively and accessibly, we should prioritize clarity and accuracy in describing experimental results and conveying scientific ideas, rather than linguistic attractiveness.

In his influential book, "The Structure of Scientific Revolutions", Thomas Kuhn distinguished between two types of scientific activities: 'normal science' and ' revolutionary science'.[5] ' Normal science' encompasses investigations carried out within a specific paradigm or explanatory framework, whereas 'revolutionary science' refers to those endeavors that prompt paradigm shifts that completely change our perspective. In life sciences, such paradigm shifts have substantially reshaped our viewpoints and catalyzed innovation (Figure 1). For instance, Charles Darwin's publication of "On the Origin of Species" marked a fundamental shift in our understanding of the natural world. This groundbreaking work contested the static perception of species and introduced the concept that species evolve over time through the mechanism of natural selection. While the clear-cut bifurcation of scientific activities into 'normal' and 'revolutionary' proposed by Kuhn is open to debate, it is undeniable that the allure of paradigm-shifting ' revolutionary science' is strong for both scientists and organizations alike. Nonetheless, it is essential to recognize that all scientific findings, revolutionary or not, are grounded in the scientific cycle. In fact, it is the accumulative body of 'normal science' that provides the groundwork for the emergence of ' revolutionary science'. By improving the scientific research cycle through publishing research work that is more rigorous and reproducible, we will help more rapidly advance our understanding of the living world and facilitate future breakthroughs and paradigm shifts.

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DECLARATION OF INTERESTS

The authors declare no competing interests.