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Science, Pseudo-science, False, and Fake science. Why is this happening, and what can you do?

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Abstract

Science publishing has many problems today. Some of them are caused by external factors, such as the computer and internet revolution. Others are because of the publication explosion and the resulting imbalance between the interests of science, authors, institutions, and the publishing business in an accelerating world. However, these pains are part of the overall growth, nothing more. Society needs science more than ever, but progress cannot be made without reliable communication. Published research articles and reviews are not science; they are yesterday's scientific information and knowledge, organized, stored, and shared on various media. It is essential to understand our recent issues with these publications and learn what you can do.

Keywords

science, pseudo-science, false "science," fake "science," publications, open access, impact, scholarly publishing

Purpose and Rationale

The purpose of this opinion article is to explain the structure of what we know, illustrate the dynamic nature of science and look at scholarly publications in natural sciences (except for books), comment on recent issues, and reflect on some of the origins of those problems as well as how to address them.

Introduction

In ancient times philosophers taught their disciples verbally. Then, religious thought leaders communicated through speeches, handwritten notes, letters, and books. Early "scientists" (e.g., alchemists) got together to discuss their findings and shared their views and experiments. Then came the printed press, which made it possible to distribute information and knowledge on paper. Large-scale printing required the use of specific heavy machinery and professional business organizations that could print, market, and sell books and journals. Thus, commercial publishing companies were formed that could distribute knowledge to the masses for money. Because one cannot sell somebody else's property, copyright law was soon introduced to prevent the mass copying of books. That is how and why requirements of originality and novelty were born, i.e., to assure the value of published content and secure the rights to sell printed products.

Scholarly publishing also emerged, and merchants soon began selling books, journals, newspapers, and magazines, and soon science publishing became a big business. Printing also made it possible to archive knowledge in journals that were then stored in libraries. During this era, news, fiction, and non-fictional stories were read in the public sphere, but scientific information was read only by scholars. Research articles were thoroughly reviewed by peers, validated, and cared for by authors, reviewers, editors, and publishers to preserve the value of information and knowledge. To make it easier for the customers to find areas of their interest, publishers bundled together topical papers into **journals** that, at that time, had a specific scope. Scientists provided the raw content, supplied quality control and readership, and publishers provided the necessary business components for the dissemination of curated knowledge. Then came the computer revolution, followed by broadband internet access, smartphones, and

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artificial intelligence, which completely changed the playing field and led to an explosion in publications. [1]

Today, for the first time in human history, information is generated faster than it could be evaluated by "traditional" methods. We are now witnessing all these technology-induced changes, such as accelerating and more complex life, globalization, increasing domination of short-term and individual interests, increasing importance of social media, virtual reality, artificial intelligence, etc.

The public often interprets scholarly publications as "science," although they are nothing else but yesterday's information and knowledge organized, stored, and shared on various media. The importance (impact, significance, value) of those pieces can only be estimated after several years. "Paradigm changing discoveries have notoriously limited early impact precisely because the more a discovery deviates from the current paradigm, the longer it takes to be appreciated by the community." [2]

Science publishing has many problems today. Some of them are caused by external factors, such as the computer and internet revolutions, and others are due to the imbalance between the interests of science, authors, institutions, and the publishing business in an accelerating world. [3]

Discussion

Science and the purpose of publications

Science has many definitions, for example, "the intellectual and practical activity encompassing the *systematic* study of the structure and behavior of the physical and natural world through observation and experiment" (New Oxford American Dictionary), "a *systematic* enterprise that builds and organizes knowledge in the form of testable *explanations and predictions* about the universe" (Wikipedia), etc. Science as a "*systematically* organized body of knowledge on a particular subject" is based on validated data, it is driven by logic, and its established elements have a long half-life. All scientific methods try to exclude subjectivity, i.e., the human element, as opposed to politics, which is perception-based, subjective, and can change anytime due to shifting interests, while business is driven by profit.

The sum of human knowledge is composed of more than one element. There exists a valid, accepted body of our system of human knowledge, and there are those elements that have not yet been merged into the present system for various reasons (quality, lack of reproducibility, debated reasoning, simply being too early, etc.). Some of these argued issues will be rejected (e.g., uncovered errors in data, data treatment, incorrect conclusions, and misinterpreted information, i.e**., false "science**"); others will be integrated into our present knowledge improving it. We will never know everything.

Pseudo-science is a substitute. [4] Substitute for science for those who long for understanding and interpreting their own world, even superficially, but did not have a chance or capability to separate facts from fiction and fell in the trap of convincingly simple explanations. One of the most characteristic staples of pseudo-scientific explanations is simplicity. In pseudo-science, everything has a simple explanation (usually based on hearsay or partial understanding) believed to be the whole truth. A classic example of partial understanding is presented by the parable about the blind man and the elephant, illustrating the limits of observation and partial perspective. [5] In reality, no simple explanations exist for complex systems, and the acceptance of any simple answer would result in contradictions with other pieces of information/knowledge that are typically ignored or rejected as false.

Fake "science" differs from pseudo-science by its intention – it pretends to be real despite knowingly being forged. Fake "science" is to make money for predatory publishers and is designed for desperate authors to formally fulfill their obligations toward administrators or gain undeserved recognition without doing the actual work. Fake "science" is based on fictional data; it injects "alternative" information and counterfeit knowledge reminiscent of reality. These are the publications for the sake of having publications. Unfortunately, they not only dilute but contaminate the literature and are detrimental to public trust in science.

Publications contain all these four elements. The goal of a publication used to be sharing information and knowledge, and authors, reviewers, editors, and publishers all

guarded this essential feature to preserve their value. Today, there are many reasons to publish an article, and to share information is only one of them because publications have recently become an **existential issue** for scientists. Authors are still forced to chase originality and novelty to fulfill institutional requirements, and many academic investigators pursue only novel materials and complicated approaches to meet the criteria for making their manuscripts acceptable. Unfortunately, for some under extreme existential pressure, this "publish or perish" attitude means "whatever it takes," and for many young scientists publishing an article is more important than dissemination of quality research findings. At the same time, for many established scientists, the purpose of most research publications is to justify the next grant application, while the real endpoint should be improving life through contributing to the sum of human knowledge documented in publications (research articles, reviews, and books).

The hierarchy of our knowledge is grounded in reproducible data. Scientific data are acquired under controlled conditions via measurements. When we understand relations between data, then we can transform them into information. When we recognize patterns in pieces of information, then we can generate a piece of knowledge. Understanding the principles (the "aha-moment") guiding our knowledge enables us to reach wisdom that permits us to simplify complexity and predict the behavior of systems. [6] (Fig. 1)

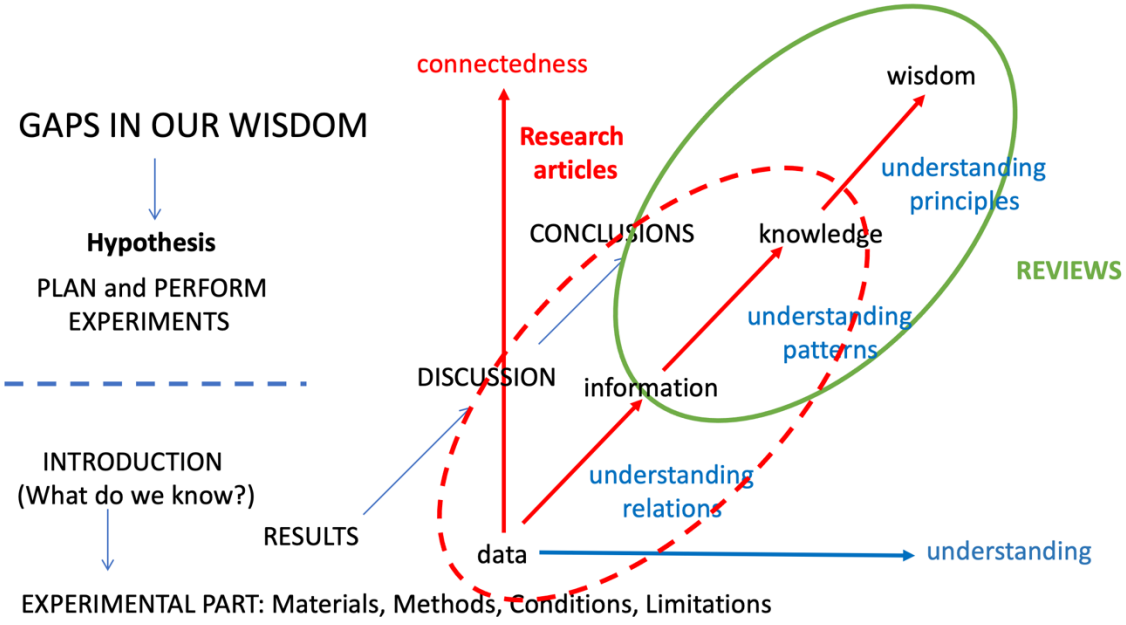

Figure 1: Scholarly publications should reflect their function. The function of a research article is to provide new information that contributes to specific knowledge. The role of a review is to reconcile these pieces of specific knowledge and clarify principles that fit a coherent system of human knowledge (based on the graph in [6])

There are, of course, limitations. In research, we never know everything because researchers always work on the diffuse periphery of known and unknown. The system of human knowledge is also dynamic: the body of scientific knowledge is constantly growing, and a new piece of information is being added literally every second. All these pieces of information have a half-life (e.g., with a new and better instrument, more precise data can be generated, a new software analyzes raw data better, etc.). Consequently, every piece of knowledge has its own half-life and science keeps shedding outdated information (old is not necessarily outdated). Elimination of invalid knowledge is

an important part of maintaining the quality of scientific knowledge.

Primary reasons for the dilution of scientific literature

1. Promotion and graduation rules set by funders and institutions before the computer age
2. Publications have become a product to sell
3. The breakdown of traditional quality control
4. All information is now electronic and remains accessible forever for everybody
5. Greed, fueled by the ease of online publishing

Promotion and graduation rules set by funders and institutions

Libraries have never had enough money and space to buy every journal. The Journal Impact Factor was created to evaluate which print journals libraries should buy, and those with the highest overall number of citations were the ones to purchase. Authors publishing in high JIF journals were more valuable for the institution because articles published in those journals carried both the name of the authors and their institutions, bringing fame home. Thus, institutions adapted rules that authors who publish in high JIF journals are more valuable than those who do not. Today, there are major problems with this approach that have been communicated extensively, e.g., [7, 8, 9]

First, the phrase "an article published in a high impact factor journal" has been truncated to "an article of high impact" (Impact on what? Science? Publishers? Scientists? Departments? Institutions? Budget?), to which authors responded by gaming the JIF (ghostwriters, Peer Review scams, fake colleagues, fake articles, fake impact calculations, etc.)

Second, all impact calculations are based on the number of citations that indicate the interest of peers, but certainly not the significance of the publication, which can be recognized only many years later. [2].

Third, publishing business models changed considerably. Today, not only full journals and magazines but individual articles can be purchased online, detaching their assumed value from a journal. The different business models have both benefits and drawbacks. The traditional subscription-based model was to sell quality-controlled information to libraries, generated and curated by scientists. Unfortunately, many scientists had only limited access. Computers and the internet came to age to make it possible to sell individual articles. The open-access model [10] has shifted the financial risk to the authors, who are willing to pay for marketing and distributing the information they have generated, which further drains their resources but offers free access for readers. The only exception is when learned societies or academia finance OA online publishing (which model eliminates the financial interest in publishing quantities instead of quality).

The Journal Impact Factor is a good indicator for **journals** but should not be misrepresented as the impact of **individual articles** published in any journals and **should not be used to judge individual authors**. [11]

Publications have become a product to sell

Scientists are now evaluated by their publication output and its "impact" as a measure of their abilities and research performance. Therefore, they must constantly demonstrate their own value by publishing "original" and "significant" results in "high impact" media. Today the primary motivation to write a manuscript is **to satisfy existential needs,** i.e., to graduate, get into high JIF journals, collect more citations so you can keep a position/job, or maybe your next grant proposal requires publications to move up the ladder and get tenure. Sharing scientific information and knowledge has become secondary until you are tenured and safe.

The breakdown of traditional quality control, i.e., peer review

What happened to the standards for sharing information? The present system encourages quantity at the expense of quality. Quantity is easy to measure, but judging quality is not simple. There are about 8-9 million scientists in the world who publish papers. According to the STM Global Brief of 2021, [11] there were 25-35 thousand active, scholarly peer-reviewed journals that published 4.5-5 million articles in English per year. To receive at least two reviews per article assumes receiving 9 million reviews. Unfortunately, reviewer response rates fell below 30%, which would require sending out 30 million invitations, i.e., 3-4 reviews per scientist on average, stretching peer-review

times even further. Peer review really meant review **by peers with equal expertise**, which is not the case today.

Unfortunately, the quality of an article is often identified as the impact factor of the journal the paper has been published in, i.e., its perceived "prestige" Although this approach is gradually being replaced by article-based evaluations considering the number and source of citations, it is still strong, especially in Asia.

Electronically archived articles live online forever and are cited forever

All information is now electronic [12] and remains accessible forever.

Science corrects itself, as new publications shed new light on earlier results and expand knowledge, but publications do not. In the printing press age, libraries used to archive knowledge in prints, which were hard to search. In a library, individual journals were tied together into annual books, which gradually traveled to the back of the library and moved up to higher and higher shelves until nobody accessed them, even though they were still valid. [13] This sometimes led to the re-discovery of earlier findings.

The present acute problem is the opposite: electronically archived articles live online forever and are cited forever, including outdated and retracted papers. For example, the 8500 papers retracted by 2005 received 30500 citations, but 658000 articles cited those papers that cited the original retracted papers. [14] Twenty thousand papers in the Retraction Watch Database in 2021 were cited in 95,000 articles *after* their retractions.

The retraction process is essential for correcting the literature and maintaining trust in the scientific process. Despite this, many papers received hundreds of more citations *after* having been retracted, demonstrating the ongoing problem of "Zombie research." [15]

Greed, fueled by the ease of online publishing.

Networked computers have opened entirely new business opportunities in publishing. Online journals require only computers and publishing software. Distributing information online is much cheaper and more efficient than on paper. It is easy to archive, store, and retrieve information (articles, journals, books, etc.) Searching for information according to one's interests is also possible, although commercial algorithms are watching to learn your preferences and give you feedback to reinforce your own beliefs and habits. The rise of preprints was especially noted during the pandemic, which contributed to spreading false information, fake publications, and outright disinformation by papermills and predatory publishers (since then, more than 200 COVID-19–related papers have been retracted, most of them in 2021). [16]

What to look out for?

Scams

We all receive *email scams and invitations* to low-quality meetings, typically organized to collect registration fees. There are specialized companies for those promoting "science-tourism," where" grant money may be used to pay for meeting expenses. Scams often include email invitations to Editorial Boards or soliciting articles offering discounts. High-quality journals don't go begging for manuscripts or editorial board members through email. It is usually the other way around.

Predatory publishers, predatory journals

These have been documented extensively. [e.g., 17] While the definition of the term "predatory "is extensively debated (especially by those that have been named one of them), it is impossible to deny that they do exist (their numbers approximated in the thousands) and they should be avoided. Various lists exist, although their selection criteria are not always clear. [18]

Clone(hijacked) journals

These are counterfeit websites that pretend to be the website of a legitimate scholarly journal. [19] The website creators then solicit manuscript submissions for the hijacked version of the journal, pocketing the money. The first described case dates back to 2011. Since then, hundreds of journals have been hijacked. They copy the ISSN and title of a legitimate journal to cheat potential clients and provide a fake inflated impact factor. They may register an expired domain, hack the site of an authentic journal, register an alternative domain, or create a clone journal with a very similar name or appearance. Some fake clone journals cheat international databases by providing homepage links to fraudulent sites.

These journals usually target researchers who are required to publish in journals indexed in international databases, such as Scopus or the Web of Science, or those included in "white-lists," e.g., the UGC-CARE Approved list which is applied in India. Detecting a network of hijacked journals by its archive recently allowed us to detect 62 more URLs of hijacked journals last year. [20]

Papermills

Papermills [21] manufacture manuscripts and submit them to journals on behalf of researchers for a fee. Many of the named authors who purchase these papers are medical doctors who may have poor English and have full caseloads but are still expected to publish in a journal with an IF to progress or graduate. Detection of articles from papermills is difficult. Current detection tools may not show up problems because modern AI-powered generation techniques produce texts almost indistinguishable from that written by humans. Physicians in China are a particular target market because they typically need to publish research articles to gain promotions but are so busy at hospitals that they might not have time to do the science. The chase of Impact Factor and resulting recognition has led to insane contract requirements. For example, last August, the Beijing municipal health authority published a policy stipulating that an attending physician wanting to be promoted to chief physician must have at least three first-author papers published in professional journals. [22]

Fortunately, an increasing number of these papermill-originated submissions are being discovered, unfortunately, mainly after publication. [23] An analysis by *Nature* has found that since January 2021, journals have retracted at least 370 papers that have been publicly linked to papermills. Many of these submissions are to medical journals - they are spreading misinformation that could cost lives. [22] More retractions are expected to follow

Peer-review for sale

Just type the phrase in Google or any other search engine. You will be surprised – it is a booming business even though publishers are fiercely fighting these rings.

Authorship for sale.

A company sells first authorship on scholarly papers, starting at about $500. Quote: "*We sell publications of finished articles in Scopus and Web of Science magazines (articles written and accepted in journals; sold in parts or in whole).*" The same company claims to have added the names of more than 10,000 researchers to more than 2,000 published articles in scholarly journals over the past three years. According to a July 17, 2019, letter from the Web of Science Group to the Committee on Publication Ethics (COPE), COPE has found 344 articles for sale on the website. Of those, 32, or 9%, are allegedly indexed on the Web of Science, and 303 (88%) appear in the Scopus database. 26% of discovered articles have been retracted or have had expressions of concern added. Many of the remainders are still being investigated. The main countries where these articles originate are China, India, Iran, and Russia, although there are other countries also involved. [22-24]

The preprint problem

Preprints have become very popular but are **not** peer-reviewed articles and are unchecked for quality. The original intention was to stake out someone's territory and "to communicate their research results quickly and freely." [25] It was a nice idea, but – as it was proven by the pandemic-related urge of knowing something quickly and for sure – COVID-related preprints (even if they were later invalidated) were referred to extensively in social media and newspapers. Facebook and Linkedin have more readers than Nature, Science, or other proven scholarly journals with quality control. Thus, hurried ideas and incorrect information got out quickly and contributed to public confusion.

Preprints have value, but they should not be mistaken for peer-reviewed articles. Preprint servers also assign their DOI to the pre-publication, which redirects to the same publisher instead of the final version of the same material in a peer-reviewed journal. In addition, often there is no link to the final record, and there is no standard way to retract preprints.

What can we do?

Most authors publish in journals they are familiar with, starting with the one with the highest Journal Impact Factor. If you are not familiar with the journal, here are a few useful tips:

1. If the journal is open access, check out the publishers at first [26, 27]
2. Answer these questions:

- Do you or your colleagues know the journal? Have you read any articles in the journal before?
- Can you easily identify and contact the publisher? Can you contact the publisher by telephone or email?
- Is the journal clear about the type of peer review it uses?
- Are articles indexed and archived?
- Is it clear what fees will be charged, if any?
- Do you recognize members of the editorial board? Do you know someone? Can you contact some of them?
- Is the publisher a member of a recognized industry initiative, e.g., the Committee on Publication Ethics (COPE)?
- Is the journal listed in the Directory of Open Access Journals (DOAJ)?

If you answer YES to all, you are safe.

3. Visit thinkchecksubmit.org [28] or other advisory sites (although most of them advise using their own services, and only a few are not directly involved commercially). I recommend taking a thorough look, starting at. [29, 30]
4. Follow Retraction Watch [31] and listen to your own sober mind.

Editors – among others - guard the quality and reliability of submissions and the journal's prestige. They do their best to make sure that submissions are based on real work and that the data in the manuscripts are solid and reproducible because they were generated by executing the right plan with the right technique. Sometimes even leading scientists disagree regarding explanations of the same data set, but conclusions are never better than the data on the deductions have been based on.

Publishers and associations are waging war against fake publications and predatory organizations. [32] Authorities fight papermills [33] and keep reforming rules. For example, in 2020, China banned cash rewards for publishing papers. [34]

Although fake "science" in publications is still relatively rare (only about 0.2% of articles were retracted by 2011, 0.1% for fraud, and 0.1% for error) [13], it is the tendency that is alarming. [14, 35] Why should these relatively small numbers ring the alarm bell? Undiscovered false or fake "science" is dangerous because it hurts public trust at a time when sensationalized pseudo-scientific "simple" explanations and manufactured "news" spread with the speed of light through social media. The more sensational the piece of "information," the more likes it generates on social media, another opportunity to make money. Who do you think has more readers, Facebook and Reddit, or Nature and Science Magazine?

Retractions take a long time, and not a lot of data is available publicly [36]. Disputed data and information were always part of publications, and we certainly should assume that their number is much higher than those of retractions. Let's keep in mind that not all retractions are because of fraud but due to honest mistakes, which is part of a normal process. **In summary, verified knowledge dominates.**

Conclusions

Scientific knowledge is getting more and more complicated. Today's research topics are way more complex than ten years ago and require the collaboration of groups from vastly different disciplines, meaning nobody understands all aspects of a multidisciplinary research project anymore. Today's scholarly publications contain published knowledge, including verified, unverified, and fake knowledge, as well as part of outdated knowledge. Although the relative number of fake publications is low, their rising tendency is certainly alarming. Science always corrects itself, and verified knowledge is dominant. However, authors must understand today's publishing landscape to detect and avoid potential problems. Once you spend money and maybe years thoroughly generating data, analyzing and crafting the content of your article, you must spend one more day to find the best solution for your publication.

Conflict of Interests

The author declares no conflicts of interest. For a signed statement, please contact the journal office at editor@precisionnanomedicine.com

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