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Toward a Japanese society that values science: Analysis and proposals! *

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Abstract: My early experiences raising and observing Old World swallowtail caterpillars captivated me with the wonders of nature, eventually leading me to devote myself to the molecular biology of living organisms. That is, the motivation for research stems generally from a spirit of inquiry that has historically been nurtured by stable, prosperous societies. Since 2004, Japan has increasingly reorganized its national and public universities and research institutions into independent administrative agencies. In tandem with this trend, Japan's research capabilities have fallen to 13th place globally. Furthermore, research misconduct has increased. In short, competition and an obsession with efficiency do not foster research. I propose government-led reforms.

Keywords: scientific fascination, research capabilities, prosperous society, Japanese science

Research begins with a sense of curiosity. Let me share a story from my early experiences. It all started with observing butterfly caterpillars (Figure 1). Around 1962, when I was in elementary school, I brought home carrot leaves from the field with several first- or second-instar Old World swallowtail caterpillars on them. Since I pored over a small insect field guide daily, I immediately recognized them as Old World swallowtail (*Papilio machaon*) caterpillars. I set up a mesh rearing box measuring about 25 cm wide, 25 cm deep, and 50 cm high and raised Old World swallowtail caterpillars almost every year. I observed them as they molted, pupated, and finally emerged from their pupae as butterflies (eclosion). I replaced the carrot leaves I used as food with wild Japanese parsley growing in the ditches of nearby fields. Through this experience, I learned that swallowtail caterpillars feed exclusively on plants in the Apiaceae family. Around this time, I was thrilled to discover adult common bluebottle butterflies (*Graphium sarpedon*), Japanese emperor butterflies (*Sasakia charonda*), and jewel beetles (*Chrysochroa fulgidissima*). Since my grandfather was a silkworm farming instructor, we had a microscope at home. In the upper grades of elementary school, I used it to explore the tiny world around me. Unfortunately, microscopes back then didn't have recording devices. I was good at sketching what I saw under the microscope. In university, I belonged to the plant pathology laboratory and became engrossed in elucidating the mechanism of action of host-specific toxins produced by the fungus Alternaria for apple blotch. To conduct time-lapse observations, I sometimes walked approx. 3 km to the lab in the middle of the night. Through this research, I saw "ATP"—the energy molecule produced by living organisms—for the first time. Until then, it had been nothing more than textbook knowledge, but I was moved to discover that it was simply a powder. Since I was quantifying ATP using luciferase activity, I bought dried firefly tails to get luciferin and luciferase. I was also surprised to learn that such items were commercially available as reagents. In graduate school, I studied gene expression. That was the first time I saw "DNA". It was a white fiber, and I thought, "Ah, so that's what it looks like." In the 1970s, it became possible to decode the genetic information hidden within DNA, the blueprint of life. Intuitively, I felt that this would reveal the essence of life, so I became deeply immersed in the study of DNA function. In fiscal year 1982, the Ministry of Education, Culture, Sports, Science and Technology (MEXT) established the "Overseas Special Researcher Program" for young researchers. Ten individuals were selected from all research fields. The program guaranteed the opportunity to study at universities around the world, funded by the Japanese government. In addition

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to an annual living allowance of 3.7 million yen (approx. US$15,400 at the time), I received 1 million yen (approx. US$4,200) for research and travel expenses. Fortunately, I was selected as the sole candidate from the field of botany. With such generous support, any university in the world would have welcomed us. I knocked on the door of Professor Lawrence Bogorad's (1921–2003) laboratory at Harvard University. Professor Bogorad was at the forefront of molecular-level genetic research, a field that was then in its infancy (1). Subsequently, at Nagoya University and later at the University of Shizuoka, I focused on photosynthesis—the only system by which living organisms capture solar energy—and devoted myself to elucidating the genetic mechanisms underlying its structure.

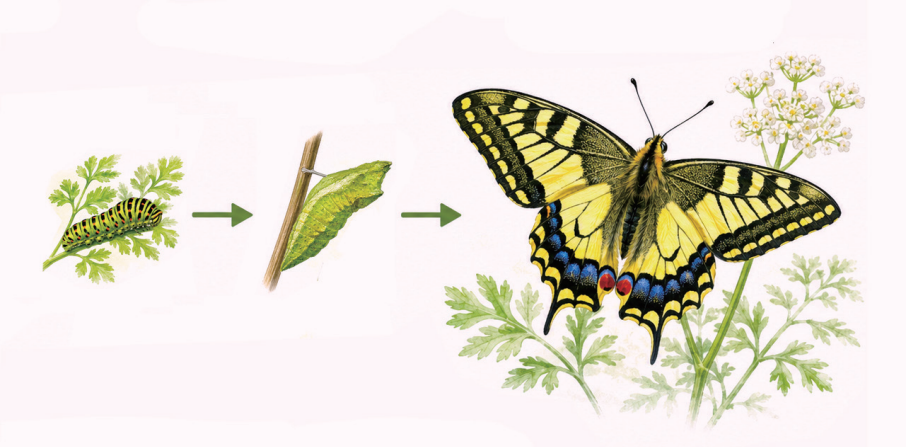

Figure 1. The metamorphosis of the Old World swallowtail *Papilio machaon* (Japanese subspecies, *P. m. hippocrates*) as the author's formative research experience (image generated by OpenAI DALL·E, partially modified). Adult Old World swallowtail butterflies are often confused with the Asian swallowtail (*Papilio xuthus*) of the same genus (see cover image). The adult Old World swallowtail is characterized by a deeper yellow color than the common swallowtail. The Old World Swallowtail is widely distributed throughout the Northern Hemisphere, while the Asian swallowtail is found in Northeast Asia. Their caterpillars differ significantly. The Old World swallowtail prefers the leaves of plants in the Apiaceae family, such as celery, carrots, parsley, and fennel. The Asian swallowtail prefers the leaves of citrus plants in the Rutaceae family, such as mandarin oranges, lemons, yuzu, and Japanese pepper. Furthermore, fifth-instar (final-stage) caterpillars of the former species have black horizontal stripes with orange spots on a green background (left side of this figure), while those of the latter species appear as if clad in green armor.

In 2023, Japan fell to 13th place in the global research performance rankings. "Is 13th place not good enough?" While I wouldn't say "no," why does this ranking seem out of step with Japan's economic strength? Although the decline of Japan's research capabilities has been noted in various circles, the proposals I've seen for reversing this trend seem unconvincing. Evaluating research capabilities is no easy task. Just as with the paintings of Vincent van Gogh (1853–1890), some research efforts go unrecognized during the researcher's lifetime and are only acknowledged posthumously. Among the various indicators of research capability, the "number of papers in the top 10%" is frequently used, although it has its limitations. This metric ranks papers by the number of citations they receive, from highest to lowest, and represents the number of papers that fall within the top 10% of that ranking. This figure is adjusted to account for variations across different research fields. From 2001 to 2003, Japan ranked fourth in the world for "top 10% adjusted paper count." Although Japan lagged significantly behind the United States in first place, it was only slightly behind the United Kingdom in second place and Germany in third place. However, from 2021 to 2023, Japan's "top 10% adjusted paper count" plummeted to 13th place. Research requires funding. A nation's economic strength is represented by its gross domestic product (GDP). During this period, Japan ranked second in the world behind the United States in terms of GDP until 2009. China overtook Japan in 2010, and Germany overtook Japan in 2023; yet, Japan still held fourth place globally. The 2023 decline is believed to be due to the weak yen affecting the value of Japan's GDP when converted to U.S. dollars.

Now, let's examine the historical relationship between society and scientific development. If we accept the definition that science is part of culture, then periods of cultural flourishing in world history include Ancient Greece (Classical Period: late 400s to 300s BCE), China's Tang Dynasty (618–907 CE), the Islamic Golden Age (700s–1200s CE), and Europe's Renaissance (1300s–early 1600s CE). The Industrial Revolution, which began in Britain in the mid-1700s, subsequently revitalized industrial production, enriched society, and led to a cultural renaissance. Significant periods of cultural advancement in Japanese history include the Heian period (late 700s–late 1100s CE), the Genroku era of the

Edo period (1688–1704 CE), the Hōreki and Tenmei eras (1751–1789 CE), and the Bunka and Bunsei eras (1804–1830 CE). The literacy rate among the Japanese population in the mid-1800s was reportedly over 70%, believed to be the highest in the world at that time. The subsequent industrial development following the Meiji Restoration supported the expansion of culture. These civilizations have one thing in common: a stable and prosperous society.

How did intellectuals, including scientists, earn a living? Socrates of ancient Greece (c. 470–399 BCE), for example, received support from his friends and disciples (Figure 2). Plato (427–347 BCE) was born into the Athenian aristocracy. Leonardo da Vinci (1452–1519 CE) of the Renaissance received support from nobles and patrons. Furthermore, scientists and philosophers were among the clergy, who were guaranteed a minimum supply of food. Among them were Roger Bacon (1214–1294 CE), who promoted empiricism; Nicolaus Copernicus (1473–1543 CE), who developed the heliocentric theory; Joseph Priestley (1733–1804 CE), who discovered photosynthesis; and Gregor Johann Mendel (1822–1884 CE), who formulated the laws of inheritance. If we define a "university" as an institution of higher learning, then the University of Bologna and the University of Paris were established in the 1100s and 1200s, respectively. By the 1800s, the Industrial Revolution had increased the importance of science and technology. Consequently, governments, universities, and other institutions began funding scientific research. As a result, researchers were recognized as professionals and were able to earn salaries. Wilhelm von Humboldt was a pioneer in this movement. He founded the University of Berlin (now Humboldt University of Berlin) in 1810. By emphasizing freedom in research and education, Humboldt laid the foundation for researchers to be recognized as professionals.

Starting in 2004, national universities involved in promoting basic research were reorganized into independent administrative agencies, and many public universities followed suit. The corporatization of national universities was intended to encourage each institution to devise innovative approaches to education and research excellence, thereby becoming more unique and attractive. At the time, Junichiro Koizumi (b. 1942) was prime minister. To address the growing deficit in government bonds, the corporatization of national universities separated their staff from approx. 800,000 national civil servants, reducing the latter group by about 150,000. Following the transition to independent administrative corporations, faculty members were burdened with tasks such as setting targets and evaluating their achievement to ensure transparency, offering public lectures as a form of social contribution, and securing research funding amid the shift from block grants to the competitive allocation of operational subsidies. Consequently, by 2023, faculty members' research time had decreased by approx. 31% compared to 2002 (Figure 3) (3). Furthermore, the number of faculty members aged 25–39 across all universities

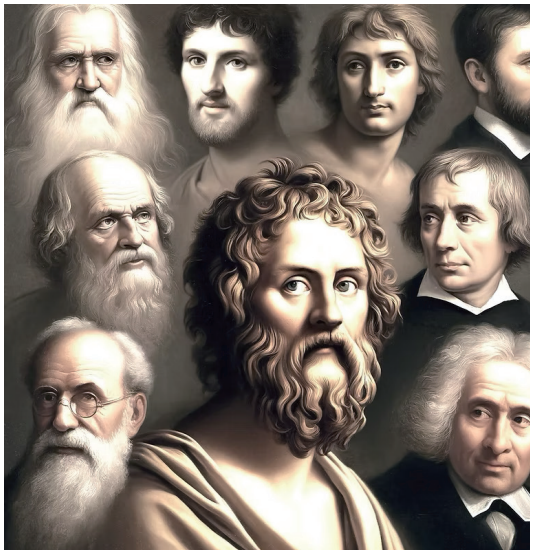

Figure 2. The work of Socrates and other prominent researchers was made possible by a stable living environment (image generated by OpenAI DALL·E).

Figure 3. The research environment at national and public universities following their conversion to independent administrative agencies (conceptual image generated by OpenAI DALL·E). Researchers at former national and public universities experienced an approx. 31% decrease in research time following the conversion (3) and became overwhelmed by so-called "menial tasks" directly unrelated to research.

peaked in 2008 and declined by about 15% by 2022 (2).

The "STAP cell scandal" involving Haruko Obokata (b. 1983), which came to light in 2014, became a tragic case that even resulted in suicide. Researchers are judged by their research achievements when seeking employment or securing research funding. Furthermore, from the perspective of securing funding, research achievements are critical to the survival of research institutions. Consequently, the pressure to produce research achievements can be stressful. While research misconduct is not a new phenomenon, it will persist as long as the employment and promotions of professional researchers are evaluated based on their research achievements. Cases of research misconduct in Japan became prominent around 2005. As a result, MEXT began publishing the "List of Cases Where Misconduct Was Confirmed in Research Activities Conducted Through MEXT Budget Allocations or Measures" in fiscal year 2015 (4). According to this list, the cumulative number of cases through fiscal year 2024 is 99. In other words, the increase in research misconduct coincides with universities' and research institutions' transition into independent administrative agencies. This shift toward a corporate-style focus on cost-effectiveness has ultimately undermined Japan's research capabilities.

Because it is difficult to verify the precision with which research results are reached, there is room for misconduct to occur. Conversely, artists, writers, and entertainers face similar competition, yet a degree of fairness remains because the audience evaluates their work. Although research papers undergo peer review, this is typically conducted anonymously by multiple researchers in related fields who can understand the research content. However, if a reviewer is in competition with or close to researchers in the relevant field, there is a high likelihood that a fair judgment cannot be made. Therefore, while authors can specify reviewers they wish to exclude or include at the time of submission, the decision regarding who will serve as a reviewer—including researchers not on that list—is left to the editor's discretion. Research achievements are highly valued when published in prestigious academic journals, but sometimes the number of published papers is used as an indicator of research output. Consequently, academic journals that publish articles without peer review have emerged. These are known as "predatory journals." There are over 1,000 such journals, and a list of them is publicly available online (5). During the pandemic, there was a growing need to quickly deliver research results related to human life to relevant researchers. Peer review typically takes several weeks. Consequently, "preprints"—which do not undergo peer review—have been increasingly published online. This type of preprint emerged in 1991 with Cornell University's "arXiv" repository (6). Furthermore, particularly in instrumental analysis, there has been an increasing trend to share vast amounts of raw analytical data among relevant researchers without first organizing it. In Japan, MEXT Advanced Research Infrastructure for Materials and Nanotechnology in Japan (ARIM)" initiative is currently underway (7). These activities are referred to as "open science," and researchers must now be able to sift through valuable and worthless information to extract what is necessary.

To address issues in Japan's research system, (I) measures to prevent and improve research misconduct should enhance reviewers' competence to accurately evaluate research achievements, research proposals, and individuals' capabilities during researcher screening for hiring and promotion, as well as competitive grant allocation. (II) To support researchers' contributions to society, reduce the burden of securing research funding, and promote intellectual property management and commercialization, it is desirable to increase the number of URAs (University Research Administrators) and improve their working conditions. (III) Since it takes time for individual universities to establish endowments large enough to generate substantial operating income, assistance from national and local governments is essential. This assistance can take the form of the 10 trillion Yen Fund (approx. 65 billion US dollars), established by MEXT. The fund is funded by government contributions and fiscal loan funds and provides long-term support for world-class research universities. (IV) Japan is the only major economy that has shown no growth for 20 years. To achieve financial independence for universities, it is desirable to incorporate the societal implementation of university research findings into university management. (V) Rather than competing with each other in various initiatives, shouldn't national and local governments lead in formulating and implementing plans to consolidate and restructure universities in response to the declining birthrate?

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