1. The Role of Thought Experiments in Advancing Microbiological Science

Volkan MAZLUM

Advisor: Giovanni Valente

Usually, we consider the observations made by our eyes, noses, and fingers. We can observe by touching, smelling, and seeing. Nonetheless, there are several ways to make observations in science. Thermometers, microscopes, telescopes, radar, radiation sensors, fMRI machines, mass spectroscopy, and other instruments are more effective at observing than humans. We still need to use them to expand and improve our fundamental senses. Additionally, many of the phenomena that science investigates are not immediately apparent to humans. Simply looking at this computer screen will never reveal the atoms that comprise it or the UV rays it produces. We need to focus on different aspects of science and methods to make different inventions.

Indirect observations will be dependent on tools in such cases since they allow us to see more accurately than primary senses ever would. For example, information can be radiation measurement from an orbiting satellite or infrared recording of a volcanic eruption. Scientists will then analyze this information to determine the influence that data has on their theories. Data may seem highly complicated. It is innumerable at the observation level at which all data appears. These observations then confirm and test all scientific hypotheses. However, it is impossible to infer theories and hypotheses from nature directly. For example, a falling ball cannot explain gravity [1]. We cannot prove the gravity in this experiment because there can be a lot of different ways to create this action. It should be specific. On the other hand, we need to conduct various experiments to understand what it is based on.

Scientific knowledge is produced from formulated theories and assumptions, regularly tested against natural world observations, and continuously refined those explanations considering new observations. Observations are essential to the scientific method but are only one part of this view [2]. In the spectrum of types of research, thought experiments occupy a unique position because they can give rise to theoretical development and investigation into theoretical consequences outside the limits of the fundamental approach. Observations alone will not be conclusive, but if they could be conducted accurately, thought experiments would allow the development of imaginary consequences. They enable the researchers to conclude some scenarios where observation would be complicated and check the hypotheses' limits. For instance, Einstein undertook a thought experiment on the nature of light concerning gravity, which changed our worldview about physics and gave a new area to revolutionary ideas in relativity theory [3]. Because of those ideas, other tools are beneficial for proving the results of experiments with the technological tools. For example, some ideas of Einstein may have been proved 5-10 years ago but are indicated during approximately 1920-1930. Between these dates, there may be 100 years to be proven. However, Einstein achieved it by using mathematical equations and thought experiments to think about it.

Thought experimentation is to lay a foundation before using specific tools. However, the experiments that have been brought to a certain level with experiments can be proven or further developed with different technological tools. Nevertheless, we can compare some arguments associated with thought experimentation regarding realism and anti-realism. In other words, thought experiments can be considered hypothetical situations that describe unobservable possibilities. Such situations generate theories that would be legitimately proven without evidence [4].

This essay explores the philosophical issues raised by thought experiments, analyzes how they advance microbiological science, and contrasts two philosophical schools of thought, scientific realism and anti-realism. I will also explain thought experiments in microbiology to provide a better understanding.

2. Contributions of Thought Experiments to Microbiology

Thought experiments are not just a theoretical exercise but an efficient way to produce new hypotheses on the behavior and interactions of microorganisms. Experimental methods produced by thought experiments would contribute phenomenally towards science, even where such techniques may not yield observable results. For example, such an instance may be the prediction of scenarios involving tests of bacteria against various antibiotic pressure concentrations. Such predictions can be tested experimentally, enabling the procedure to proceed with increased efficiency and controllability.

It is difficult to see many microbiological activities directly since they occur at long-term or microscopic sizes. Without waiting for direct empirical evidence, scientists might use thought experiments to explore theoretical frameworks. However, it is possible to develop a specific framework by only investigating theory without any boundaries in its practicability and then just continuing. A technical investigation may present ethical problems or practical challenges regarding certain bacteria. Here, thought experiments can solve those situations. With thought experiments, researchers may base their research on theoretical results without endangering live organisms. For example, one can study what will happen to an organism and the public health and ecological impacts if a harmful bacterium is genetically modified without conducting dangerous research.

2.1 Practical Applications: The Study of Antibiotic Resistance

There is a popularly known instance of a thought experiment on microbiology, which is antibiotic resistance research. Such hypothetical scenarios are what researchers usually rely on to explain how the mechanisms that give bacteria their resistance change over time. Otherwise, they would entail very long actual implementations of ideas. By conducting thorough experiments, scientists could quickly advance their studies compared with experimental procedures. For instance, consider a bacterial colony exposed to escalating doses of antibiotics. Some bacteria may develop mutations that grant them resistance, while others may obtain resistance genes through horizontal gene transfer. Thought experiments can help generate predictions about the dynamics of resistance evolution and guide experimental designs to understand better the specific processes involved in developing resistance.

2.2 Philosophical Issues

Applying typical thought experiments raises quite several philosophical questions in microbiology. The first one is Epistemological Validity. One of the most significant solutions to crack concerning thought experiments in micro-biology is establishing whether knowledge from thought experiments is as good as empirical observation. This question reverses the conventional hierarchy in which empirical data are weighed more than theoretical inference. Scientists argue that experiments can be crucial to mechanisms that are yet to be seen. By framing such investigations before they have been fully formulated or even realized, upcoming attachments can be anticipated. Second, realism and anti-realism generally focus on phenomena that cannot be seen or occur in hypotheticals.

The discourse questions if the idea has some good in it. Criticisms deny that these could be counted as substitutes or engines for propulsion of any significant advancement in science; they ridicule such things as pseudoscientific, equalizing that with astrology. At the same time, rationalists argue that thought experiments illuminate processes that would otherwise be obscured. On the contrary, the anti-realist argument insists that these are only heuristic ways, without any doubts about the reality of nature.

2.3 Philosophical Approaches

Scientific realists claim that theories attempt to ensure a truthful correspondence with reality, including all that inner realities involve. Accordingly, supporters argue that thought experiments might help to understand reality, as they reveal new considerations about the conditions in which such entities exist and interact. Realists could say antibiotic exposure can induce change among microorganisms by positing theoretical assumptions or simulation outcomes. However, this claim could land them into indirect arguments about nature, resulting in insignificant new information or improvements but mostly challenging debates.

Thus, thought experiments raise important philosophical questions about realism and anti-realism while also making significant scientific advances in microbiology by generating hypotheses and using information from other disciplines. It clearly maintains such issues with epistemological validity, which emphasizes experimental sufficiency and pragmatic application compared to ontological commitments to unobservable things. Helping themselves to such a stance will allow scientists to make adequate use of the advantages of thought experiments while circumventing their philosophical difficulties.

2.4 Realism and Antibiotic Resistance

They hold that every scientific theory should be used to explain observable and unobservable phenomena. However, they say that besides this, all the basic processes, like the horizontal transfer of genes or genetic modifications, can be very well attributed to our scientific theories, which cause antibiotic resistance. Penicillin became effective for bacterial infections; people initially had high hopes. However, it has now been shown that far more complex realities exist along with the emergence of resistant strains.

The realist claim holds that such research discovers the reality and shows what people are beginning to know regarding microbe genetics and ecology. Health history, such as that of antibiotics, treating diseases, gives it credence that even presenting theories on the causative agents of resistance will also shed light.

For example, advancements in the genetic basis of bacterial resistance, such as E. coli and Klebsiella pneumonia, will probably form a basis for new treatment applications after understanding mechanisms. Scientific realism is considerably compatible with ordinary scientific activity- that is, knowing the behavior of microbes. It is a rational framework for thinking about the relation between unobservable entities like resistance genes and observable outcomes: treatment efficiency. Both elements will be crucial to create a reality hypothesis. In this way, realism will be of high value to science. Moreover, based on the effectiveness of treatment, we may devise new ways to redress the severities.

2.5 Anti-Realism and Antibiotic Resistance

Anti-realism includes a wide range of views opposing the claims of scientific realism, particularly regarding the existence of unobservable entities. Instrumentalism is one of the most widely known anti-realism. Everything about science should be judged on its predictive power rather than on the truth of its theories. Anti-realists contend that knowledge of antibiotic resistance is crucial. However, the focus should be on how healthy theories predict outcomes rather than how correct they are about invisible processes. For example, models that predict the formation of resistant strains may be helpful despite their potential inability to accurately represent the fundamental biological reality because anti-realism does not demand philosophical truths regarding unobservable events. It allows for freedom in scientific modeling. This sort of view is vital since bacterial resistance is developing so rapidly that we might not be able to understand its processes fully. One advantage of anti-realism is that it eliminates the risks of becoming overly devoted to specific ontological claims about entities that cannot be seen. It places more emphasis on empirical sufficiency and practical implications than it does on abstract truths. Furthermore, anti-realism finds it challenging to explain the success of specific models if they do not correspond with any truth about reality. Also, pessimism toward scientific advancement may grow if all hypotheses are considered practical instruments with no claim to integrity.

Observable and unobservable entities are at the heart of the clash between realism and anti-realism. Realists believe visible and unobservable elements are necessary to understand antibiotic resistance thoroughly. According to these anti-realists, such as instrumentalists, observable facts alone should be considered valid, while their unobservable theoretical constructs for prediction are void of any ontological commitment. Indeed, the debate between realism and anti-realism is significantly based on our understanding of antibiotic resistance in microbiology. Anti-realism is thus a point of view that appreciates that and evaluates scientific models in their values and effectiveness. On the contrary, realism is concerned with truth about objective reality, including processes behind those resistance mechanisms in bacteria. These are different approaches but with an equal potential yield on the grounds of careful thought experiments.

However, it is essential to realize that experiments alone are insufficient. For them to be sufficient, they need to be supported by experiments. This is because thought experiments prepare predictions for scientific studies. The science of microbiology, as is well known, cannot only be conducted through thought experiments. It can reach a certain point, but the result cannot be fully achieved. For example, technological tools such as microscopes must be used to conclude these thought experiments.

In a nutshell, scientific realism versus anti-realism, while discussing antibiotic resistance, refers to the hurdles that must be crossed during a scientific investigation. In this way, it sheds light on the philosophical foundations of perceptions from which microbes are thought to behave. Furthermore, it argues that scientific realism demands a more rigorous study of genetic mutations in ecosystem interactions that cause resistance and reliability in treatment methods and their causes. In contrast, anti-realism emphasizes the quantitative output of models via which their predictions are intended to be practically applicable in therapy.

For instance, studies science and philosophy since these discourse about resistance against antibiotics. Resistance would be apparent as sometimes as possible, and both realism and anti-realism point out hurdles to be cleared in achieving scientific investigation. Some ways would further trigger its philosophical bases, shaping delusions of how microbes would behave. Less on the requirement for scientific realism than on a study about genetic mutations as brought by ecosystem interactions that will ultimately, with more reliability in treatment and causation, produce a regimen of resistance. Such models, however, will only be possible through the patient allowance of anti-realism, with the quantitative output of their models proving to be valid and yielding predictions with therapy applications.

A broad approach that considers both points of view can enhance our understanding of this pressing health concern and allow for multidisciplinary collaboration. Scientists may create novel ways to find a solution to antibiotic-resistant illnesses and ultimately safeguard public health in a time when such risks are becoming more common by appreciating both theoretical depth and real-world applicability. On the other hand, in a nutshell, we don't need to focus on microbiology. We can also focus on other aspects of science, and these ideas are very beneficial when conducting experiments for our research. Many different ideas can be used, but the most appropriate one is ours, and we need to find a way to achieve success. In that paper, we used anti-realism and realism to go deeper by using thought experiments in microbiology.

As Schrödinger and other physicists used the term, the purpose of a thought experiment is not to predict the future—indeed, Schrödinger's most famous thought experiment shows that the "future," on the quantum level, cannot be expected—but to describe reality, the present world.

Ursula K. Le Guin, The Left Hand of Darkness [5]

References

[1] Stuart, M. T., & Fehige, Y. (2021). Motivating the History of the Philosophy of Thought Experiments. https://doi.org/10.1086/712940

[2] Daston, L. (2008). On scientific observation. Isis, 99(1), 97-110.

[3] Hallsworth, J. E., Udaondo, Z., Pedrós-Alió, C., Höfer, J., Benison, K. C., Lloyd, K. G., ... & Amils, R. (2023). Scientific novelty beyond the experiment. Microbial Biotechnology, 16(6), 1131-1173.

[4] Boyd, N. M., & Bogen, J. (2009). Theory and observation in science.

[5]Quote by Ursula K. Le Guin: “The purpose of a thought-experiment, as the ter...”. https://www.goodreads.com/quotes/678643-the-purpose-of-a-thought-experiment-as-the-term-was-used