Openness in Scientific Research: A Historical and Philosophical Perspective

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Abstract. Openness is widely regarded as a pillar of scientific ethics because it promotes reproducibility and progress in science and benefits society. However, the sharing of scientific information can sometimes adversely impact the interests of human research participants, human communities or populations, scientists, and private research sponsors; and may threaten national security. Because openness may conflict with other important social values, solutions to ethical and policy dilemmas should include meaningful input from those who are impacted by the sharing and use of scientific information, including research participants, communities, and the public. Data sharing and use policies should be reviewed and revised periodically to account for ongoing changes in science, technology, and society.

Keywords: openness, science, data sharing, transparency, reproducibility, progress, ethics, history, philosophy

1. Introduction

Openness is widely regarded as a pillar of scientific ethics (Resnik 1998; Hosseini *et al.* 2022). The influential American sociologist Robert Merton (1910-2003) was one of the first scholars to study the function of openness in scientific communities. Based on his observations of and interviews with researchers, Merton proposed four norms that he believed guided scientific behavior. One of those norms, communalism, implies that the products of scientific research, such as data, results, methods, and materials are common property and should be shared freely (Merton 1973; Rader 2019; Hosseini 2022). Although most scientists believe in the importance of openness, other important considerations, such as the protection of human subjects, scientific careers, intellectual property and proprietary information, and national security, may discourage free and open sharing of scientific information (Mitroff 1974; Mulkay 1976; Resnik 2006, 2007, 2010; Levin and Leonelli 2017; Maxson Jones *et al.* 2018; Hosseini *et al.* 2022). Accordingly, many philosophers and sociologists of science regard openness as an ethical ideal rather than an absolute rule that must be followed in all circumstances (Mulkay 1976; Resnik 1998). In this article, I will provide a historical and philosophical perspective on openness in scientific research. I will argue that openness and secrecy have coexisted through the history of science and that there are legitimate reasons for not sharing scientific information in some circumstances. I will conclude by suggesting that the best way to balance the ethos of scientific openness with other social values is to engage affected stakeholders, communities, and the public in a meaningful discussion about practices and policies related to the sharing and use of scientific data.

Before embarking on my analysis, it will be useful to have a definition of scientific openness in mind[1]. Research funding organizations, professional journals, and scientists have proposed various definitions of openness, and there is no single, widely-accepted way of characterizing this idea (Levin *et al.* 2016). Since there is not sufficient space in this article to describe, compare, and contrast these different definitions, I will propose a definition that I think captures some key features of the concept:

> **Scientific openness** is the commitment to publicly and freely sharing the products and means of scientific investigation, including data, results, theories, models, hypotheses, methods, protocols, materials, and computer code used in processing and analyzing data and images.

Three things are important to note about the definition I am offering. First, it involves the free, public sharing of the products of investigation. By 'free,' I do not necessarily mean 'free' in the economic sense, since it may be reasonable to charge a fee for publishing papers, hosting public databases, and sharing materials (such as chemical reagents and transgenic animals) to defray the costs of sharing. By 'free' I mean unencumbered by conditions that unreasonably interfere with sharing[2]. Second, the definition applies to the products and means of scientific investigation. It is not very helpful to share the product of an investigation, such as data, if one does not also share the means used to generate the data, such as methods, protocols, materials, and so on, since these are needed to reproduce or verify the data. Third, openness

[1] I use the term "scientific openness" rather than the related term "open science" because open science is often taken to include the idea of open access to scientific publications (Levin *et al.* 2016). Under an open access system, readers (or end-users) can have access to scientific papers without paying a fee. The costs of publication are usually borne by researchers, their institutions, or their funders (Greussing *et al.* 2020). I think one can have openness in science without insisting that end-users bear no financial costs for access to scientific papers, data, materials, etc. Someone has to pay the costs of sharing. Moreover, openness is a scientific norm that predates the open access movement.

[2] See note 1.

is an ongoing commitment and not simply a particular action. Openness is therefore like other concepts that involve ethical or epistemological commitment, such as truthfulness, objectivity, and fairness. Fourth, openness has much in common with transparency, which involves disclosing the information needed to reproduce, verify, or evaluate research (Cambridge University Press 2022). There are some key differences between openness and transparency, however. One of these is that transparency involves disclosing information that is not necessarily the product or means of scientific investigation, such as sources or funding, conflicting of interests, and authorship, because this information may be important in evaluating research (Resnik 2019; Elliott 2022).

2. A Historical Perspective on Openness in Science

Scientific openness has its origins in ancient Greek philosophy. Greek philosophers developed what is called the Socratic method, after its namesake, Socrates (470-399 BCE). The Socratic method is a form of dialogue in which participants ask each other questions about fundamental philosophical and scientific[3] topics and attempt to develop rigorous answers in response to queries. The dialogue can continue indefinitely, as participants challenge answers offered by other participants. Answers to questions should not be based on tradition or authority but on reasoning. The modern scientific method is based, in part, on the Socratic approach, because science involves continuous questioning and examination of ideas, hypotheses, and theories. Because effective dialogue cannot take place without the sharing of information, free and open debate is essential for using the Socratic method (McMullin 1985). It is important to note, however, that not all Greek philosopher/scientists used the Socratic method exclusively. Aristotle (384-322 BCE), for example, engaged in public debates with other philosophers but also made careful observations of the natural world while working alone. Followers of Pythagoras (570-495 BCE) engaged in public debates but also believed that some types of knowledge were special and mysterious and should only be shared with those who were worthy of receiving them (McMullin 1985).

From the Dark Ages to the Middle Ages (circa 476-1200 AD), science stagnated in Northern Europe but flourished in parts of the world dominated by Islam, including Persia (Iran), Mesopotamia (Iraq), Egypt, Arabia, Iberia (Spain), and India (Burke 1985). While not a great

[3] The Greeks did not distinguish between science and philosophy. The distinction between science and philosophy did not occur until the 19th century (Frank 1952).

deal has been written about the ethos of Islamic science, it is likely that openness was highly valued, because Islamic scientists, such as Muḥammad ibn Mūsā al-Khwārizmī (780-847 AD) and Ibn al-Haytham (965-1040), embraced ancient Greek philosophies and theories; translated Greek texts into Arabic; learned from scientists living in other parts of the world, such as India and China; performed their own experiments; and engaged in rigorous debates about scientific theories and beliefs. While it is reasonable to assume that Islamic scientists had a commitment to openness, it likely that they also practiced secrecy. For example, many Islamic scientists also practiced alchemy, a mixture of primordial chemistry and spiritualism, and guarded this knowledge (Saliba 2011).

During the Renaissance (circa 1350-1500 AD), European science reawakened from centuries of slumber as a result contact with Islamic science; rediscovery of ancient Greek texts, especially the works of Aristotle; the creation of universities in Bologna, Oxford, and Paris; and a renewed appreciation of the beauty and order of the natural world (Debus 1978). Although the methodologies associated with modern scientific reasoning, such as controlled experimentation and mathematization of knowledge, originated in the Renaissance, scientists were not uniformly committed to the kind of openness that we associate with modern science (Debus 1978). Many scientists were secretive because they feared that their ideas would be stolen by others. Italian artist and inventor Leonardo Da Vinci (1452-1519), for example, invented his own shorthand and wrote in mirror writing to keep others from stealing his ideas (Koestler-Grack 2006). Danish astronomer Tycho Brahe (1546-1601) carefully guarded his data on the orbit of Mars and reluctantly shared it with his assistant, the German mathematician Johannes Kepler (1571-1630). Kepler did not have full access to the data until Brahe died (Ferguson 2002).

Johannes Guttenberg's (1406-1468) invention of a printing press with moveable type in 1440 helped to promote openness in science by facilitating widespread distribution of important books, such as Polish astronomer-mathematician Nicholas Copernicus' (1473-1543) On the Revolutions of the Heavenly Bodies and Flemish anatomist Andreas Vesalius' (1514-1564) On the Fabric of the Human Body (Burke 1985). Although the publication of these and other ground-breaking books helped to facilitate the sharing of scientific ideas, communication among scientists still mostly took place through personal meetings, seminars, and letters until the first scientific journals were established in the 1660s

(Resnik 2022).

Another important step in promoting openness was the enactment of patent laws in the US, UK, and other countries. Although some critics of the patent system view patenting as antithetical to openness (see Radder 2019), throughout history it has largely had the opposite effect, because it encourages inventors to disclose information in exchange for being awarded a patent. Inventors disclose information about how to use and make an invention in the patent application, which is available to the public once the patent is awarded. Although patenting encourages short-term secrecy while researchers are developing their inventions, in the long-run it promotes the sharing of scientific and technical information, because it rewards disclosure and gives inventors and companies a profitable alternative to trade secrecy (Resnik 2004; 2007).

By the 1800s, scientists had many ways of sharing their ideas and information and openness was becoming the norm. Even so, secrecy still took place. During the 1800s, the notion of the industrial laboratory was born as scientists in Europe and the US began working for private companies that treated the products of research as proprietary information. Although companies often shared this information with the public by applying for patents, sometimes they preferred to protect it through trade secrecy. In Germany, for example, chemists conducted research for dye manufacturers, but these companies did not want to share information about chemical formulas and processes with their competitors (Dickson 1988).

In the academy, scientists were also often careful about sharing their research with competitors. The English naturalist Charles Darwin (1809-1882), for example, waited twenty years to publish his theory of evolution by natural selection. He formed the theory during his five-year voyage on the HMS Beagle and discussed it with colleagues but did not share it with the wider scientific community, because he wanted to gather additional evidence and solidify his arguments. What prompted to Darwin to share his theory widely was his fear that he would be scooped by English naturalist Alfred Wallace (1823-1913), whom Darwin had learned had independently developed similar ideas about evolution (Berra 2008).

During the twentieth century, governments began to emphasize the importance of science and technology for national defense, and many scientists began working for the military. Military research, like industrial research, was kept secret, to the extent that this was possible. During World War II, scientists made essential contributions to the war effort. English mathematician Alan Turing (1912-1954) developed a computer that was used to break German codes, and US physicists, such as Robert Oppenheimer (1904-1967) and Hans Bethe (1906-2005) worked on the Manhattan Project, which produced the world's first nuclear weapon. By the 1950s, the US and the Soviet Union were spending huge amounts of money on secret military research and President Dwight Eisenhour (1890-1969) warned about the dangerous effects of the confluence of science, the military, and private industry, which he called the military-industrial complex (Resnik 1998, 2009).

From this brief historical review, we can see that openness and secrecy have coexisted throughout the history of science (Vermeir 2012). When Merton wrote about the norm of communalism in 1973, he had identified an important aspect of scientific behavior, but he had not described an absolute standard for scientific ethics. Indeed, one might argue that the ethics of science includes the sharing of the products of research but also opposing norms related to protection of individual intellectual interests and property (Resnik 1996; Resnik 2006; Resnik 2022).

3. A Philosophical Perspective on Openness in Science

Although scientists have not always practiced openness throughout history, today most scientists willingly share data and materials and acknowledge the importance of openness (Levin *et al.* 2016). Additionally, numerous funding agencies, journals, and scientific organizations have policies that require researchers to share data and materials (Maxson Jones *et al.* 2018; Resnik *et al.* 2019; National Institutes of Health 2022; National Science Foundation 2022; World Health Organization 2022). So why is openness now widely regarded as a keystone of scientific ethics and policy? There are three main arguments for this position.

The first argument, which was alluded to earlier during the discussion of transparency, is that openness is essential for reproducibility and verifiability in science. To reproduce or verify another scientist's research, one must have access to the information (e.g., supporting data, methods, protocols, etc.) and materials (e.g., chemical regents, cell lines, etc.) they used to produce the research (National Academies of Science, Engineering and Medicine 2019). While transparency applies mostly to disclosing information, openness includes sharing of materials and thus goes a step beyond transparency. Reproducibility and verifiability are regarded as some of the most important values in science because they are indicators of objectivity and truthfulness (Popper 1963; Haack 2004; Resnik 2022). It is worth noting, however, that in some research disciplines, such as sociology, ethnography, paleontology, or geology, strict reproducibility may not be possible due to the uniqueness or complexity of phenomena. When reproducibility is not possible, it still is important for scientists to verify research and to do this they need access to information and materials used to produce the data.

The second argument is that openness is important for progress in science (Munthe and Welin 1996; Resnik 2006; Sabatello *et al.* 2022). Scientists make progress by building upon the work of other researchers, or as English physicist and mathematician Isaac Newton (1643-1727) so aptly put it: "if I have seen further, it is by standing on the shoulders of giants (Newton 1675)." To build on someone else's work, one must have access to it. Since access to scientific information chiefly occurs through publication and other forms communication, it is not surprising that technologies that enhance communication, such as the printing press, radio, and the internet, have been key drivers of scientific progress (Burke 1985; Warden 2010). Ideally, communication should be public because it reaches a wide audience than private communication. For this reason, many journals require authors to share data by uploading it on public databases (Resnik *et al.* 2019).

The third argument is that openness can benefit the public by making scientific data, results, and ideas available to citizens and public officials (Munthe and Welin 1996). Scientific information often has direct relevance for public policy issues, such as climate change, pandemics management, pollution control, chemical and drug regulation, and so on (Resnik 2009). Public officials and citizens can use scientific information to make decisions about policy issues, and scientists can help public officials and citizens understand and interpret this information (Resnik 2009; Resnik 2019). Scientists have a moral obligation to benefit the public, and sharing information and expertise is an important way to fulfilling that responsibility (Resnik 2022).

While these three arguments provide strong support for openness in science, there are some compelling reasons for practicing secrecy in some situations. Some of these include:

3.1. To protect researchers' professional interests.

Although science is a social activity that involves considerable cooperation and collaboration, individual researchers still have a right to protect their own professional interests, and ethical standards in science must strike a balance between promoting the good of the scientific community and protecting the rights and interests of individual scientists (Resnik 1996) (Resnik 2022) (Paseri, 2022). One reason why scientists may not want to share ideas, data, materials, and methods prior to publication is to ensure that they receive proper credit for their discoveries and innovations. If a scientist shares information with a competitor prior to publication, the competitor may use the information to "scoop" the scientist and publish first. Another reason is that scientists may want to carefully review, audit, process, clean, and analyze the data prior to sharing it widely so that they can prevent erroneous or unreliable data from being used by other scientists and protect their own reputations. Both of these reasons probably had an important bearing on Darwin's decision not to share his theory of evolution widely until he was in danger of being scoped by Wallace.

Most data sharing rules recognize the importance of research interests and only require data sharing after publication (see National Institutes of Health 2022). Although most scientists agree that there is no obligation to share prior to publication, dilemmas can arise after publication, because scientists may still want to protect their research interests. For example, if an epidemiologist spends five years collecting data for a huge database, they may want to publish a series of papers based on the data. If they are required to share the entire database once they publish their first paper, they may lose out on opportunities to publish subsequent papers on other topics because competing researchers may use the data to publish these papers on these topics. A similar type of problem can arise when a researcher develops a transgenic animal and then shares it with other researchers who publish papers based on data from the animal model. One way of dealing with dilemmas like these is for scientists to collaborate with researchers that use their data, methods, or materials, so that they can share their work and receive credit.

3.2. To protect intellectual property interests.

Publication of information concerning an invention can invalidate a potential patent on the invention by undermining the novelty of the invention, which is one of the criteria for receiving a patent (Resnik 2004). Most scientists who are planning to patent products of their research do not publish until they have filed a patent application. Although patenting encourages short-term secrecy, in the long-run it can promote openness because, as mentioned earlier, information disclosed on the application becomes public (Resnik 2004).

3.3. To protect propriety information.

As mentioned earlier, companies usually treat research that they financially support as proprietary, and they may keep this research secret in order to gain a competitive advantage over other companies or elude government oversight or regulation (Resnik 2007; Michaels 2008). While a certain amount of corporate secrecy is ethically acceptable so that companies can protect their economic interests, secrecy should not be used to hide illegal or immoral activity. For example, a pharmaceutical company should not be allowed to hide adverse effects of one of its drugs from regulatory agencies (Resnik 2007).

3.4. To protect personal (or private) data pertaining to human research participants.

Ethical guidelines and legal rules require that researchers protect personal data from human participants (Resnik 2018). Protecting personal data is important to protect participants from harm, such as bias or discrimination, which may result from disclosing their private information, and to protect their right to control access to their private information (Resnik 2018). For many years, researchers who shared human participant data were able to protect privacy by removing personal identifiers (such as name, address, or medical record number) from the data (Resnik 2010). However, in the last fifteen years statisticians have developed various methods for reidentifying individuals in databases containing de-identified genomic data (Lippert *et al.* 2010; von Thenen *et al.* 2019; Shabani and Marelli 2019). It is also often possible to reidentify individuals in databases containing de-identified demographic and geographic data (Richardson *et al.* 2015; Zipper *et al.* 2019). The possibility of reidentification of research participants raises difficult ethical issues for researchers, who must decide how they can share data while still protecting privacy.

There are two different ways of dealing with this issue. One way is to alter the data to make it harder to reidentify individuals (Resnik 2010; Richardson *et al.* 2015). Another way is to require data recipients to sign legal contracts, known as data use agreements, in which they agree to protect the confidentiality of the data and not share it without permission (Resnik 2010). However, both of these ways of dealing with the data sharing dilemma have drawbacks. Altering the data may reduce its quality and utility, and data use agreements can impede data sharing by imposing administrative and legal burdens on researchers.

3.5. To protect human communities or populations.

Sometimes data that are shared publicly may harm human communities or populations that are being studied. For example, publishing a study which shows that a community has unusually high rates of incest, rape, sexually transmitted diseases, or drug abuse could lead to bias or stigma against the community (Sabatello *et al.* 2022). Publishing data about an indigenous population could lead to exploitation of that population (Mc Cartney *et al.* 2022). Researchers have addressed these sorts of problems by consulting with affected communities or populations about publication issues (Sabatello *et al.* 2022). In some cases, it may be possible to minimize harm by omitting the name of the community or population being studied from the published data as well a geographical information necessary to identify the community or population. However, altering the data in this way may decrease its quality and utility.

3.5.1. *To protect endangered species.*

The sharing of data may also harm endangered species that are being studied. To protect a newly discovered endangered species from poaching, researchers may decide to not describe the exact location of the species, which could negatively impact the quality and utility of the data (Tulluch *et al.* 2018).

3.6. To protect national security.

Scientific data may also have implications for national security. In the US, research that is supported by the federal government can be classified if its disclosure would pose a threat to national security. While most classified research in the US is supported by the Department of Defense (DOD), other agencies, including the National Institutes of Health (NIH) and the National Aeronautics and Space Administration (NASA), sometimes conduct classified research (Resnik 2021). It has been the policy of the US government since 1985 that fundamental research supported by the US government, i.e., research that is not protected for national security or proprietary reasons, should be shared openly with the public. However, this policy has been called into question because there have been numerous publications in the biomedical sciences since 2000 that could potentially be used to make weapons for bioterrorism or biowarfare. For example, in December 2011, two papers, i.e., Imai *et al.* (2012) and Russell *et al.* (2012), reporting the results of NIH-funded experiments to genetically modify the H5N1 avian flu virus to make it transmissible by air between mammals were submitted to Science and Nature. The NIH asked the National Science Advisory Board for Biosecurity (NSABB) to review the papers for biosecurity and biosafety issues. The NSABB initially recommended that some key information needed to reproduce the experiments be redacted from one of the papers (i.e., Russell *et al.* 2012), but then later reversed its decision after obtaining more information about biosecurity and biosafety issues. Both papers were published in 2012. Because redaction interferes with reproducibility, it is an extremely rare event in scientific publication, but it has occurred. For example, Dover *et al.* (2014), redacted genomic data from a paper reporting the discovery of novel neurotoxin genes in Clostridium bacteria because there was no effective treatment for the neurotoxin. In 2014, the NIH decided to temporarily stop funding of gain of function research (e.g., research that could increase the transmissibility, virulence, or host range of a pathogen) involving potential pandemic pathogens, but then resumed funding in 2017 after adopting new guidelines. The NIH is currently in the process of revising its gain of function research policies based on biosafety concerns that became apparent during the COVID-19 pandemic (Kozlov 2022).

4. Concluding Discussion

In this paper, I have given a brief overview of the history of openness in science and provided a philosophical justification for sharing data, materials, and other products and means of scientific research. I have also shown, however, that there are some legitimate reasons for restrictions on openness, since publicly and freely sharing scientific information can threaten important values, such scientists' interests in receiving credit for their accomplishments and acquiring intellectual property, the privacy of human research participants, the welfare of communities and populations, the interests of companies, endangered species, and national security. Because openness may conflict with other important social values, solutions to ethical and policy dilemmas should be based on meaningful input from those who are impacted by the sharing of scientific information, including not only researchers and funding organizations but also (as appropriate) research participants, communities, populations, companies, and the public (Sabatello et al. 2022). Decision-making should occur by means of democratic processes that involve fair and reasonable consideration of diverse perspectives.

In some cases, these processes may yield decisions that entail more openness than is currently practiced; in other cases, they may have the opposite effect.

Additionally, data sharing and use policies should be reviewed and revised periodically to account for new developments in science, technology, and society. In the last thirty years, major innovations in the data landscape, such as the internet, social media, global positioning systems, cell phones, wearable health monitoring devices, the use of statistical algorithms and artificial intelligence in data processing, consumer and commercial genetic databases, forensic genealogy, and video surveillance, have eroded traditional notions of privacy and altered how most people think about control and use of personal data (Shaw 2009; Harnish 2017). While it is difficult to predict how data sharing and use will evolve in the future, it is important to be aware of significant changes and adjust practices and policies accordingly.

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