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On the Practical Applications of Philosophy of Science[i]

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Perspective

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Abstract

This paper discusses applications of results from the philosophy of science outside the discipline itself. Part I focuses on applications of general public interest along five fronts. Section I.1 considers the general relevance of the critique of the ideas, methods, and results of science as articulated by philosophers. Section I.2 discusses some of the uses of works on the rise of modern scientific thought as a new form of rationality and sensitivity. Section I.3 takes on the theme of science and the opening of the imagination. Section I.4 comments on the general interest of clarifications offered by philosophers of science of the ongoing project of knowing without guarantees or absolutes. Section I.5 considers applications of the philosophy of science in education. Part II focuses on explicit uses of philosophical works in the sciences. Section II.1 discusses the presence of informal philosophizing. Then Section II.2 explores explicit influences of philosophical works in science. Section II.3 comments on some hostility towards the philosophy of science apparent in some scientists. Finally, Section II.4 ventures a suggestion about scientists as philosophers and its meaning for the relation between the two disciplines.

Keyword: Life; Humanity; Scientists; Secret philosophers; Philosophical works

Most people recognize science as one of the great forms of contemporary creativity (another, according to Isaiah Berlin, is the cinema). Over the last 300 years, scientific knowledge and the power associated with its uses have grown exponentially. Its extraordinary intellectual achievements invite much philosophical reflection about the scope and limits of scientific knowledge and action.

On the "practical" side, the scientific-technological applications of the last century and a half are correspondingly enormous. Today the sciences generate unprecedented resources to emancipate us (or subjugate us). For example, in the Laboratory of Creative Machines at Columbia University, a new generation of robots self-replicate, ask questions, and seem to be variously creative. Drawing inspiration from existing animals, the scientists in charge seek new biological concepts for engineering and new engineering insights for biology[i]. In the biomedical field, the applications of quantum physics, nanotechnology, molecular biology, and experimental psychology are changing our possibilities of action by leaps and bounds and, with it, our understanding of "life" and "humanity." Advances such as these open avenues to realize ancient longings for human fulfillment and liberation. Some innovations are alarming, however. Technology is making disturbingly easier to hack into our minds. We imagine that we make most of the decisions, but psychologists offer evidence that our minds spend much of the time on "automatic pilot." Marketers, social media

i Shuguang Li, et al. (2019); V. Zykov et al., (2005); N. Cheney et al. (2013)

companies, and worse make the most of that pilot.

The sciences are rich in debates of philosophical interest. Consider, as an illustration, the ongoing discussion between nurturists and naturists around the existence of sexual cognitive differences. These include, for example, differences found in the results of standardized tests widely used for college admissions (such as the SAT exam in the US), particularly in the areas of mathematics and analytic reasoning. "Nativist" explanations of such differences focus on biological factors invariant to culture, notably genes. By contrast, "nurturist" explanations emphasize cultural and environmental factors. The resulting debate is both passionate and one of the most interesting of our time, rich in metaphysical, epistemological, and ethical implications. The fight remains in mid-flight[ii]. Philosophers of science critically examine these debates. To this end, they study the ideals of public accessibility, critical attitude, justification, and explanatory and predictive success immersed in scientific practices. They look at specific scientific proposals (like those on cognitive differences), contrasting the claims at play with the evidence adduced for them, trying to sift the reliable from the unreliable. Their efforts include analyses of the arguments deployed in the different disciplines (deductive, inductive, abductive, statistical), the nature and structure of the theories proposed on a case-by-case basis, the methodologies employed for accepting and rejecting hypotheses, and the scope and limits of the resulting scientific verdicts.

More generally, philosophers scrutinize the philosophical history of scientific thought, the ontologies of theories taken literally, the relationships (harmonious or tense) that theories have with other perspectives at play today. And they examine the roles played by facts and values in scientific practices, among other themes of interest. The studies that result from all this certainly keep philosophers fascinated and busy. But, outside their field of specialization, what is the use of the results they obtain? Today, the philosophy of science has significant applications of general interest, or so I suggest in this paper.

Overview

This paper discusses applications of results from the philosophy of science outside the discipline itself. Part I focuses on applications of general public interest along five fronts.

Section I.1 considers the general relevance of the critique of the ideas, methods, and results of science as articulated by philosophers.

Section I.2 discusses some of the uses of works on the rise of modern scientific thought as a new form of rationality and sensitivity.

Section I.3 takes on the theme of science and the opening of the imagination.

Section I.4 comments on the general interest of clarifications offered by philosophers of science of the ongoing project of knowing without guarantees or absolutes.

Section I.5 considers applications of the philosophy of science in education.

Part II focuses on explicit uses of philosophical works in the sciences.

Section II.1 discusses the presence of informal philosophizing.

Section II.2 explores explicit influences of philosophical works in science.

Section II.3 comments on some hostility towards the philosophy of science apparent in some scientists.

Section II.4 ventures a suggestion about scientists as philosophers and its meaning for the relation between the two disciplines.

A caveat emptor is in order at this point. Controversy, far from being rare in philosophy, is a persistent and pervasive presence at nearly all levels. Current studies in the discipline encompass a diversity of interpretive approaches. Philosophical reviews of the sciences are correspondingly multiple regarding theories and practices, their character, function, intellectual and practical impact. For example, regarding the relationship between theories and their intended domains, the positions held presently range from radical anti-objectivism to strongly objectivist positions. Arguably, most projects under the analytic philosophy banner (broadly construed) take non-extreme positions that allow for some local consensus. Still, in philosophy, consensus is unstable, and the latitude of options alive in the field makes it difficult to describe the external uses that philosophy of science has today. So, there is a predicament here. In addition to trying to be balanced, all I can do is keep the reader on guard and grounded. (It seems appropriate to disclose that my views generally lean towards a naturalist functionalist variety of selective realism[iii]).

Part I: Contemporary Uses of General Interest

The Critique of Scientific Ideas

Philosophy of science does not aim primarily to celebrate the yields of science but to examine them critically. Philosophers try to assess scientific proposals and, to the extent possible, integrate the best established of them into a picture of the world and ourselves in it. Many try to articulate "vital epistemic maps" that can be used to understand the

ii Philip Kitcher (2001, Chapter 8); and Alberto Cordero (2005).

iii Cordero (2017, 2020).

world and we in it, know what to expect, and act accordingly.

One use for such maps is apparent in ordinary life. Take, by way of example, the mythopoetic reactions to the Covid-19 epidemic we get these days continually. On April 1, 2020, Donald Trump described the coronavirus as "our great enemy in a 'total war.'" Within days (April 9), Pope Francis proposed that the coronavirus pandemic is one of nature's responses to humans ignoring the current ecological crisis. Other leaders followed suit with similar explanations. Their accounts ring true to many people. There is, however, the critical alternative of looking at the current pandemic through the "scientific-naturalist map" of the world. In that map, nature does not appear as an "agent;" it cares about nothing or anyone, except perhaps the transmission of genes to the next generation. The Covid-19 virus does not cause harm intentionally. The on going plague does not expose wars against malicious agents. In the scientific-contemporary map of the world, the coronavirus is like any other virus or pathogen. It is merely a reproductive machine adapted to today's human environment. Fighting with other organisms often brings us despair and tragedy. But from a general evolutionary perspective, the drama it depicts has a neutral value. As Stephen T. Asma (2020) notes, strictly speaking, the biological struggle for existence and natural selection are not even a drama because, strictly speaking, there is no plot in nature—natural selection is neither malevolent nor benevolent. Why, then, mythical interpretations remain so well received in society? The anthropological region of the scientific map suggests that mythopoetic stances have short-term unifying social value. According to Asma, personifying nature helps us better prepare for the future and correct our environmental policies. Imagining that we are at war with an enemy helps us make difficult personal sacrifices (such as practicing social distancing and home confinement) that go beyond our selfish hedonism. To imagine that our sins against the environment have unleashed nature's vengeance can be adaptive and beneficial. In situations such as this, philosophical labors like the ones mentioned above can be helpful.

Philosophers of science seek to evaluate science products and, to the extent possible, integrate the most convincing of them into a family of reliable maps of the world and us in it. Different pragmatic perspectives give rise to appropriately different charts, each a potentially useful "vital resource" to understand the world and act in it.

A New Way of Knowing

In the seventeenth century, proper knowledge, free of any possible doubts, seemed within reach. To René Descartes, such knowledge could only come from clear and distinct ideas. To the Cartesians, a proposition was "intelligible" only if the ideas involved were "clear and distinct." Not explaining in terms of such ideas counted as a failure. Soon, however, scientific thinking would abandon this auroral optimism for a more modest approach.

The dilemma between admitting or not ideas that flunk the requirement of clarity and distinctness ("opaque" ideas) has an iconic expression in Isaac Newton's arguments for the Law of Universal Gravitation in the editions of the Principia published during his life. The ideas he puts forward there proved successful and very fruitful. Still, Newton never explained his proposed gravitational action at a distance in terms of clear and distinct ideas. Documenting the Law was easy, but understanding it was not. While accepting the need to make mechanical sense of the Law, in the Opticks he rejects the Cartesian suggestion that not doing so paralyzed his epistemic project:

"These Principles I consider, not as occult Qualities, supposed to result from the specifick Forms of Things, but as general Laws of Nature, by which the Things themselves are form'd; their Truth appearing to us by Phaenomena, though their Causes be not yet discover'd. For these are manifest Qualities, and their Causes only are occult." [Query 31 of *Opticks*, 1704].

In fighting back, rationalists accused Newton of introducing "occult" influences into science. Gottfried Wilhelm Leibniz complained that Newtonian gravity acts in an unacceptably mysterious way. He expressed doubts that it corresponded to real action. Newton responded by recognizing his theory's conceptual opacity and adopting an agnostic stance on "deep explanations" of the Law of Gravitation (hypothesis non fingo). While admitting that his Law and associated equations gave an incomplete description of how objects behave, he considered adequate the story provided. But he never stopped hoping to achieve a fuller interpretation of gravity, free of mysterious influences.

Physics would increasingly follow Newton's chosen course. To the extent that Newton did not explain why objects behave as they do, his proposed scientific discourse gave only a "partial explanation" of the phenomena. Critics voiced fears that the Newtonian project had abandoned the search for intelligibility. For this reason, "modern science" was long regarded among the academic elites as "natural pseudo-philosophy"—a pursuit of second-class knowledge. Over time, however, the new style of doing physics would supplant the traditional philosophical project in an increasing number of areas. But the modern admission of epistemological and metaphysical limitation did not make nature less intelligible. The shift helped the explanatory project in many areas. One success here was the discovery of "intermediate" levels of explanatory knowledge that have, nevertheless, proved to be enlightening, fruitful, and arguably as reliable as anything at our disposal.

Since the mid-eighteenth century, the empirical sciences *have increasingly settled for modest* and sober answers compared to traditional philosophy, accepting explanations that are teleologically opaque, fragmentary, hypothetical, tentative, and open to change in light of new data and reasons. Explanatory programs directly guided by the Newtonian model of natural philosophy proliferated throughout the nineteenth century. They include, among other developments, modern compositional chemistry, a new geology based on uniform universal laws governing geological processes, the theory of evolution by natural selection, and the general Newtonian takeover that took place in the aftermath of energetism (one of the last bastions of Leibnizian dynamism) early in the twentieth century.

Today the empirical sciences keep alive many of the central philosophical options Newtonians took. Although "partial" by the standards of early modern philosophy, scientists generally aim at explanations that are still illuminating and compelling. Most scientists seemingly think there is reason to hope that more profound and less opaque theories will come to the fore.

Opening the Imagination

The development of modern science has gone hand in hand with the breaking of barriers to creative thinking. Boldly imagining what had seemed previously unimaginable is a hallmark of science. In 1900, it seemed absurd that any objects might move in empty space at the same speed for all reference systems, regardless of the relative velocities between them. A few years later, however, this idea, initially so unreasonable, had found coherent expression in Einstein's revolutionary conception of space, time, and matter.

Numerous scientific innovations of the last century show how deeply it is possible to revise conceptual ideas and relationships. Beliefs long held to be incontrovertibly true have been proven wrong, and ideas that contradicted traditional intuitions have developed into fruitful constructs. In twentieth-century physics, numerous developments illustrate such breakdowns of intellectual barriers. One is Einstein's approach to space-time-matter-energy. Another conspicuous example is quantum mechanical challenges to the classical principles of separability, locality, and the traditional metaphysical principle of identity. The history of science abounds in similar breakthroughs in the study of organic life, the mind, human nature, and the natural history of ethical categories, among other areas.

In our time, studies in the foundations of quantum mechanics are rich in examples of the opening of the imagination referred to here. The most advanced versions of the so-called "many worlds" approach remain controversial. Still, they attest to significant gains in internal coherence. Notably, they offer tighter formulations of the idea (originally regarded as "absurd") that what we perceive as an "instantaneous collapse" of the wave function can be understood as part of the branch-rooted, branch-relative-reality character of the phenomenon we call "awareness[iv]."

Without Absolute Guarantees

One interpretation of the intellectual openings noted in the previous section is that, in addition to helping us learn about the world, science helps us *learn how to learn*. This idea is one of the contributions of the historical turn in the philosophy of science from the 1970s and 1980s in reaction to relativist views of science encouraged by Thomas Kuhn (1962) and others. Works by Dudley Shapere from the period provide articulations of the noted thesis about learning (see, e.g., Shapere 1983, 1990). Suspicious of essentialist interpretations in philosophy, Shapere denied that any synthetic ideas deserve to be considered "essential" or "necessary" in science. In his view, the knowledge available rests on the best scientific information at every moment, but this knowledge never ceases to be open to the possibility of critical revision. Like Kuhn before, Shapere rejected the "thesis of inviolability" (1984: pp. xix-xx). In scientific thought, he urged, there is nothing that cannot be questioned and revised in the light of future findings. He thus denied that for science to work appropriately, research programs need to have fixed semantic and conceptual identity. He argued that the criteria of rationality do not have to be universal and timeless to contribute to the unveiling of theoretical truths. Through science, he maintained, "we learn to learn." Shapere rejected the notion that the dynamical features of scientific reason ruined the project of objectivity. In his view, for the most part, the evaluation criteria involved are not so mortgaged to paradigms as to make it impossible to affirm the rational superiority of one theory over another. Inter-theoretic comparison—he contended—can go a long way by focusing on selected theory-parts that show empirical success and freedom from specific doubts (i.e., properly scientific doubts, as opposed to global or "metaphysical" doubts).

One decisive episode of learning was the modern articulation of the piecemeal approach to the study of nature. In the seventeenth century, some natural philosophers realized that we could fruitfully study the world by breaking it into partial domains open to empirical scrutiny. Among the first domains benefiting from this strategy were the motions of bodies, the properties of light, the behavior of gases, and the world of chemical transformations—each studied

iv For an excellent presentation of advances in this direction, David Wallace 2012.

in isolation from other domains that traditionally had accompanied them. The results were then compatibilized as much as possible, without any guarantee of unification. The separations of domains were periodically revalued in the light of its scientific results. Gradually, scientists learned to study partial aspects of the world by methodologically abstracting them from their total context in nature. Today, no scientist tries to describe anything in terms of all the possible variables relevant to the matter at hand. Physicists represent the silver atom primarily by its atomic and mass numbers and by its energy levels. The resulting descriptions ignore indefinitely many aspects of the "total reality" of any silver atom—its immediate location, the biological species and mountains around it, the spectrum of radio waves in its vicinity, the location of large silver deposits on Earth, the languages spoken by miners extracting silver, and so forth. Backed by this research strategy's empirical success and fruitfulness, scientists assume that the causal relationships, regularities, and processes not taken into account impact the entities studied negligibly.

In these ways, forged from an imperfect epistemic situation, the modern "scientific" style of knowledge is modest compared to others in history. Still, many naturalist philosophers are cautiously optimistic about the result. In numerous fields of interest, they argue, this humble way of studying the world has succeeded in accomplishing many of our epistemic and practical goals better and more efficiently than other imagined ways of doing so. The successes achieved go far beyond what our ancestors had imagined possible in cosmology, the physical sciences, biology, psychology, and anthropology. One naturalist reaction is that, while the knowledge made available by science lacks absolute certainty, to know, we do not need to know that we know.

Pedagogical Applications

Another important use of the philosophy of science occurs in the field of education. Today's life, immersed in scientific ideas and products, leads us to value science teaching in schools. The young need competent training to enable them to understand and critically evaluate the scientific proposals before them. The benefits here are not only technical but also civic and cultural. On the civic side, there is an urgent need to nurture and defend the democratic project by fostering critical attitudes at all levels. In democratic societies, citizens must increasingly decide at the ballot box between projects with high scientific and technological content. To do so, citizens need to understand the topics involved and the existing options. Achieving such competence is virtually impossible without teachers capable of understanding the ideas, methods, and scientific ways used in representing the world and passing that on to their students. Democratic societies need also to fight the conformity and alienation that invades contemporary life almost everywhere. The allure of futures like that of the Brave New World imagined by Aldous Huxley, in which the gods of consumption, comfort, and lack of critical reflection finally triumph, making people extremely happy at the expense of sacrificing long-cherished human values.

On the cultural side, part of the pedagogical interest in science's philosophy lies in helping teachers and students see the great scientific discoveries as the intellectual and human adventures they are. Fortunately, work is underway in this direction. For more than forty years now, movements such as the International History, Philosophy, and Science Teaching Group, founded by Australian educator and philosopher Michael Matthews, have been active. The studies fostered by this and other groups show how science teaching and science teachers' education can be improved by including courses and activities on science's history and philosophy in their curriculum[v].

The above uses matter if, as many of us think, citizens need to understand the choices in front of them.

Part II: Philosophy of Science in the Sciences

This second part comments on the uses of the philosophy of science in scientific practice.

Informal Philosophizing

Philosophical concerns are informally present in science, perhaps most noticeably regarding conceptual clarification, observation, and theory appraisal.

(a) Conceptual clarifications improve the precision of scientific terms everywhere in science, leading to differentiation that improves empirical explorations of the field at hand. One instance in point is the way the concept of sex has gained structure in recent decades. Biologists and psychologists now distinguish five levels (see, e.g., Baron-Cohen (2003), Chapter 8):

(i) Genetic sex (determined by the individual's set of XY chromosomes).

(ii) Gonadal sex (determined by the hormonal function of the individual's testes or ovaries).

(iii) Genital sex (determined by the functional state of the individual's penis or vagina.

(iv) Brain sex (determined by the individual's brain type).

(v) Behavioural sex, which usually follows "brain type."

(b) Observations are *theory-informed*— they depend on some accepted theories. Believers in "pure facts" may wish things to be otherwise, but there are no facts unmediated by

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v Matthews (2000, 2014, 2018).

theory—all statements of fact presuppose one hypothesis or another. All claims made at the public level rest on some theory and are correspondingly fallible and open in principle to reinterpretation. With a home telescope, we can see that the Moon has mountains. We accept as faithful the images the telescope gives because we are satisfied that it is a combination of lenses arranged according to well-established optical theory. Even the most low-level observations are theory-informed. If so, no public-level statement is "purely factual". The idea that scientists trade in purely factual claims (or can coherently aspire to do so) is a myth. Thus, there is a general need to reflect on this matter and its impact on the objectivity of scientific theories and proposals. And many scientists do so.

(c) Theory assessment is also a component of science prone to philosophical "outbursts." Typically, the acceptance or rejection of a theory rests on the existing evidence for or against it. But the available evidence can be ambiguous and, when it is, scientists must think outside the standard rules. Judgment is needed. As Ernan McMullin (1983) urged, theory-appraisal is a sophisticated form of value-judgment. This explains why controversy, far from being rare, is a persistent and pervasive presence in science at nearly all levels. Many of the disputes at play in science have philosophical cores, as attested by current debates on the foundations of physics, evolutionary biology, chemical building blocks, consciousness and the brain, to mention just a few.

To the extent that explorations like the ones just mentioned take place within science, scientists do philosophy. But this is not enough to claim that practicing scientists *use results from the philosophy of science*. Whether recognized or not, science abounds in philosophical applications.

Explicit Influences

Explicit uses of philosophical results are, in fact, widely apparent in the sciences. Recall, for example, Darwin's careful readings of the writings of the most influential custodians of scientific thought in England at the time, John Herschel and William Whewell. Darwin particularly favored the argument that scientific explanations should identify "true causes" and the associated project of explaining the epistemological quality of Newtonian astronomy. In his book *On the Origin of Species*, published in 1859, Darwin scrupulously put Herschel's and Whewell's ideas into practice, especially the latter's concept of "consilience" (Ruse 1975, 2006).

On the physics front, in the last quarter of the nineteenth century, positivist philosophy grew influential in physics, conspicuously in the foundational work of Ernst Mach, then in Einstein's Theory of Special Relativity in the early years of the twentieth century, and yet again in the development of quantum mechanics between the 1920s and the 1940s. Positivism also played a significant role in the constitution of behaviorist programs in psychology. Anti-positivism, too, has had a presence. Ideas of ontic and epistemological realism gained purchase within theoretical physics in the mid-1950s and have remained influential since, especially in critiques of "Copenhagen" versions of quantum mechanics. The resulting developments illustrate the topic of this section well and merit a short detour.

Most quantum mechanics textbooks introduce the standard theory through a set of prescriptions presented with surprising contempt for clarity. In particular, the term "measurement" functions in them as a primitive term, left opaque, even though quantum mechanics purports to pass as a fundamental theory of matter. Along the way, the standard theory divides the physical world into a classical realm and a quantum realm, without specifying exactly where the division lies between the two. All it offers are loose tips about where to place the cut "for all practical purposes." This isn't very reassuring for those who expect physics to provide a physical description of the world (Maudlin 2019). In important respects, the textbooks in question provide recipes that, admittedly, lead to extraordinarily accurate predictions in numerous kinds of applications, albeit in ways that are left mysterious. Through those applications, students learn in a "practical way" how to handle phenomena such as quantum interference, the quantum state, quantum uncertainty, probabilities, the Born rule, complementarity, quantum non-locality, and effective separability. Yet those textbooks provide only vague clues about which parts of the mathematical formalism represent the world's physical characteristics and which do not. The theory offers falls short in explanatory value. The authors address the vagueness of the rules by appealing to "classical intuitions," setting aside the question about what the physical world is like behind the recipes.

The resulting critiques of the standard version of quantum mechanics illustrate the growing intertwining of physics and science's philosophy since the mid-1970s. They have led to fruitful interactions between physicists and philosophers over the last half-century. Some of those interactions have brought to maturity at least three families of ontic interpretations of quantum mechanics—i.e., interpretations that go beyond the quantum state's epistemic interpretations[vi]. Jointly developed by philosophers and physicists, in these contributions, the fundamental level of

vi According to ontic interpretations, a difference in the wavefunction necessarily implies a difference in the underlying *ontic* state of the system at hand. "Psi-epistemic" interpretations deny that implication. Three prominent ontic families have gained prominence since the 1980s, each postulating explicitly physical interactions.

theoretical description is free of references to measurement, belief, the observer, and such[vii]. Two of the families (the so-called "many worlds" approach and the "pilot wave" approach) keep the quantum state dynamics free of discontinuous changes. The other family incorporates a process of wave function collapse. These studies make a genuinely interdisciplinary branch of physics and philosophy. Furthermore, they make good examples of the opening of the imagination referred to earlier in this paper.

A similar collaborative trend between scientists and philosophers is on view in other areas. In chemistry, for example, opportunities for philosophical collaboration are rich and promising. For example, the question about the scope and limits of physics is a lingering concern in chemistry and other basic sciences. One worry is the role of quantum mechanics in explaining chemical phenomena. Consider the property of handedness or "chirality" and the optical isomers associated with it. A proper physical explanation seems complicated because Coulomb interactions determine the Hamiltonian and so, the latter only depends on the distances between the particles composing the molecule. In optical isomerism, all the inter-atomic distances are the same for the two members of the pair and hence the Hamiltonian is the same for both. Accordingly, quantum mechanics gives the same description for two structures that can, nevertheless, effectively be distinguished in practice through their optical and biological activity. Why do specific chiral molecules show temporally stable optical activity associated with a precisely defined chiral state (as opposed to a superposition of possible chiral states)? The Hamiltonian operator is parity invariant, and so it cannot have chiral states as eigenstates—its eigenstates are superpositions of chiral states (see, e.g., Amann 1992). Optical isomerism is difficult to explain quantum mechanically in terms of molecular structure. Philosophers of science and physicists working together on this problem make suggestions that arguably improve the ongoing debates[viii].

Many branches of science display similar cooperation from philosophers. Recent contributions of philosophers of science to biology include, for example, works on levels of selection in the neo-Darwinian program (e.g., S. Okasha (2006), and on the logic of chance (e.g., E.V Koonin (2011), to mention just two cases. On a different front, in recent decades cognitive science has developed ties with the philosophy of psychology and the philosophy of mind. One example is apparent in reactions to the pioneering experiments on the limits of free will conducted by Benjamin Libet. In the 1980s, Libet had subjects choosing a random moment to move their wrist while he measured the associated activity in their brain. The initial findings suggested that the experimental subjects decided following choices first made on a subconscious level and subsequently turned into a "conscious decision." Controversies ensued. Three decades later, many neurophysiologists have concluded that free will is a complicated subject, whose treatment can improve with help from philosophers. Presently, a research program involving 17 universities and backed by more than $7 million from private foundations hopes to break the deadlock by bringing together neuroscientists and philosophers (Bahar Gholipour 2019). Eight neuroscientists and nine philosophers involved in the program are committed to getting compelling results by asking precise questions and designing philosophically sound experiments. They hope to find out what it takes to have free will, whether we have what it takes to make us "free," how (if at all) the brain enables conscious control over decisions and actions. In general, the team hopes to establish the neuro-philosophy of free will as a new field in the study of the brain.

Direct cooperation between scientists and philosophers is not hugely widespread but seems to be growing. To the degree that this is so, philosophers of science have a presence in contemporary science, even if this often goes unnoticed. Routinely scientists confront issues that cannot be resolved by invoking facts alone. Time and again, at crucial points, scientists explicitly turn to elucidations contributed by philosophers of science.

Some Hostility

Why, then, do scientists often show hostility to the philosophy of science? Many good scientists regard philosophy as the locus of ideas and debates that get nowhere. They contrast philosophy with science, which they see as tightly concerned with the discovery and systematization of "solid" facts we can rely on to guide our decisions and actions. This suggestion would seem unfair, however. Although much of what passes for philosophy probably warrants the verdict just noted, arguably there is plenty of good philosophical work within science.

At any rate, formal scientific education tends to discourage explicit incursions into philosophical inquiry. One common reason for this is an institutional desire to focus students' attention on officially important issues in each discipline, a consideration fortified by the noted idea that philosophical controversies are somewhat second class. Subrena Smith (2017) highlights the relative disdain for philosophy among scientists who believe no special training is needed to address the philosophical problems in their respective disciplines. Another source of mistrust comes from a frequently ruthless appreciation of efficiency in scientific circles. From this perspective, Stephen G. Brush (1974) elaborates on a

vii Cordero (2019).

viii Sebastian Fortin, et al. 2018

paradox presented to science educators by Thomas Kuhn (1963)'s argument that historical readings would be harmful to a science student. In the history of theories, he thinks, the student might discover other ways of regarding the problems discussed in a science textbook, which might lead to wasting time doing work that will not have a home in scientific journals. Philosophical readings would be if anything, more disruptive. From this perspective, impressionable students at the start of their scientific careers should be shielded from the writings of contemporary philosophers and science historians. Why? Brush notes that those writings "often do violence to the professional ideal and public image of scientists as rational, open-minded investigators, proceeding methodically, grounded incontrovertibly in the outcome of controlled experiments, and seeking objectively for the truth, let the chips fall where they may." On the other hand, in the same article, Brush observes that some exceptional interpretive articles and books on twentieth-century physics have led many teachers to conclude that such studies might indeed beneficially challenge their brightest students. Topics in point include analyses of the views and debates of Albert Einstein, Niels Bohr, Erwin Schrodinger, Werner Heisenberg, Paul Ehrenfest, and others, as well as the joint philosophical efforts highlighted in II-2 above.

For better or worse, practicing scientists tend to be unaware of the philosophical adventures underlying the theories they accept and deploy. However, appreciating the intellectual mortgages scientific proposals carry can improve scientists' performance, as has occurred several times. Recall, for example, Einstein's scrutiny of the simultaneity relationship. Recall also Bohr's equally fruitful revision of the classical concept of separability. Even the most objective and reliable discourses in the sciences have philosophical underpinnings.

Philosophers should perhaps do more to explain in accessible ways this dimension of science. Some colleagues (unfortunately not many yet) strive to do this.

Scientists as Philosophers

I close with a suggestion about scientists as "secret philosophers." The sciences, particularly the more fundamental ones, are recent descendants from philosophical projects. The old spirit lingers in many of their practitioners. To the extent that this is so, the philosophy of science is a resource for making explicit the philosophical dimension of their scientific lives. As noted, among other things, philosophers offer maps of the intellectual adventures underpinning on-going scientific projects. The point here is that adequately presented, philosophy of science can help scientists to enjoy their scientific work more consistently and fully. Many scientists concur with this view, judging by their appreciation for forums such as the journal *Foundations of Physics* and other similarly oriented journals and meetings. Similar situations are apparent in other scientific disciplines. Of course, Kuhn's (1963) followers might stress the pragmatic inconvenience of making room for philosophical reflections amid the heat of "properly scientific" research. It is a matter for each scientist to decide.

There are other applications of the philosophy of science, but I think the lines outlined in this paper represent the overall public relevance of the discipline today.

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