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Chapter 6
Serendipity and the History of the Philosophy of Science

Samantha Copeland

Abstract Samantha Copeland takes this chapter to delve into the history of philosophy of science, paying particular attention to the discussions around scientific discovery and the assumptions made by philosophers along the way about what parts of the discovery process can and cannot be studied. Copeland suggests that serendipity research might shed light on what has been left outside of philosophical investigation. She focusses in particular on the seeming 'leap' that scientists must take when discoveries happen, between a state of not-knowing to a state of recognizing the scientific value of an observation or event. Most philosophical accounts tend towards internalism (that is, assuming the important steps in discovery occur only in the mind), or the focus remains on what happens *after* an accident or chance encounter rather than on the encounter itself. Copeland offers an alternative interpretation from the perspective of her serendipity research, on what the interaction between chance and reason can tell us about scientific discovery more generally. That is, she argues, the intersection of chance and wisdom provides philosophy with the opportunity to better understand how our minds interact with the world to produce knowledge.

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There is little work done in the philosophy of science[1] that focusses explicitly on the nature of serendipity, that category of discoveries which occur at the intersection of chance and wisdom (Copeland 2019). Literature on serendipity and accidental discovery can be found more often in the social sciences. There, the contingencies of personal traits, context and culture are studied as driving forces behind scientific knowledge production, looking closely to the history and practice of science (instead of philosophy's more narrow emphasis on the reasoning that scientists employ). Merton and Barber (2004) note in their seminal work on the word 'serendipity' that appreciation for the role of chance in the practice and progress of science has risen and fallen over time, varies from field to field, and that the opinions of scientists and the public may differ on whether it is a good or a bad thing that discoveries often occur accidentally.

Some have argued that science is even mostly due to chance (e.g., see Chap. 5 in Trout 2016). Whereas others have judged a reliance on happy accidents to be a sign of laziness, arguing that a belief in progress through serendipity is for those who want science to be easy enough for anyone to do it, or to discredit those who consider it an elite, skilled enterprise (e.g., Merton and Barber 2004, Chap. 9). Indeed, because serendipity occurs in all areas of life and study, there seems little reason to think it marks something special about science itself, or scientists, and so it might well fall outside of the scope of interest for many, belonging to the mundane. For others, however, serendipity happens only to the 'prepared mind' and as such can indeed be a sign of deep skill and scientific ability (Cannon 1940; Copeland 2018; McAllister 2016). Western philosophers of science,[2] however, most generally focus on teasing out the nature of what we call scientific reasoning, and explaining how we obtain knowledge through practice (see Strevens 2020 for a critique of this assumption). I argue that in the philosophical literature we see little concern for a deeper understanding of chance, and the accidental tends to be left out of accounts of how science happens—externalised,[3] mentioned but unexplained, tangential or missing altogether from what counts for understanding discovery—with few exceptions.

[1] There are other areas of philosophical study where luck and chance have played a more prominent role, namely in epistemology, where examples of 'epistemic luck' have been famously used to critique universal theories of knowledge acquisition (e.g., the Gettier examples, wherein people have knowledge but have gained it or are able to confirm it because of accidental features of the process, rather than rational, intentional processes in themselves). There is ongoing debate on epistemic luck (see particularly the work of and in response to Duncan Pritchard, on veritic and reflective luck; see also (Rescher 1995) for some similarities between serendipity in science and epistemic luck).

[2] My focus here and elsewhere in my work so far remains unfortunately constrained by a Western approach; there is much to be done, and work I hope yet to do, toward understanding non-Western accounts of science in relation to chance.

[3] For instance, accounts of science often consider the social context in which scientific practice and theory formation take place to have influence on its development, but I contend that describing the accidental as a condition for science to occur, is not the same as including it within our account of science itself. The accident is taken for granted as a precursor to the subject of interest, and thereby stipulated in such accounts rather than studied.

Nonetheless, it is the case that in the study of science and discovery, experts have been unable to avoid at least mentioning the frequency with which accidents, error and chance do come into play. Discovery stories often mention the interference of a dream, forgetfulness or other disruption in the otherwise rational research process. Famous examples such as Fleming's chance noticing of the nearly-discarded petri dish to observe penicillin in action, or Kekulé's dream of the encircled snake to arrive at an explanation for benzene's chemical shape, capture the imagination in popular collections of tales of discovery (e.g., Meyers 2007; Roberts 1989; van Andel 1994). These elements in such tales create a sense of magic around discovery that lends itself to storytelling.

Merton may have been the first to really establish a theoretical use for Horace Walpole's invented term, serendipity—coined to capture 'discoveries made by accident and sagacity' (see page xi this volume for the relevant passage). Merton's 'serendipity pattern' (Merton 1948) describes what he considers a fairly common occasion in scientific practice, one of several ways in which events can affect theory fairly directly, when an 'unexpected datum imposes itself' upon an investigating scientist. Since then, various approaches to studying discovery in science have led theorists to conclude that the unexpected plays a key role, and that the strategies employed by scientists in response to the unexpected tell us something about scientific discovery in general (e.g., Dunbar and Fugelsang 2005, p.61). Again, most of these examples and theoretical approaches come from outside of philosophy.

Part of the explanation for the relative lack of investigation into discovery (compared to the attention paid to explanation and justification) from within philosophy of science comes down to history: decades ago, a distinction was made between the context of discovery and the context of justification, with the latter thought of as being the proper subject of philosophical investigation, relegating the former to psychology, history and sociology. As a consequence, discovery-talk maintains a general vagueness about it, using concepts such as genius, chance, and serendipity, which seem to hold place for something 'other than reason' rather than offering meaningful alternative categories. That is, the moment of transition into discovery remains highly contingent and particular: mysterious and potentially ungraspable except in the very context in which it occurs (e.g., Okasha 2016, p.73–4). At the very least it is emergent and complex, and thus difficult if not impossible to make explicit, and easier to describe than to theorize.

Yet we are drawn towards the 'leap' from ignorance to knowledge that discovery represents (see also Arfini, Chap. 7, this volume). Indeed, the distinction between discovery and justification has been increasingly maligned of late: we can hardly understand how theory comes about or how we might assess one theory over its rivals without a comprehensive picture of the process of science that includes discovery. In this chapter, I explore how this gap in our ability to explain what happens when discovery happens is part of why serendipity and accident have been so frequently left out of philosophical accounts of scientific reasoning, theory and practice. I argue that, in contrast, accident and chance, and especially serendipity are an important topic for philosophical study.

Serendipity is especially relevant because it is more than mere luck—sagacity, a kind of wisdom accredited to the serendipitous (but not the merely lucky), separates it out as a different kind of thing, one that includes the contingencies of fortune but also the wise perception often attributed to a genius and marking skilled observers. Indeed, I hope to show that the inclusion of sagacity as one of its primary criteria makes serendipity a very useful, bridging category, suitable for helping us understand better how we make discoveries, and when and how we can be prompted to make the move from confirming what we already know into the realm of creation and innovation.

Rather than a mystery, recent research points to sagacity and chance being interacting phenomena, an interaction we can not only come to understand but that we could purposefully develop and prepare for, and this in turn changes how we might think about the role that chance plays in scientific reasoning. Thus, in this chapter, I offer a review of key approaches to serendipity in science, from diverse disciplines and fields within them, with a focus on how the intersection of accidents or chance with sagacity or wisdom can provide philosophers with insight into the practice and progress of science and indeed provides a more comprehensive and correct picture of scientific progress than accounts which elide them could do. I propose, in turn, that integrating accident into our understanding of scientific practice is the right approach for philosophers of science—reason does not merely compensate for chance interruptions but rather takes them up into rational processes; if we take serendipity seriously, then we can see it as presenting a case study for the direct interaction of reason with chance.

The Context of Discovery

Within philosophy of science, the decades of avoidance of the nature of discovery as a topic for study is often suggested to have been the result of the division between the contexts of discovery and of justification, suggested by Reichenbach but taken to heart by highly influential logical empiricists. Justification, according to Popper, was the proper subject of philosophy, the study of reasons and natural laws. "Every discovery", on the other hand, "...contains 'an irrational element', or 'a creative intuition'" (Popper 2005). Paraphrasing Einstein, Popper suggests thus that the path to discovering new laws through experience is not something we can rationally reconstruct, nor would we want to.[4] And moreover: "If it is the processes involved in the stimulation and release of an inspiration which are to be reconstructed, then I should refuse to take it as the task of the logic of knowledge. Such processes are the concern of empirical psychology, but hardly of logic" (Popper 2005, p.8). In similar fashion should the investigation of serendipity, which according to this distinction

[4] Even before Reichenbach, and as I discuss further on in the chapter, Whewell and others had suggested that the role of chance and genius in discovery meant that there could be no way to explicate the art of discovery (Schickore 2006; Silver 2015, p.249).

may be seen as one of the least rational categories of discovery, be cast to the social sciences and out of philosophy.

Brannigan (1981), in his review of the history following Popper's distinction, points out that addressing the role of chance was a continuing problem for those seeking to pull discovery back under the cover of philosophy-worthy topics. For instance, an early critique by Hanson (1967, see p.322) of this contextual distinction and dismissal of discovery, notes the relationship between the non-rational nature of inspirational moments and concerns about the role of chance. Because chance frequently inspires discovery, that is, poor Popper assumed mistakenly that there can be no logic of discovery, in turn. For Hanson, however, the solution is fairly simple—reconsider the nature of discovery to separate chance out as an unimportant step. That is, how new ideas are generated is a reasonable thing to investigate, both for its importance to science but also because that reasonable part of the process can be differentiated from the 'trigger' or inspiration—not *all* of discovery is due to chance, and so the presence of chance ought not prevent us from investigating discovery at all. This represents one tactic for engaging discovery with philosophy and yet resisting the incorporation of chance and accident into accounts of scientific reasoning.

Blackwell, who followed, gave a bit more room for chance within his analysis of scientific discovery: accidental discovery is one category of discovery, falling under what Blackwell labelled as 'discovering that', for those discoveries of things that exist, and how and what they do. In such cases, "the conceptual readiness for a puzzle solution is combined with the fortuitous circumstances of its realization" (as Brannigan paraphrases 1981, p.17). However, Blackwell still appeals to mystery in the guise of 'genius' in order to justify the seeming role of luck in enabling the right scientists to witness the right puzzles at the right time: "Certainly, it cannot be denied that Lady Luck has occasionally smiled upon the men of science by providing situations that may otherwise have been overlooked or never deliberately contrived" (quoted in Brannigan 1981, p.19/20). Thus, the separation of the accident itself from the discovery occurs here by moving the act of noticing into the realm of context—offering the conditions for noticing, rather than learned skills and practiced reason—and by keeping the mystery intact with vague concepts of the personal like 'genius', which serve somehow to translate those conditions into discovery.

Kuhn's concept of an anomaly, those interruptions and eventual disruptions of the problem-solving activities that mark periods of 'normal science', is perhaps the most significant move toward incorporation of chance into our understanding of discovery and the progress of science (Kuhn 1996). For Kuhn, an historian by training, accumulations of anomalies eventually lead to the introduction of a radically new framing for how to understand and explain the world—and, more specifically, the outcomes of our experiments and scientific work—that can incorporate them in a way that explains them (making them, that is, no longer anomalies). But, as Brannigan 1981, p.22) points out, Kuhn does not tell us what makes something become that kind of disruptive anomaly—how it passes from the threshold of dismissible mistake or

outlier into the status of paradigm-shifting, undeterred fact.[5] Rather, "Kuhn glosses this transition with an oblique reference to the 'individual skill, wit or genius' of the researcher" (Brannigan 1981, p.22, see also Celluci 2017, §11.3). The only difference between a noticed and an unnoticed anomaly, that is, is the noticing itself. When the scientific community is ready to witness and reason differently in response to an anomaly, then they will be able to do so: "as anomalies accumulate, a burgeoning sense of crisis envelops the scientific community" (Okasha 2016, p.76). Again, in such accounts a gap is allowed to remain, in the form of a threshold reached through this temporal process of accumulation that is pointed to but not itself described in detail. We are left without a clear account of what tips the balance at the level of the scientific community, nor of what leads individual scientists to reconsider errors as anomalies.

The pattern I wish to attend to here is the tendency, even within proponents of logics of discovery, to presume that neither chance itself nor the initial response to it are possible topics for philosophical investigation in relation to scientific discovery. That is, attempts to rescue discovery as a topic for philosophical study have generally and nonetheless left the constituents of serendipity somewhat to the side, even while acknowledging the importance of chance and the unexpected in the progress of science. Chance, accident, genius, noticing and surprise, are concepts that, as used, leave a gap and an air of mystery in such accounts, ultimately failing to resolve the dichotomy of contexts they critique.

To see what closer examination of serendipity can add, consider further this idea of an anomaly, a status given only when enough encounters with similar results creates a pattern that can be recognized as significant. That is, a paradigm shift does not result from a single individual observation or instance: Anomalies that shift paradigms in Kuhnian scientific revolutions do not act alone. Like with the statistical significance of adverse side effects presenting when a drug is under clinical trial, there is a threshold of importance: at a certain point, once so many such reactions have been observed, action in response to the unexpected result is demanded from the experimenters, the trial stopped or the drug recalled. And if we turn to empirical work done with practicing scientists, to observe their reasoning and responses to error in real time, we can see that iterative exchanges between colleagues generate a threshold of interest and the need for further investigation. Possible explanations for the anomaly as error or outlier are themselves interrogated and dismissed through deliberation, debate and experimentation (Dunbar and Fugelsang 2005). This aspect of discovery, that it can operate via threshold, is closely tied to accounts of serendipity

[5] Here I attend to critiques of Kuhn in respect to the implications of the accidental in how we reason about anomalies toward discovery rather specifically. The reader can note that what Kuhn gets right, particularly in respect to my other work that focusses on the role of network interactions in scientific discovery and serendipity, is his emphasis on the nature of discovery as a process—thus, there is no definable 'moment' of transition in his theory to explain (see especially Kuhn 1996, p.55–57). As I point out here, however, this leaves the transition itself an empty notion, a retrospective explanation of something already observed rather than an observation of the thing itself. In the following paragraphs I turn to how the process dimension of discovery intersects with what we know of serendipity in science.

as well, which highlight that while an individual experiences the surprise of the unexpected, potential value, an accident is not serendipitous science until it is accepted as a discovery (Copeland 2015; Kantorovich 1993). This multi-scalarity, acting at both the individual and community levels, in the moment and over time, is a feature of discovery that investigations into serendipity can elucidate.

In sum, efforts to defer rather than resolve the issue merely push the borderline further to one side rather than showing us how to bridge the gap that the distinction between the contexts of discovery and justification represents. Seen through the lens of how chance is dealt with, the split between discovery and justification has been a matter of debate, but it represents something different than simply our ability to explicate rational processes (with this capacity marking the threshold between the two and the border of the realm of logic), but rather where we feel contingency or chance rather than reason and agency dictate the turn of events. I posit that philosophers have tended to shy away from analysing discovery before theory choice because chance and contingency are seen as things human reason must deal with or work around—as constraints or confounding variables, you could say—and philosophy concerns human reason itself. However, research on serendipity has shown that rational agency and chance are intertwined in a way that reveals how arbitrary or forced the division must be when we leave these aspects of discovery out of our accounts. The accounts of philosophers of science who call into question this division would benefit from even more radical moves than the shifts and shuffles of the boundary described above. Rather, I suggest that a suitable type of rational agency to elucidate what happens in scientific discovery would consider chance from *within* the account, an account that in turn must be much broader than those entertained so far in philosophy of science.

I provide in what follows, therefore, a complementary reading of the role of accident and chance and, in turn, of the philosophy of discovery, through the lens of serendipity as a bridging concept. Entailing the integration of accident and sagacity, the use of this concept to describe discoveries marks our acknowledgement that some kind of skill or intelligence is related to the recognition of value in a chance or unexpected encounter. Chance does not have to be left out of our understanding of discovery, as a trigger or precursor, nor does our engagement with it need to remain at the descriptive level, and it is neither mysterious nor epiphemonenal in respect to the aspects of discovery thereby more worthy of study. To show this to be true, I will first put this 'gap' or dichotomy further into context, and then we will see what the 'friends of discovery' can offer to our understanding of serendipity in science. In the final section, I propose an epistemology of serendipity as a way to fill this gap.

Serendipity as a Bridge

Nickles (2009, p.174) points out that leaving aside aspects of discovery—namely the movement from observation or encounter, to reason and knowledge—means assuming that when we hypothesise, we take (blind) risks in testing those hypotheses rather than having reasons for selecting them. Those who leave discovery out of

the scope of science, that is, must concede that it does not matter where our ideas and solutions originate—and philosophy's task is reduced to understanding how ideas are justified and tested, once they are thought. While more recent approaches to how scientific ideas are generated may push the boundary back to include the making of a connection between previously thought ideas to generate a novel idea (e.g., combinatorial approaches, like those of Thagard and Simonton), they leave the gap I discussed in the previous section virtually unaddressed. Silver (2015, p.236) argues that this gap, problematic 'conceptual leap', or what Duffin (2000) calls "the heuristic quantum leap of a discovery" (p.159), has a long history of complicating our conception of science. Indeed, this was what the turn to method was supposed to correct: so long as the key to science is not the moment of discovery but what we do with it to generate knowledge, then the right topic for study is method, no mystery.

In his review of the history of philosophical approaches to discovery, Nickles suggests that, "For both Bacon and Descartes, method was the very antithesis of chance" (Nickles 2009, p.168). Method was meant to bring the practice of science into maturity, out of the state of lurching in the dark and hoping for discoveries to happen across, and into an enlightened application of clear reasoning for sorting out the world into "causes and deterministic laws" that could then be applied with success. You could have either chance or method, with no overlap, and with the latter being the ultimate aim.[6] While it stems from an attempt to understand how to generate scientific progress through discovery, this dichotomy ultimately underlies the later distinction between discovery and justification discussed above. But the advent of method did not mean the end of chance, nor prevent serendipity from playing a role in discoveries nonetheless widely accepted by the scientific community; the focus on method did not prevent even philosophers from seeing science as a practice imbued with accident and chance (Trout 2016, p.391).

As Silver (2015) points out, Bacon's imposition of method as the way to do what we now consider science did not eliminate the gap between searching and finding that accidental discovery highlights. Indeed, Silver traces Walpole's invention of the term back through Bacon's use of the hunt as a metaphor, particularly in his telling of the Fable of Pan. Pan offers us a case of serendipity under this interpretation: Having refused to participate in the search for the goddess Ceres, Pan nonetheless happens upon her while pointedly on the hunt for deer instead. Echoed later in Walpole's words for serendipity as finding something valuable while *à la chasse* of something quite different (see the passage from Walpole's letter, page xi this volume), the hunt plays an important role in Bacon's explanation of how science progresses. However, with Bacon as with those who came later, the accidental discoveries that mark early advances in the arts should be left there, and reasonable search be the province of science thenceforth: "'The mechanical arts draw little light from philosophy,' Bacon

[6] As Nickles (2009) puts it: "Chance and luck are the very things that method traditionally is supposed to exclude…If luck is unavoidable in inquiry, if inquiry presupposes luck, then the classical discovery program is doomed from the start" (p.178). Or from Trout (2016): "Under an ideology that equates science with prediction and control, the role of luck or fortune seems incompatible with great discovery. We desire to find something out and, having gathered and evaluated the evidence, we have the feeling that the evidence is now under our cognitive control-that we understand" (p. 394).

lamented, precisely because they take their lesson from accidents" (Silver 2015, p.247).

The discoveries by accident that lead to the development of arts and technology differ from science, according to Bacon, because they produce ways of engaging with the world instead of knowledge about the world. We are unable, that is, to move from the particulars of an accident—a situation of contingency—to generalizable truths, insofar as accidents produce the wrong kinds of methods. The methods of art deal with specific contexts and interactions, not with logic or laws, according to this distinction…in much the same way that the distinction between discovery and justification separated out the contingencies of noticing from the knowledge gained through testing and validation. Silver hones in on this underlying problem of how particulars can lead to generalities as a fundamental problem in the philosophy of science, unresolved by Bacon. I suggest here that siphoning off the contingent and accidental aspects of discovery from the advancement in knowledge that discovery represents provokes a similar dilemma. What we learn through serendipity are not only new facts about the world, but about new ways to do science (or, new ways to engage with our world, through accidental success). Thus, serendipity offers a broader understanding of scientific discovery that can take in processes such as paradigm shifts without relying on straightforward induction. Understanding serendipity can help us to understand how we make the leap through discovery into the realm of method.

Conceptualising general truths when one encounters a particular case, for instance, is an aspect of the sagacity involved in serendipity. As Silver notes, serendipity "names the way concepts emerge from the unexpected bumps and nudges of the material world, and it therefore isolates a critical tension in the method of the sciences" (2015, p.236). Merton's description of the serendipity pattern as a common method for developing theory from empirical data, includes the 'strategic' application to theory of the 'unexpected datum' encountered (1948, p.507). As I have noted, however, the focus from a philosophical perspective has been on what happens after the 'bump', 'nudge', or datum 'imposes itself' upon the observer. That is, the focus has been mainly on what happens in the head, during or to signal a discovery, carrying over the division between contexts that Popper embraced—the psychological trigger of surprise to a novel combination, and then, after that, the discovery described as rational processes of search, abduction and justification. In the next section, I pull together philosophy of scientific discovery and serendipity research to show how we can understand sagacity in cases of serendipity as the kind of reasoning and perception we also find in the early stage instances of noticing, or intuition, for example.

From the Hunt to Heuristics

Philosopher of science Whewell thought that there could be no explication of the art of discovery, because it began with a 'happy thought'. Such thoughts were happy because of their value, and as prompts to discovery they were unplanned emergences

from scientific activity (see Schickore 2006, p.61). They were also happy and fortunate because they occurred in the mind of someone ready to have them, and able to see their value; they arise as 'colligations' from the knowledge already present in the mind of a genius with the talent to perceive the value of a new connection. As discoveries, then, they are not really accidental and certainty not lucky. Thus does the role of sagacity mark serendipity in science different from mere luck. The requirement of what many call 'the prepared mind' after Pasteur's famous comment highlights the fact that some kind of perception, wisdom, or expertise is involved, as necessary as chance, luck or accident to serendipity.[7] But, as Dunbar and Fugelsang have noted: "It is interesting that, other than quoting Pasteur by stating that 'Chance favours the prepared mind,' scientists have not given many insights into what the prepared mind *is*; neither do they provide a clear account of what strategies they use when they encounter results that were not expected" (2005, p.61–2).

The difficulty in understanding the prepared mind in relation to accidental discoveries or chance observations lies in the fact this can only really be done retrospectively. Taleb (2010), for example, describes unexpected events with negative impact as Black Swan events, which after the fact may be fully explainable in terms of cause and effect and thereby seem inevitable, although before the event no one could have predicted it would happen. Thus, the circumstances for which we must be prepared remain necessarily unknown; every instance of serendipity will be different. Given the particularistic nature of what counts as preparation, then, it is not surprising that the concept of the prepared mind itself remains quite vague.[8]

More recent work has recognised the role of chance in relation to the prepared mind in cognitive, representational terms. These accounts tend to focus on how accidents can trigger discoveries, separating out the discoveries themselves to be described in cognitive, representational terms, as novel combinations thereof. Harnad (2007, p.174), e.g., argues that while discoveries can be the result of 'fortuitous' combinations made by trial and error, these must also be recognized as valuable by an experienced mind. He calls his own account 'cerebral', focussing on combinations of mental representations, which constitute the creative acts of discovery he describes (p. 171–2). Thagard similarly develops a theory of discovery as the generation of novel combinations of cognitive, representational content (Thagard 2012). In his approach (e.g., Thagard 1998, 2002), serendipity is a kind of discovery, one that is triggered by surprise—but otherwise, not really different than those arrived at by search.

Brannigan (1981) comments (p.5) that the positivist ideal, that scientists ought to apply logic and theory in their practice, resulted in a separation of the behavioural approaches to scientific practice from the philosophical approaches to scientific theory. He proposes instead to flip the understanding of discovery over to a purely

[7] One could say that this adds only further layers of chance. That is, the idea not only has to occur unplanned, but in the right person and at the right time in their development of expertise and awareness. I simply sidestep this regress here; it does not lead anywhere, so I take the more fruitful route.

[8] See Glaveanu (2022) for an alternative and contemporary example of improving focus on this from a creativity study perspective.

social category (rather than being about individual experience), with his 'attributive' model—but these types of approach also fall short as explanations of what kind of discovery serendipity is (Simonton 2022). That is, purely social accounts fail to take up the multiscalar aspects of serendipity, which bridges the individual and the social.

A similar issue is raised by the account offered by philosopher of science Kantorovich (1993). Serendipity earns pride of place in his evolutionary account of scientific progress, playing the role of random mutation—the driving force behind novelty and change in science. However, this can also be seen as another way of externalizing rather than intertwining chance with reason. That is, serendipity includes sagacity in Kantorovich's account, but not intentionality or agency; chance opportunities become scientific discoveries by way of a naturalistic rather than a reasoned process—it can be described but not applied. The scientific community (as a whole) acts like a prepared mind, but only insofar as it selects the opportunities that arise by accident and chance for uptake into shared scientific knowledge, just as in classic evolutionary theory natural environments 'select' animals with mutations that better enable them to survive and reproduce. Thus, the interaction between individual reasons for following up on unexpected observations and the community's validation of that effort by accepting it as a serendipitous discovery is left outside the realm of reason, a gap that must be crossed with a leap.

However, serendipity seems to rather entail *overlap* between the phenomenological and theoretical aspects of discovery—cases of serendipity, as they are told, generally include a response of surprise, an 'aha', or even a 'eureka' in the moment. There is an emotional or affective valence to the shifting of expectations that occurs when serendipity is recognized and a new direction opens up by chance, which denotes a distinctly personal aspect to serendipitous events (Sauer and Copeland 2021).[9] Further, consider that, despite an otherwise combinatorial account of creativity as 'bisociation'—"the synthesis of a single idea with two apparently inconsistent contexts"—Koestler's explanation of discovery also says that it is "characterized by a mix of elation and catharsis" (in Brannigan 1981, p.27–8). Bisociation is one of the more common terms used to describe how serendipity happens. For de Rond, for instance, serendipity is not an event so much as a capability for bisociation, for identifying useful 'matching pairs' of events (de Rond 2014).

I suggest that serendipity offers either a dilemma or a bridge. It straddles the borderline between phenomenal experience and the empirical, perceptual encounter with the world, and the reasoned processing and evaluation of one's observations, thoughts and encounters as potentially valuable and pursuitworthy. If regarded as a dilemma, the integration of chance means that we lose the ability to examine serendipitous discoveries holistically, and have to split it in two, as 'accidents' plus

[9] Although I don't have room to explore further here, it is notable that such 'aha' responses are also generated by stories of serendipity—listeners and readers experience joy at making the same realization of how fortunate an accident turned out to be, perhaps as much as those who perceived it first may have felt, which goes far in explaining why serendipity stories are such popular literature. The link to be followed up on this is with Erdelez's comment that super-encounterers, those who experience intentional and surplus serendipity in their seeking activities, often also create serendipitous opportunities for others while they are at it (Erdelez 1999, p.26, and Chap. 12 in this volume).

'sagacity'. The prepared mind sets the stage for the rational uptake of the chance moment, but the accident in this kind of account amounts to an interference in a rational process rather than part of that process. This accords with Walpole's and later proponents' conception of serendipity as occurring only while we are engaged already in search or other such activity when the accident occurs (Chumaceiro 1999).

But Walpole also calls it 'accidental sagacity', suggesting that the two elements are conjoined under one conception, rather than separable and distinctly conceived.[10] In Merton and Barber (2004), we find the idea of sagacity traced back through Samuel Johnson to John Locke, who suggests that the sagacious are wise in the sense of being able to perceive the links between ideas; leaning on perception in this way, according to Merton and Barber, lends the use of sagacity the sense of being "a psychosocial cognitive mechanism" (Merton and Barber 2004, p.261 Footnote 38). Thus, serendipity indeed is a kind of trigger, but one that simultaneously reveals a link, perceived because and only once chance draws one's attention toward it. As an act of perception, accidental sagacity does not seem separable from the recognition of potential value, and so chance, attention and recognition (or 'noticing') work together rather than one following the other.

According to Bacon, the wisdom of Pan on the hunt is a combination of "sagacious experience and general knowledge of nature" (quoted in Silver 2015, p.243).[11] Sagacious experience, if sagacity is a matter of noticing links that others (would) have missed, in this case might entail a perception of the connections within nature. A good hunter sees tracks, signs of movement, and comes to understand the environment she moves within as a set of patterns (waterholes for drinking from, trails to and from burrow to food…) that can lead her reliably to her prey. Making cognitive connections between the observations one makes is insufficient for discovery however; not just any connection will do, and mentalistic accounts will have a difficult time distinguishing between the processes that generate discovery and those that do not (hence the tendency to rely on additional factors, such as 'genius' to fill the explanatory gap). The metaphor of the hunt draws our attention to the fact that when these perceptions are insights into the workings of the world, then our engagement with that world is what tells us when our connections are well made; if the pattern I perceive isn't really there, I will find neither deer nor goddess on my hunt.

In addition, arguments from creativity theory as well as within serendipity research have connected the emergence of serendipities with what is often called an 'incubation' period (e.g., process models of serendipity by Makri and Blandford 2012; McCay-Peet and Toms 2017; McCay-Peet and Wells 2016, and specifically on this topic, Gilhooly 2022).[12] As Scheffer et al. (2015) carefully note, an important part

[10] This is noted as well by authors March and Vallee-Tourangeau in their contribution to the *Art of Serendipity* (eds. Ross and Copeland, see references for Simonton, Gilhooly and Glaveneau 2022, at the end of this chapter), but besides this noted point about inseparability the approach I take here in respect to 'accidental sagacity' differs from theirs.

[11] Silver further offers evidence that this idea of sagacity would indeed be the one picked up by Walpole later, when he wrote the famous letter to Mann (Silver 2015, p.244).

[12] Note that I cite here serendipity scholars, mostly, and that this represents only an echo and not a reflection of the work done in psychology, for instance, on the nature of incubation.

of science includes 'priming' for discoveries to be made in this way: allowing time for associations between ideas and memories to occur (or, in mind wandering, to collide with seemingly random thoughts). But, as with other cognitive models, this approach keeps our opportunities for discovery very much within the confines of the prepared mind. To combat this, Scheffer et al. suggest diversifying the information we encounter, including drawing from the arts for "finding interesting input for our hypothesis testing machinery" (Scheffer et al. 2015, p.3). Thus, despite the integration of intuitive and creative thinking into accounts of scientific reasoning, there remains a tendency to still relegate chance and accident to external triggers of the reasoning processes involved in 'actual' discovery.

Nickles, however, offers a promising account of heuristic appraisal or 'HA'. This is the form of (often unconscious) reasoning which "evaluates the promise or potential fertility and feasibility" of something (Nickles 2006, p.159). In relation to cases of serendipity, I have previously called this the perception of "potential value" (Copeland 2019)—this is value that is not yet realized, and so it therefore really represents an assessment of the fecundity of the chance observation at hand. As a method, "HA has one foot in context of discovery and one foot in context of justification yet belong to neither as defined by the standard [positivist] distinction" (Nickles 2006, p.160). Indeed, Nickles takes up heuristic appraisal as the key form of reasoning in science partly because, "In [his] view, all innovation involves at least small elements of luck or serendipity, a view that makes HA even more obviously indispensable—and more difficult" (2006, p.178 Footnote 9). The very practical and experiential nature of HA draws out the role of our tacit relationships with our environment and each other in such reasoning processes: for example, we incorporate considerations of how to most economically use our time and resources, implicitly, when we decide whether to follow up on something that catches our eye or to keep heading in the direction we are already going (e.g., Barber and Fox 1958). This overlap of appraisal with action, I suggest, captures more closely the nature of sagacity in cases of serendipitous discovery, setting us in the right direction.

An Epistemology of Serendipitous Discovery

What is particularly attractive in an evolutionary account such as the one proposed by Kantorovich above, or Campbell whom he follows, is that it seems to incorporate chance into the trajectory of scientific process (as random mutation, and thus still independently and externally from the context that ultimately gives it value) without giving up reasoning processes that prevent an equivalence between error and discovery (e.g., the 'selection' of good ideas out from the bad). That is, we can generalize our explanation of chance (Nickles 2009, p.182)—but, as I argued above, it offers little in the way of understanding sagacity better. Serendipitous discoveries can be thought of as those moments in science when we make theory fairly directly out of the clay given to us by the world (as Merton suggests), when we move from the particular and contingent to the general and true (as Silver puts it). Discovery

by chance may be contingent and random from one perspective, but causal explanations are available from another (as with Taleb's Black Swan). Indeed, as Nickles notes, in a biological system it is precisely the noise in the system that provides the means for progress and change—innovation—and discoveries require what Max Dulbruck called the 'principle of measured sloppiness' (Nickles 2009, p.185). This is in keeping with other accounts of serendipitous discoverers: Fleming, for instance is often commended for leaving his petri dishes unwashed, with the conviction that if he had kept a tidier bench, penicillin would have remained undiscovered (Copeland 2018).

Thus, personality attributes that lead to an increase in overall noise and/or perceptive abilities tend to be used to explain 'sagacity', focussing again on chance (being the 'right kind of person') rather than providing an explanation of the reasoning processes that may lead up to and include a recognition of potential value. Recent proposals for how to increase serendipity in a variety of contexts illustrate this belief that increasing the number of chance connections made is the key, so that they may more likely befall the 'right person' to recognize their value. For instance, building designs that promote random interactions between people within them are exemplified by Google's New York campus, a "workplace designed to encourage 'collisions'",[13] or the Pixar building designed similarly by Steve Jobs, where "you can't avoid running into people".[14] Increasing 'collisions' between people at the water cooler or elsewhere, that is, is commonly conceived as sufficient for increasing serendipity in an institution (see Busch & Grimes, Chap. 5, this volume, for more examples). There are two things I would like to note about this approach: First, that it illustrates the ubiquity of the role of chance in discovery and progress. Innovation is known to arise by chance and accident on a regular basis, and the growing desire to somehow 'engineer serendipity' highlights the wide recognition of this fact. Second, more than increasing the number of random encounters that happen is needed for serendipity to follow from such measures.

The second point calls for further elaboration. Sagacity is required in addition to accidents for serendipity. But, as I have pointed to above, the strategy is frequently to internalize sagacity and externalise chance in order to understand the former as a rational process, which leads to an individualised model of the discoverer as having innate characteristics, such as genius or having the right personality. Other traits assigned to the sagacious in serendipity have included being a maverick or being a novice, and hence susceptible to new ideas in a way that trained experts full of expectations are not (e.g., Meyers 2007). In others, persistence in the face of opposition and uncertainty denote their special talent for taking an unexpected observation to the level of scientific discovery, as with Barry Marshall, commended (in hindsight,

[13] From an online article accessed in May 2022: https://www.anitainsights.com/blog/building-for-serendipity-at-google-nyc/, published for a blog on Workspace Innovation, November 7, 2016 by Time.com, "Building for Serendipity at Google NYC".

[14] From a Forbes online blog by Robert C. Wolcott, published January 22, 2021 and accessed May 2022: https://www.forbes.com/sites/robertwolcott/2021/01/22/vr-storytelling--serendipity-pixar-co-founder-ed-catmull-and-composer-harold-oneal/.

of course) for his insistence to the point of self-experimentation[15] against prevailing wisdom that bacteria could in fact live in the acidic environment of our stomach, as he had observed (e.g., Dreger 1999). These talents, however, seem quite separable as such from the scientific skills of the main characters in the story; like the accident or surprising observation that started it all, the success of the discovery in these accounts relies on the 'right person' having made the observation, with the success criteria for this being personality and psychological traits, or the generic and vague 'prepared mind', rather than developed and refined skills of scientific practice.[16] Again, we see serendipity 'outsided' from scientific activities, influencing by interfering with, rather than seen as an integral part of discovery processes.

An epistemology of serendipitous discovery, however, would address the interaction between wisdom and chance directly instead of side-stepping it. One way to do this is to assume that much or at least a significant part of scientific progress is simply determined by contingency and chance (Trout 2016). Evolutionary approaches adopt this assumption, but also social scientists and historians of science have addressed the role of contingency by looking to examples to say more about how discoveries do happen, than how they ought to happen. For instance, Holton et al. (1996) write about how a discovery 'is made' through the case study of high-temperature superconductivity: "Our findings emphasize the great importance for scientific research of unintended interactions or applications" (p.373). That is, when an observation is made or results obtained, their eventual use is not yet obvious—often, the value of scientific knowledge emerges from interactions and 'borrowing', allowing it to be developed in a context and for a purpose quite different than originally intended (Holton et al. 1996).

For Kantorovich (1993), this represents the process of selection by the scientific community; as knowledge is exchanged, it is selected for or against by other scientists and either dropped, or shaped into a discovery and accepted as new knowledge through such exchanges. But this diffuses sagacity across the collective 'scientific mind', thereby eliding the role that individual scientists do play when they agree or disagree about the (potential) value of a (potential) discovery.[17] And while the original intentions in producing results that were later found to be relevant to super-conductivity did not give hints as to that ultimate value, the nature of the 'borrowing' that Holton et al. (1996) describe, despite resulting often from chance encounters with other scientists and their results, suggests that there was some intentionality involved—this process was not entirely due to chance without thought, nor did it lay outside of the range of scientific skills that the borrowers had to hand.

[15] And later, critiqued for this particular part of the story.

[16] Notably, Thagard (1998) offers in two companion articles a far more thorough history for the perception of Marshall as a maverick, illustrating the professional relationships and use of scientific skill that went into making his observation a renowned discovery. As I note elsewhere in this chapter, the observation itself remains a trigger in Thagard's account, but the role of contingency and complexity in context is captured with care.

[17] In (Copeland 2018) I mention that this also diverts attention to how responsibility as well as credit ought to be assigned to those who influence that scientific mind, which is problematic.

Indeed, borrowing the knowledge of others to put it to new use is, one might argue, a fundamental practice for all sciences and a basic scientific skill.[18]

In accounts such as Kantorovich's, where chance and accident is emphasised as the necessary trigger to initiating the processes of selection and, thus, the root of scientific progress, the ideas expressed about science and sagacity raise deep questions about the merit-based system we employ to ensure science continues to progress. That is, if success is due mainly to chance, then discoveries are made by luck—in turn, systems that reward scientists with funding and accolades ought to take this role of luck more seriously (see e.g., Sand and Chiapperino, Chap. 10, this volume). Others, in reflection on the prominence of chance, have gone so far as to suggest that we ought to abandon our claims to reward only or primarily merit altogether, and acknowledge the influence of luck by adopting lottery systems for scientific funding, for instance (Gillies 2015; Sand and Copeland 2020).

From Holton et al. (1996) we get the suggestion that, "the chance of serendipitous encounters with key ideas is increased by permitting research to proceed at an unforced pace" (p.375). They found it striking that many of the interactions that led to the discoveries they examined occurred because scientists were working in an environment that allowed for 'projects with long gestation periods'—demonstrating a "willingness to give good people the freedom" to follow new directions that may not lead to immediate rewards. Ironically, perhaps, this kind of freedom is often rewarded to those who already have a long track record of success, possibly even reinforcing the arguments of proponents for funding lotteries who claim that it is privilege and not merit being most often rewarded.[19]

However, I would argue rather that the fecundity of research without pressure to produce value *quickly* shines light upon an underlying reason for why 'freedom' is so valued by proponents of serendipity in science; *it takes time* for chance and accidental events to develop into a discovery (Solomon 2016). The role of incubation was mentioned already, but the importance of interactions—social, cognitive and physical, as well as through the tacit or explicit communication of ideas—to serendipity offers an additional way to understand how long it might take for contingent circumstances to arise and evolve, through such interactions, to allow serendipity to emerge.

Emergence is a key concept for understanding serendipity at all levels (Copeland 2019). Key to understanding emergence is the idea of unpredictability: An emergent phenomenon is (more or less) one that could not have been predicted, given what we do or could know about the conditions that ultimately caused it. Pickering, for instance, gives an account of science in terms of the 'mangle' of complexity we engage through practice, and he describes the experience of emergence as our experience of 'brute chance' while we are so engaged:

[18] In fact, in their final point Holton et al. (1996) say that any given discovery ultimately requires a breadth of disciplines involved in the exchange of knowledge, and that we cannot neatly separate between pure and applied science, or draw a sharp distinction between curiosity-and mission-driven research (we should rather support a 'seamless web of research' for progress—see esp. p.375).

[19] Merton noted something similar with his concept of the Matthew Effect—notoriety can also lead to eminent scientists getting more credit for their discoveries than novices do for theirs.

> I have emphasized that brute contingency, sheer chance emerging in time, is integral to practice—in the tentative fixing of goals, in the emergence of specific resistances, in the substance of particular accommodations and their success or failures. (Pickering 1995, p.209)

For Pickering, the production of scientific knowledge is best described as an encounter; like in Merton's serendipity pattern, the world imposes itself upon the scientist, for whom the capacities and nature of that world *emerge* (p.18).[20] From this perspective, too much planning can interfere with our ability to perceive such emergences (e.g., see Bush 1945). To induce, or rather, to rush science is to preclude such chance discovery (see also the discussion around superconductivity following Holdon et al., above).[21]

Picking up on Pickering's emphasis on the encounter, one way to address the dichotomy of the accidents—and sagacity—account of serendipity that we are led into when we offer an overly cognitive account of sagacity, is to resist it. As others have said before, it is paradoxical to bring an element of control into serendipity, contradicting its definitional dependence on chance (e.g., Nickles 2009, p.179). But we can work from the other direction, bringing our concept of sagacity in line with other rationality-based approaches to how we actively engage chance, in science and in our everyday lives.

That is, I think we can in fact take up the assumption that a significant portion of scientific progress is due to accidental encounters without letting go of the individual sagacity or skills that must play a role in discovery and progress. For this, I propose we widen the understanding of sagacity beyond the cognitive and individual, and yet resist dispersing it across the whole of science or the contingent world—that is reducing it to neither logic nor luck, but rather trying to understand it as a kind of reasoning of its own, suitable for situations where the two meet.

The pragmatist Peirce most famously conceptualised this kind of reasoning as abduction, an approach taken up in philosophy of science and serendipity research alike to explain the rationality of discovery. For Peirce, abduction is closely tied to surprise. He offers the following formula: "The surprising fact, C, is observed; But if A were true, C would be a matter of course; Hence, there is reason to suspect that A is true." (Peirce 1903). Again, we see the surprising fact playing the role of trigger to thought, or to inference about the best or at least a likely explanation for that fact. We see the dichotomy arise in many uses of abduction in relation to serendipity—for instance, van Andel writes, "serendipity is an apt description for the observation of

[20] Note that Pickering does differ from Merton in a fundamental way; while Merton's narrative implies a realism about the world, which will thereby reveal its nature to us, Pickering adopts a more contemporary approach to the interaction between constructivism and realism in scientific practice. There isn't room to go into this here, but suffice to say that the implications for realism in science of different approaches to serendipity is another topic that could do with a closer look by philosophers of science.

[21] Also along these lines, Nickles (2009) suggests that, next to trial and error, serendipity may be the most economical of scientific methods: "…check instead for any coherent or sufficiently interesting manuscript, whether previously anticipated or not. Prespecifying a goal and rigidly sticking to that research plan not only reduces the probability of hitting something interesting but also limits the innovation to what we currently think we know or can plausibly imagine" (p.191).

a surprising fact followed by a correct '*abduction*'" (1993, p.692). Rather than both describing the same phenomenon, surprise and sagacity in these accounts arrive one *after* the other.

But contemporary scholars have thoroughly considered what abduction is meant to capture, and offer additional considerations.[22] For instance, consider computational philosophers such as Magnani (2006), who uses 'chance discovery' as a frame to investigate the role of what he calls *manipulative abduction* in scientific discovery. More than an inference or creative invention of possible hypotheses (what he calls 'theoretical abduction', which lies entirely within the cognitive realm), there are "many cases of explanations occurring in science when the exploitation of environment is crucial" (p.1747; see also Magnani et al. 2016). In cases of manipulative abduction, "action can provide otherwise unavailable information that enables the agent to solve problems by starting and by performing a suitable abductive process of generation or selection of hypotheses" (p.1748). Importantly, in this account, abduction is part of the observation process, insofar as the action is a performance of both encountering the (surprising) fact and generating a hypothesis about it; by both 'starting' and 'performing' the abductive process itself. In other words, Magnani describes manipulative abduction as 'thinking *through* doing' (2006, p.1751). Similarly, where chance and wisdom, or accident and sagacity come together, there is also an intersection of cognition and environment (Arfini et al. 2020).

Grinnell, philosopher and scientist, describes Peircean abduction as he sees it happening in scientific practice as "a surprising observation that becomes reconfigured as an unintended experiment about an entirely new research problem" (2019, p.225; see also Grinnell 2009). The phenomenology of this experience is like having one's attention 'abducted' from the original problem and set upon a new one in a response to surprise (Grinnell 2019, p.224–5). In such cases, Grinnell suggests that the surprise effects a 'gestalt switch', where the scientist sees the situation at hand in two different ways: in respect to the original problem, as a problem or anomaly; in respect to the abduction or novel explanation for the surprising observation, as a completely new problem worthy of investigation (Grinnell 2019, p.221). In this way, one sees the unexpected results from the perspective of original intentions instead as an expected result, given the new explanation for what actually resulted from one's experimental set-up. Rather than *following* the surprise, as van Andel suggests in his explanation of serendipity, the abduction in this case *constitutes* the surprise in the form of a gestalt switch in perspectives on what has occurred and been observed.

In an analogous fashion, some theorists have used affordances to explain how serendipity and discovery occurs at the site of interaction between reason and experience. Björneborn describes serendipity as an affordance, "i.e., as a three-way relationship between an environment, a human being, and a potential activity" (Bogers and Björneborn 2013, p.207). Following Gibson,[23] affordances are like enacted clues.

[22] As Grinnelll (2019) notes, this discussion has much more nuance than the usual use of abduction in common parlance, which tends to mean simply 'inference to the best explanation'.

[23] To quote Gibson (1979, p.127): "The *affordances* of the environment are what it *affords* the animal, what it *provides* or *furnishes*, either for good or ill. The verb to afford is found in the

The way in which an object or environment is perceived, that is, conjoins with the potential actions or behaviours that it allows. A chair, for instance, is perceived as 'something to sit upon' by someone who has an interest in sitting (as well as the right kind of body to accomplish 'sitting upon a chair'). The interest in sitting and the perception of the chair are inseparable in this account; the chair affords sitting, and that is how it is perceived by me. A cat, for instance and in contrast, may perceive a landing pad that affords jumping up onto the counter. Insomuch as it is an affordance, serendipity affords the perception of an accident, for instance, as potentially valuable, or as an opportunity.

Rietveld and colleagues (e.g., Bruineberg et al. 2021; Kiverstein and Rietveld 2018; Yakhlef and Rietveld 2019) have recently furthered the approach via affordances in relation to innovation by developing a theory of "innovative action as skilled affordance-responsiveness" that also looks at how individuals respond via both learned and novel behaviours to unexpected and 'unconventional' affordances given to them by their environment.[24] They describe this in terms of 'skilful coping', wherein the experiential background and skills possessed by individuals couple with the environment through affordance perception. When the environment offers unexpected or novel affordances, the specific skills and thus expertise of acting individuals may enable their perception of those affordances. Given the novelty of the affordance situation, such individuals may then respond to those perceptions by acting in innovative ways within their environment; where atypical affordances are perceived, then typical behavioural responses do not automatically follow. This approach thereby avoids the temporal and physical dichotomies, such as observation as *followed by* evaluation, as discovery followed by justification, or surprise as a trigger followed by cognition, and offers instead a way to examine philosophically the intersection of perception and reasoning (like surprise and abduction) through examining the nature of rational, human responses to the unexpected.[25]

These avenues for investigation all suggest that there is room in philosophy of science for looking closely at serendipity, but also and importantly for seeing it as a bridging concept or a concept that captures the intersection of what are normally considered separately, and that will give us real insight into the nature of discovery. In my current work, I have been examining the potential of a type of reasoning from the categories of reasoning of ancient Greece, *metis*, as a frame for understanding

dictionary, but the noun *affordance* is not. I have made it up. I mean by it something that refers to both the environment and animal in a way that no existing term does. It implies complementarity of the animal and the environment".

[24] In the 2019 article cited, the authors' focus is a bit more on the other direction: how to cultivate novel affordances in otherwise behaviourally deterministic environments.

[25] Also notable is the correlation between the way Yakhlef and Rietveld (2019) describe the rise of affordances as 'soliciting and prompting action from the body' (p.5) and Merton's description of the serendipity pattern (1948), wherein the surprising datum imposes itself upon the investigator, whose perception of it is strategic, that is intimately tied to its potential value in relation to theory. The dual nature of 'strategic' in Merton's account, that is, offers a similar bridging of reason and perception as these theories, along with the sense that the world directly affects the capacity of an individual to perceive and reason about her environment (e.g., the skills related to her affordance-responsiveness in that particular situation).

how embodied and situational engagement with the world can be explained in philosophical terms as a form of rationality. Metis is particularly interesting because of the way it has been left out of Western philosophical discussions of rationality that follow the Greeks but focus only on episteme, techne and phronesis; metis is left to the side of these discussions much as serendipity is elided or avoided in philosophical approaches to science. But metis offers a way to capture the reasonable response to a changing landscape of affordances in philosophical terms: 'metis' is the cunning wisdom of agonistic encounters as well as sophistry, and democracy as well as the defensive strategies we employ in a changing environment (Copeland 2022). Sagacity, when part of serendipity, highlights the relationship between innovation and discovery not only in these dynamic contexts but also within scientific practice, itself a dynamic way of engaging with the world through action.

Concluding Comments

The epistemology of serendipity I have sketched above is more a set of new directions to take philosophy of science than it is a detailed examination of how serendipity produces knowledge. In looking closely at the nature of serendipity as well as its rhetorical significance in the stories we tell about science, as a term that points to the role of wisdom in even accidental discovery, I have found that rather than a mysterious gap between chance observations and the production of knowledge, serendipity offers philosophy of science a bridging concept. Philosophy of science, rather than avoiding or deferring investigation of what happens when that gap is crossed—in the mind of the discoverer as well as in the world so discovered—has missed opportunities to understand how discoveries are made, more generally speaking. Contemporary philosophers, social scientists and science and technology studies scholars have taken up the cause, portraying scientific progress as partially or mostly the result of contingencies and chance (see Strevens 2020, for but one example) but they are only beginning to explore how rationality and chance truly intertwine in both 'aha' moments and in lengthy processes of scientific discovery. For this reason, serendipity science, I suggest, still has much to offer philosophy of science toward the clarification of what sagacity consists in, and how it enables us to recognise potential value in the unexpected.

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