Forthcoming in Shan, Yafeng, ed. 2022. *New Philosophical Perspectives on Scientific Progress*. 1st ed. Routledge Studies in the Philosophy of Science. New York: Routledge. https://doi.org/10.4324/9781003165859.

Introduction: Philosophical Analyses of Scientific Progress

Yafeng Shan

George Sarton, the first Professor of History of Science at Harvard University, once wrote: 'The history of science is the only history which can illustrate the progress of mankind. In fact, progress has no definite and unquestionable meaning in other fields than the field of science' (Sarton 1936, 5). This is a 'corollary' of his 'definition' and 'theorem' of science.

> *Definition*. Science is systematized positive knowledge, or what has been taken as such at different ages and in different places.
>
> *Theorem*. The acquisition and systematization of positive knowledge are the only human activities which are truly cumulative and progressive. (Sarton 1936, 5)

These big claims about the nature and development of science might seem controversial to many, but few would deny that there are good examples of progress in the history of the sciences. For example, it is widely accepted that the Copernican Revolution marks a progressive shift from Ptolemaic astronomy to Keplerian astronomy. By the end of the seventeenth century, our geocentric model of universe was abandoned and replaced by the Keplerian model in which the sun is located in one of the foci of an elliptical orbit of the earth. Other classical examples include the Chemical Revolution and the Einsteinian Revolution. As R. G. Collingwood (1965, 332) puts it, scientific progress exists and is verifiable is 'the simplest and most obvious case'. However, there has been no consensus among historians and philosophers of science on what is the best way to characterise the nature and pattern of scientific progress.

In the current literature, there are four main approaches to the nature of scientific progress: the epistemic approach, the semantic approach, the functional approach, and the noetic approach. According to the epistemic approach (e.g. Bird 2007; 2022), science progresses if and only if scientific knowledge accumulates. According to the semantic approach (e.g. Niiniluoto 1980; 2014; Rowbottom 2008), science progresses if and only if our scientific theories are approximating the truth. According to the functional approach (e.g. Laudan 1981; Shan 2019; 2020), science progresses if and only if the functions of science are better fulfilled. According to the noetic approach (e.g. Dellsén 2016; 2021), science progresses if and only if the scientific community has a better understanding of the phenomena in the world. In addition, the pattern of scientific progress has been widely debated (e.g. Bury 1920; Sarton 1936; Nagel 1961; Kuhn 1962; Lakatos and Musgrave 1970; Laudan 1977). A widespread view is that science progressed in a cumulative way: new theories, paradigms, or

traditions always fully suppress old ones in some sense. For example, Heinz Post (1971, 229) maintains that 'as a matter of empirical historical fact', new theories always explained the whole of the well-confirmed part of their predecessors, while Kuhn (1970, 20) observes that in history a new paradigm typically solved 'all or almost all the quantitative, numerical puzzles that have been treated by its predecessor'. In contrast, Larry Laudan is highly sceptic of this view and argues for a non-cumulative account of scientific progress: 'the growth of [scientific] knowledge can be progressive even when we lose the capacity to solve certain problems' (Laudan 1977, 150).

What is worse, we lack a comprehensive philosophical examination of scientific progress. First, the recent debate pays too much attention to the epistemic approach and the semantic approach (see Rowbottom 2008; 2010; Bird 2008; Cevolani and Tambolo 2013; Niiniluoto 2014). Shan's new functional approach and Dellsén's noetic approach are still insufficiently assessed. Second, there is little in-depth analysis of the progress in the history of the sciences. It is unclear which of the main approaches best captures the historical development of a particular scientific discipline. Nor is it very clear whether different disciplines differ in the nature and pattern of their progress. It is also worth examining whether there is any progress in some disciplines. Third, many related philosophical issues are still to be explored: What are the implications of scientific progress for the scientific realism/antirealism debate? Is the incommensurability thesis a challenge to scientific progress? What role does aesthetic values play in scientific progress? Does idealisation impede scientific progress? How does scientific speculation contribute to scientific progress? Do interdisciplinary sciences progress in the same way as mono-disciplinary sciences? How does science progress through perspective-shifts?

This book fills this gap. It offers a new assessment of the four main approaches to scientific progress (Part I). It also features eight historical case studies to investigate the notion of progress in different disciplines: physics, chemistry, evolutionary biology, seismology, psychology, sociology, economics, and medicine respectively (Part II). It discusses some issues related to scientific progress: scientific realism, incommensurability, values in science, idealisation, scientific speculation, interdisciplinarity, and scientific perspectivalism (Part III).

1. Main Philosophical Approaches

In Chapter 1, Alexander Bird defends the epistemic approach. He maintains that scientific progress is just the accumulation of scientific knowledge. He argues that many cases of scientific progress found in the history of biology and of astronomy cannot be accounted for by Dellsén's noetic and Shan's functional accounts. He claims that there are many instances of modest contributions to progress through the addition of new scientific knowledge that does not bring with it new understanding or new exemplary practices. Bird concludes that progress can be made also by knowing that some novel phenomenon, such as X-rays, exists, even when that knowledge does not include new understanding or new methods and practices.

In Chapter 2, Ilkka Niiniluoto argues for the semantic approach. He reviews the historical roots of the debate over scientific progress. Based on Popper's notion of verisimilitude, Niiniluoto develops an account of truthlikeness. He argues that an increase of estimated truthlikeness is a mark of progress development in science. He also argues that such a semantic account is more adequate and fundamental than its alternatives: the epistemic, functional, and noetic accounts.

In Chapter 3, Yafeng Shan defends his new functional approach. He argues that the functional approach should not be conflated with the Kuhn-Laudan functional approach. There are other versions of the functional approaches, such as the Popper-Lakatos approach and his new functional approach. According to his new functional approach, progress is best characterised in terms of usefulness of exemplary practices. He shows that this new functional approach is immune to the main objections to old functional approaches. Moreover, Shan argues that the new functional approach is better than the epistemic, semantic, and noetic approaches by providing a fuller picture of scientific progress.

In Chapter 4, Finnur Dellsén argues for a version of the noetic approach according to which scientific progress on some phenomenon consists in making scientific information publicly available so as to enable relevant members of society to increase their understanding of that phenomenon. He compares this version of the noetic approach compared with four rival accounts of scientific progress, viz. the truthlikeness approach, the problem-solving approach, the new functional approach, and the epistemic approach. In addition, Dellsén tries to precisify the question that accounts of scientific progress are (or should be) aiming to answer, viz. 'What type of cognitive change with respect to a given topic or phenomenon *X* constitutes a (greater or lesser degree of) scientific improvement with respect to *X*?'

2. Historical Case Studies

In Chapter 5, Olivier Darrigol examines seven episodes in the history of physics, which are widely accepted as major progress. He shows that these cases involved conflicts between formal and empirical criteria of progress, with the latter kind, empirical adequacy, winning in the end. He argues that the physicists' ability to judge and compare the empirical adequacy of their theories crucially depended on a modular structure that defined a sound basis of comparison. He thus suggests that such a modular structure plays an essential role in physical theories. Darrigol argues that progress in physics should be best understood as an increase in the modular measure of empirical adequacy.

In Chapter 6, Robin Hendry defends a cumulative account of the progress in chemistry. He surveys seven key episodes dating from the 1790s to the 1980s: the chemical revolution, chemical atomism, the emergence of the periodic system, structure theory, the instrumental revolution, the application of quantum mechanics to chemistry, and the discovery of quasi-crystals. Hendry argues that chemistry has developed cumulatively, in the sense that theoretical claims about the composition and structure of particular substances tend to be retained, and enriched and deepened by further research, rather than being radically revised or reinterpreted. The development of the general theoretical frameworks for understanding composition and structure has also been cumulative, with new frameworks tending to be

conservative extensions of previous approaches. The relationship of this cumulative development to the problem-solving and epistemic conceptions of progress in science is also explored.

In Chapter 7, Paul Needham argues for an epistemic approach in progress in chemistry. Like Hendry, Needham shares Hendry's conviction that the pattern of progress in chemistry is cumulative. Unlike Hendry, he maintains that the epistemic account well captures the nature of progress in chemistry by focussing on some themes in the development of theorising and conceptual clarification at the macroscopic and microscopic levels during the 19th and 20th centuries. He argues that the accumulation of knowledge concerning the character and transformations of substances from ancient times constitutes progress in chemistry. Needham concludes that the epistemic approach seems to give the best account of progress in chemistry amongst philosophical views on scientific progress currently on offer.

In Chapter 8, Eva Jablonka develops a developmental system approach to examining scientific progress in research into epigenetic inheritance. The approach combines the systems biology approach of Conrad Waddington for investigating embryological development with the sociological approach of Ludwik Fleck for analysing the development of scientific systems. She argues that the case study of epigenetic inheritance therefore highlights the context-sensitive nature of assessments of scientific progress during periods of theory change and suggests that progress is relative to the delineation of the theoretical boundaries of the scientific system and the time scale that is chosen.

In Chapter 9, Teru Miyake offers a functional account of progress in seismology between 1889 and 1940. He argues that the main problem for seismologists in that period was that seismic wave recordings are extremely information-rich but extremely complex, and progress in seismology during this period resulted from advances in methods for extracting information from complexly structured data. Miyake divides the rough half-century in question into three periods. In the first period, seismological research focused on the question of whether the waves that are recorded by seismographs are correctly theoretically characterized. In the second period, the research focused on accounting for anomalies in the seismic wave recordings by finding an interpretation for each significant anomaly. In the third period, the research focus was on making inferences from interpreted seismic wave recordings to features of the earth's interior. In particular, he draws a contrast between British and German seismology, showing that progress in British seismology was stifled by the lack of methods for properly interpreting seismic wave recordings.

In Chapter 10, Uljana Feest focusses on conceptual developments in psychology and inquiries into the criteria by which such developments constitute progress. She distinguishes between the issue of (a) what are units of psychological analysis, and (b) what are objects of psychological research, positing that the units of analysis are human (and animal) individuals and that the objects of research are (cognitive, behavioural, and experiential) capacities, which are often individuated by means of folk-psychological terms. While this suggests that conceptual progress occurs when concepts provide improved descriptions of the objects in their extension, Feest raises some doubts regarding the (seemingly intuitive) notion that are

natural and/or ahistorical facts of the matter that settle what psychological concepts 'really' refer to. She argues that (1) conceptual progress occurs when concepts track their (potentially changing) objects, and (2) such efforts rely on the availability of epistemic resources, which include both propositional and non-propositional knowledge. Regarding this latter point, she articulates a broad conception of progress in psychology as the accumulation of epistemic resources and argues that the history of psychology provides us with a trove of such resources.

In Chapter 11, Stephen Turner examines the questions of whether and how sociology progresses. He indicates that the first question relates to the status of 'theories' in sociology, which, despite historical aspirations to universality, are not predictive systems that generate puzzles but second-order definitions and ideal-types, which abstract over intelligible world of the subjects. They can loosely be said to progress in the sense of providing new ways of framing in response to generically defined concerns, such as the stability of elites, and novel social situations. The second question relates to quantitative models. Examples from causal modelling, a basic form of statistical modelling, are discussed to show how this same problem bears on them. They depend on assumptions about which correlations can be plausibly regarded as causal, and which are outside the system and can be ignored. As the social world changes, these assumptions gain or lose plausibility, and the models themselves lose applicability and predictive power. Change here amounts to providing a better fit to novel situations. But the models are purpose relative and the aims, and therefore progress, is externally defined, typically by changing normative or policy concerns.

In Chapter 12, Marcel Boumans and Catherine Herfeld discuss a specific kind of progress in economics, namely progress that is pushed by the repeated use of mathematical models in most sub-branches of economics today. They adopt Shan's functional account of progress to argue that progress in economics occurs via the use of what they call 'common recipes' and the use of model templates to define and solve problems of relevance for economists. They support their argument by discussing the case of 20th century business cycle research. By presenting this case study in detail, they show how model templates are not only re-applied to different phenomena. They also show how scientists come up with them in the first place and how – once they are considered less useful – they are replaced with new ones. Finally, Boumans and Herfeld argue that the case also illustrates that it is not only the mathematical structure that is re-used but that such a re-use also requires a shared conceptual vision of core properties of the phenomenon. If that vision is not shared anymore among economists, a model template can become useless and has to be replaced – sometimes through overcoming resistance – with a different one.

In Chapter 13, Harold Cook examines the notion of progress in medicine. He proposes that impersonal methods of assessing weight, measure, and currency, which were fundamental for establishing commensurable norms in marketplaces, provided the foundation for considering how to apply material commensurability to a knowledge of natural kinds. Once material sameness is defined and accepted, it disappears from the group of issues that are contested. The narrowly-focused but powerful activities in biomedicine show how important material

commensurability is for creating a scientific field that can include anyone, anywhere. Historical examples are introduced to show how an understanding of medicinal substances ('drugs') shifted from personal qualitative experience to impersonal materialistic experiment. Cook argues that the power to materially define and to extract or manufacture globally understood substances illuminates a widely-understood version of progress of medicine. Its deep roots in market exchange also point to the limits of biomedicine to better the health of humans without other forms of governance.

3. Related Issues

In Chapter 14, David Harker examines the relation of scientific progress and scientific realism. He argues that conceiving of scientific success in terms of scientific progress provides a distinct and useful perspective, for purposes of defending a modest form of scientific realism. Harker suggests that scientific realists should be attending to patterns in the history of science for evidence that, over time, science doesn't just achieve more empirically adequate theories, but that it corrects the errors contained within previous scientific work, and thereby achieves greater truthlikeness. To identify such patterns it is important that scientific realists pay more attention both to the varieties of progress and the means by which these are achieved.

In Chapter 15, Eric Oberheim addresses the following questions: What is incommensurability? What causes it? What are its consequences for intelligibility? What does it imply about theory comparison? And finally, what does incommensurability imply about truth, reality, and progress? He argues that incommensurability implies there are at least two kinds of progress (commensurable and incommensurable), which correspond to two methods of writing history (hermeneutic historiography and present-centred historiography). According to the present-centred historiography, scientific progress is a series of better approximations to current theories assuming they are true (or at least approximately true and the closest to the truth available). The hermeneutic historiography, by contrast, characterizes scientific progress as it happened.

In Chapter 16, Milena Ivanova explores the questions concerning the role of aesthetic values in science and how throughout scientific progress the questions we ask about the role of aesthetic values might change. Her examination starts with the traditional distinction between context of discovery and context of justification and shows that neither context is value-proof. Then she illustrates how aesthetic values shape different levels of scientific activities, from designing experiments and reconstructing fossils, to evaluating data. Ivanova then explores how we could justify the epistemic import of aesthetic values and develop some concerns. Last, she examines whether we should expect the questions surrounding aesthetic values in scientific practice to change with scientific progress, as we enter the era of post-empirical physics, big data science, and make more discoveries using machine learning and artificial intelligence.

In Chapter 17, Insa Lawler focusses on a challenge to the philosophical accounts of scientific progress: Idealisations are deliberately and ubiquitously used in science. Scientists thus work

with assumptions that are known to be false. Any account of scientific progress needs to account for this widely accepted scientific practice. She examines how the four main accounts—the functional account, the semantic account, the epistemic account, and the noetic account—can cope with the challenge from idealisation, with an eye on indispensable idealisations. Lawler concludes that, on all accounts, idealisations can promote progress, but only some accounts allow them to constitute progress.

In Chapter 18, Peter Achinstein discusses the role of scientific speculation in the development of science. He offers a broad definition of 'speculating', followed by an account of how scientific speculations are best evaluated, illustrated by the case of James Clerk Maxwell's kinetic-molecular theory of gases. He also examines the question of whether what will be called 'evidential progress', or the lack of it, in science generally can be appealed to in assessing the credibility of a speculative theory. By doing so, Achinstein offers a pragmatic solution to the problem of pessimistic meta-induction.

In Chapter 19, Hanne Andersen provides a philosophical qualification of the political discourse by examining how interdisciplinary progress can be characterised. I argue that in addition to the categories of incremental and transformative progress that are well-known from mono-disciplinary science, interdisciplinary research can sometimes also offer another category of progress that she calls quasi-transformative. In examining these three kinds of interdisciplinary progress, Andersen argues, first, that interdisciplinary progress does not necessarily require a specific type of integration between the involved disciplines or specialties, second, that social relations between scientists with different areas of expertise may play a crucial role in especially transformative progress, and third, that different disciplinary perspectives on what constitutes progress can draw wedges between scientists from different disciplines.

In Chapter 20, Michela Massimi develops a human-right approach to scientific progress. She starts with an analysis of the 'right to enjoy the benefits of scientific progress and its applications' (REBSP). Its long history goes back to the UN Declaration of Human Rights in 1948 and the International Covenant on Economic, Social and Cultural Rights (ICESCR) in 1966. Massimi offers a diagnosis for the patchy implementation to date, back to a number of assumptions about scientific knowledge and its progressive nature that are common to what she calls the 'manifest image' of progress and the 'philosophical image'. Thus, Massimi offers a different image of scientific knowledge and its growth, building on her work on perspectival realism. She urges replacing individuals with situated epistemic communities, the siloed picture with interlacing scientific perspectives and a view of progress sub specie aeternitatis or 'from here now' with one of progress 'from within'. She lays out the contours of a possible 'deontic framework' as a way of reinterpreting the core content of REBSP in light of perspectival realism. By doing so, the REBSP can be read as a 'cosmopolitan right' no longer trapped between the strictures of individual rights vs. the rights of the communities to share in it. Massimi argues that this epistemic shift brings with it much needed 'cosmopolitan obligations' when it comes to sharing in scientific knowledge and its advancements. It has ultimately the potential to change the legal landscape where the

prescriptive force of REBSP currently remains delegated to the good will of individual nations ratifying ICESCR.

References

Bird, Alexander. 2007. "What Is Scientific Progress?" *Noûs* 41 (1): 64–89.

———. 2008. "Scientific Progress as Accumulation of Knowledge: A Reply to Rowbottom." *Studies in History and Philosophy of Science* 39: 279–281.

———. 2022. *Knowing Science*. Oxford: Oxford University Press.

Bury, J. B. 1920. *The Idea of Progress*. New York: Macmillan.

Cevolani, Gustavo, and Luca Tambolo. 2013. "Progress as Approximation to the Truth: A Defence of the Verisimilitudinarian Approach." *Erkenntnis* 78 (4): 921–35.

Collingwood, Robin George. 1965. *The Idea of History*. Oxford: Oxford University Press.

Condorcet, Marquis de. 1795. *Outlines of an Historical View of the Progress of the Human Mind*. London: J. Johnson.

Dellsén, Finnur. 2016. "Scientific Progress: Knowledge versus Understanding." *Studies in History and Philosophy of Science* 56: 72–83.

———. 2021. "Understanding Scientific Progress: The Noetic Account." *Synthese* 199: 11249–78.

Kuhn, Thomas Samuel. 1962. *The Structure of Scientific Revolutions*. 1st ed. Chicago, IL: The University of Chicago Press.

———. 1970. "Logic of Discovery or Psychology of Research?" In *Criticism and the Growth of Knowledge*, edited by Imre Lakatos and Alan Musgrave, 1–23. Cambridge: Cambridge University Press.

Lakatos, Imre, and Alan Musgrave, eds. 1970. *Criticism and the Growth of Knowledge*. Cambridge: Cambridge University Press.

Laudan, Larry. 1977. *Progress and Its Problems: Toward a Theory of Scientific Growth*. Berkeley and Los Angeles, CA: University of California Press.

———. 1981. "A Problem-Solving Approach to Scientific Progress." In *Scientific Revolutions*, edited by Ian Hacking, 144–55. Oxford: Oxford University Press.

Nagel, Ernest. 1961. *The Structure of Science: Problems in the Logic of Scientific Explanation*. New York: Harcourt, Brace & World.

Niiniluoto, Ilkka. 1980. "Scientific Progress." *Synthese* 45 (3): 427–62.

———. 1984. *Is Science Progressive?* Dordrecht: Springer.

Forthcoming in Shan, Yafeng, ed. 2022. *New Philosophical Perspectives on Scientific Progress*. 1st ed. Routledge Studies in the Philosophy of Science. New York: Routledge. https://doi.org/10.4324/9781003165859.

———. 2014. "Scientific Progress as Increasing Verisimilitude." *Studies in History and Philosophy of Science Part A* 46: 73–77.

Post, Heinz R. 1971. "Correspondence, Invariance and Heuristics: In Praise of Conservative Induction." *Studies in History and Philosophy of Science* 2 (3): 213–55.

Rowbottom, Darrell P. 2008. "N-Rays and the Semantic View of Scientific Progress." *Studies in History and Philosophy of Science Part A* 39 (2): 277–78.

———. 2010. "What Scientific Progress Is Not: Against Bird's Epistemic View." *International Studies in the Philosophy of Science* 24 (3): 241–55.

Sarton, George. 1936. *The Study of the History of Science*. Cambridge, MA: Harvard University Press.

Shan, Yafeng. 2019. "A New Functional Approach to Scientific Progress." *Philosophy of Science* 86 (4): 739–58.

———. 2020. *Doing Integrated History and Philosophy of Science: A Case Study of the Origin of Genetics*. 1st ed. Boston Studies in the Philosophy and History of Science. Cham: Springer.