**Scientific Pluralism**

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***Forthcoming in Stanford Encyclopedia of Philosophy***

Science is a complex epistemic and social practice that is organized in a vast number of disciplines, employs a dazzling variety of methods, relies on heterogeneous conceptual and ontological resources, and pursues diverse goals of equally diverse research communities. Philosophers of science have often aimed to find order in this complexity through methods of unification and reduction (Carnap 1927, Oppenheim and Putnam 1958, Nagel 1961). Pluralism, as an explicit program in philosophy of science, emerged from an increasing frustration with the limitations of unifying frameworks in the light of the disunified reality of scientific practice. As philosophers of science increasingly highlighted in the 1970’s and 1980’s, scientific theories often do not reduce (Fodor 1974, Putnam 1973, Suppes 1978), there is not one universal scientific method (Feyerabend 1975, Nickels 1976, Ströker 1971), not only one fundamental scientific ontology (Dupré 1981, Kitcher 1984, De Sousa 1984), and successful science requires not only epistemic but also social diversity (Feyerabend 1978, Harding 1987, Longino 1987).

While scientific pluralism has often been framed in opposition to the unity of science and “the ancient notion of philosophy as unified knowledge“ (Cat 2012), pluralist philosophy of science has become a broad platform for negotiating post-positivist philosophy of science in the light of epistemic and social diversity. The literature on scientific pluralism has therefore increasingly moved from a simple contrast between monism and pluralism to debates about different ways of articulating pluralism (Ruphy 2016). For example, is scientific pluralism grounded in a metaphysical thesis about “the disorder of things” (Dupré 1993) or is it a “methodological stance” (Kellert et al. 2006)? What are the normative resources of scientific pluralism in addressing issues of scientific disagreement and dissent (Dellsén and Baghramian 2020)? What are the demands of inclusive science that represents social and global diversity of scientific communities (Ludwig et al. 2021)? This article explores this “plurality of pluralisms” (Wylie 2015) through four main areas of the debate about scientific pluralism: “Theories, Models, and Explanations”, “Practices and Methods”, “Ontologies, Classifications and Concepts”, “The Social Organization of Science”.

**1 - Historical Context**

Scientific pluralism, as an explicit program in philosophy of science, is of relatively recent origin. Influenced both by Kuhn’s (1962) diachronic and Feyerabend’s synchronic (1965) case for methodological and theoretical plurality, pluralism emerged as a core concept in the negotiation of the post-positivist identity of philosophy of science. The increasing linguistic fragmentation of post-war philosophy led to relatively isolated national discourses about scientific pluralism. For example, scientific pluralism in West Germany emerged as a core topic in philosophy of science (Diemer 1971, Landgrebe 1972) in the wake of the positivism dispute of the 1960s (Adorno et al. 1972) and became widely embraced by critical rationalists in the tradition of Popper who positioned pluralism as a crucial component of non-dogmatic fallibilism and of science in an open society (Spinner 1968, Albert 1970). In contrast, critical theorists challenged the pluralism of critical rationalists as propagating a free market of ideas that actually excludes emancipatory conceptions of science (von Bretano 1971) and falsely assumes neutrality while failing to reflect on its own normative assumptions (Habermas 1970).

In the United States, the articulation of scientific pluralism as an explicit program for philosophy of science has often been related to Patrick Suppes’ presidential address “The Plurality of Science” at the 1977 *Philosophy of Science Association* (Suppes 1978, see also Galison and Stump 1996, Kellert et al. 2006). Suppes’ address indeed marks an important point in the development of pluralist philosophy of science, both because it synthesized a growing discomfort with unificationist agendas in North America and because it articulated a pluralist program that later grew into the *Stanford School of Philosophy* which included the works of Nancy Cartwright, John Dupré, Peter Galison, and Ian Hacking, among others.

The early phase of scientific pluralism in the United States differed from its European counterparts in being less engaged with the social and political organization of science and more focused on questions of theory reduction and physicalism that were promoted both by émigré logical positivists and a new generation of American philosophers like Nagel (1961), Suppes’ doctoral advisor. In the United States, scientific pluralism thereby became framed as a counter-program to unity of science (see Galison and Stump 1996) and Richardson (2006, 3) has aptly described pluralism as a continuing key topic “because current philosophy of science is still working out the ways in which it is not logical empiricism anymore.” Presenting scientific pluralism as a new philosophical paradigm in direct opposition to the unity of science movement, however, runs the risk of an oversimplified historical narrative both because of rich traditions of pluralist thinking in the first half of the 20th century and because of their multifarious connections with the unity of science movement.

American pragmatism constitutes a philosophical tradition with rich pluralist resources, ranging from James’ (1909) commitment to pluralism as a metaphysical claim about the fundamental structure of reality to Dewey’s pluralist case for the epistemic and social benefits of disciplinary diversity and coordination. Dewey’s “Unity of Science as a Social Problem” (1955 [1938]), published in the *International Encyclopedia of Unified Science*, illustrates the complex relations between pragmatism, unity of science movement, and scientific pluralism (Risch 2005). Dewey emphasizes that “in the house which science might build there are many mansions" and takes unity of science as a coordination challenge of a plurality of scientific fields “in common attack upon practical social problems” (1988 [1938], 276). While North American philosophers of science increasingly embraced “analytical philosophy [...] as part of a scientific philosophy against the American followers of traditional philosophy” (Schliesser 2013), the pragmatist roots of philosophers like Nagel challenge a simple divide between a monist and a pluralist phase as two sharply distinguished stages of post-war philosophy of science (Pincock 2017, Schliesser 2020).

On the European side, Neo-Kantianism constitutes an influential intellectual tradition that developed pluralist interpretations of scientific and non-scientific knowledge through emphasis on human perspectivity rather than one absolute account of reality as it is in itself (Cassirer 1929, Rickert 1896, see also Flach 1994). Kant continues to be an important point of reference for scientific pluralists especially in Europe and Latin America in the sense that “Kant’s rediscovery of the human vantage point” is mobilized to argue for “the situated nature of our scientific knowledge” (Massimi 2017, 165, see also Abel 1993, Lombardi and Ransanz 2011, Torretti 2016). Furthermore, Neo-Kantianism also constitutes an important historical link between pluralist intellectual traditions and the Vienna Circle as reflected already in Moritz Schlick’s *General Theory of Knowledge* according to which “every sensible and philosophically honest worldview must be pluralistic. For the universe is variegated and manifold, a fabric woven of many qualities no two of which are exactly alike. A formal metaphysical monism, with its principle that all being is in truth one, does not give an adequate account; it must be supplemented with some sort of pluralistic principle” (Schlick 1918, 305).

In the early development of positivism, Auguste Comte (1998 [1830]) distinguished himself by rejecting the search for universal explanations or methods in science and defended, in contrast with many later positivists of the Vienna Circle, the existence of a variety of research methods specific to each fundamental scientific domain. Other major figures of the French tradition of historical epistemology, such as Gaston Bachelard (1949) and Georges Canguilhem (1965), also defended a lack of methodological unity of the sciences, emphasizing “regionalist” modes of rationalism.

Early positivism, American pragmatism and Neo-Kantianism not only illustrate the diverse historical roots of scientific pluralism but also its complex historical connections with logical positivism and the unity of science movement. A simple contrast between positivist unity and post-positivist disunity has also been challenged in other areas of the history of philosophy of science. For example, Neurath has been recognized (Cartwright et al. 2008) as a core organizer of the unity of science movement who embraced an interdisciplinary mosaic view of science rather than a reductionist physicalism (e.g. Neurath 1935). Furthermore, Carnap’s (1950) pluralism of conceptual frameworks has seen a new wave of popularity debates about both ontology and conceptual engineering (Blatti and Lapointe 2016, Novaes 2020).

Rather than thinking of scientific pluralism as an entirely new paradigm that displaced the unity of science in a linear historical development, the historical context therefore suggests a more complex process of negotiating the identity of post-positivist philosophy of science in metaphysical, epistemological, and social terms. First, metaphysical renegotiation is exemplified in the work of the *Stanford School* such as Cartwright’s (1999) account of a “dappled world” and Dupré’s (1993) case for the “disorder of things”. This metaphysical case for plurality focused less on logical empiricism but rather challenged post-positivist reformulations of the unity of science thesis that heavily relied on assumptions about intertheoretic reduction (Oppenheim and Putnam 1958, Nagel 1961) and increasingly interpreted physicalism as a metaphysical thesis about what fundamentally exists (Hellman and Thompson 1976, Smart 1978).

Second, scientific pluralism has been embraced as a framework for renegotiating the epistemology rather than the metaphysics of science. Most clearly expressed in Kellert et al’s (2006) metaphysically agnostic “pluralist stance”, much of this research reflects the increased integration of philosophy with history and social studies of science. Challenging a sharp divide between an abstract “context of justification” and a historically contingent “context of discovery” (Schickore and Steinle 2006), scientific pluralism can often be understood as an attempt to reconcile systematic philosophy of science with the historization of scientific knowledge production from Bachelard’s (1934) and Fleck’s (1935) historical epistemologies to Kuhn’s (1962) historical challenges of a unified scientific method. The institutionalization of both “integrated history and philosophy of science” (Arabatzis and Schickore 2012) and “philosophy of science in practice” (Ankeny et al. 2011) reflects how much of this integration of historically contingent plurality and systematic philosophical analysis has become mainstreamed in philosophy of science.

The relation between science and society constitutes a third area of pluralist renegotiation of the post-positivist identity of philosophy of science. While early pluralist frameworks such as Suppes (1978) remained in a depolitized frame of epistemological and metaphysical issues that characterized analytic philosophy of science in post-war America (Reisch 2005), scientific pluralism has become a fertile meeting ground for debates about the interaction between epistemic and social diversity. Although European debates about scientific pluralism were intimately connected to politics both by critical rationalists (Albert 1970) and critical theorists (von Bretano 1971), feminist philosophy of science (Harding 1987, Longino 1987) played a crucial role in establishing questions of social and political diversity as core topics for pluralist philosophy of science in North America. More recently, debates about scientific pluralism have become deeply intertwined with wider debates about “science and values” (Douglas 2009) and “science and democracy” (Kitcher 2011). Through this expansion towards questions about the social and political organization of science, pluralist philosophy of science has become increasingly engaged with interdisciplinary science and technology studies (STS) as well as science governance (Jasanoff 2004, Gorman 2010, Latour 2014 [1999]).

Scientific pluralism would be misunderstood as a new paradigm that replaced the unity of science movement. Instead, pluralist challenges of unification have emerged in different contexts and led to a “plurality of pluralisms” (Wylie 2015) that reimagines post-positivist philosophy of science along different metaphysical, epistemological, and social dimensions. Generic commitments to “plurality” by philosophers of science are therefore not much more informative than generic commitments to “diversity” by science administrators. The interesting question is not whether to endorse plurality or diversity in general terms but how to specify plurality and diversity in scientific practice. The following sections outline four areas in which pluralist philosophy of science has made substantial contributions to rethinking scientific practice.

**2 - Theories, models, and explanations**

The coexistence of heterogeneous representations (including theories, models, and explanations) is ubiquitous in scientific practice. Different branches of science offer different theories and laws, raising questions about the nature of the (e.g. reductive and non-reductive) relationships between them. Within a discipline, heterogeneous models or explanations of the same phenomenon may also co-exist. Such cases of representational plurality are now well-documented in various scientific fields. In nuclear physics, for example, several models of an atomic nucleus are available and the same goes for fluid mechanics, which offers various types of modelisation of turbulent flows (Morisson 2011); in economics, a multiplicity of models exist side by side as a base for policy decisions (Rodrik 2015); in climate science, the use of multiple simulation models is a common strategy (Parker 2006, Edwards 2010); behavioural biology offers many examples of co-existence of multiple explanations (Mitchell 2003, Longino 2013, Muszynski and Malaterre 2020). Various pluralist frameworks have been developed to address such cases of plurality, which amount to different views both on the *raison d’être* of these situations and on the appropriate epistemic attitudes towards them.

2.1 Intertheoretic Reduction and Antireductionism

The emergence of pluralism as an explicit program in North American philosophy of science is intertwined with challenges of reductionist and physicalist projects. While “unity of science” received heterogenous interpretations during the interwar period (Symons, Pombo, and Torres 2010), early post-war philosophy of science increasingly focused on unification through theory reduction and on physicalism as an ontological foundation that demands reducibility of all scientifically acceptable phenomena. Scientific unity was assumed to be achieved through reduction of theories and laws developed in the various branches of science. Classical conceptions of reduction conceive it as cross-sciences derivations having explanatory virtues (Nagel 1961, Oppenheim and Putnam 1958). Various modifications of these classical conceptions have been proposed to better accommodate actual cases of intertheoretic reduction (e.g. Wimsatt 1976, Schaffner 1967), but pluralist critiques of intertheoretic reduction have mainly targeted Nagel’s paradigmatic form of reduction.

A first influential antireductionist strategy challenges the very feasibility of reductions. Fodor (1974) appeals to cases of multiple realization to argue that generalizations in “special sciences” such as psychology or social sciences will often not correspond to generalizations in the physical sciences. For example, a generalization in economics may provide interesting insights about patterns in the social world but not correspond to unified physical generalizations or even strict physical laws. Economic events can be realized through vastly different structures “whose physical descriptions have nothing in common” (Fodor 1974, 103) and the reductionist program of unification at the level of microphysics is therefore doomed to fail. A second influential antireductionist strategy is to deny that reductions, even if they were feasible, provide successful explanations by making the case for autonomous explanatory levels. For example, Kitcher (1984a) argues that eliminating macroexplanations provided by classical genetics would constitute an epistemic loss since microexplanations at the molecular level fail to identify causally relevant features of the macrosituation. In the same vein, Garfinkel (1981) contends that micro- and macroexplanations do not have the same object and that a microexplanation can only tell us the mechanism by which the macroexplanation operates, hence the ineliminability of the latter.

Fodor’s and Kitcher’s influential antireductionist arguments purport to establish stronger and more general claims than just showing that the theories of some branch of science are currently not reducible to those of another branch. Their arguments purport to establish that reductionism fails permanently because of some features of the world. As Kitcher (1984a, 371) puts it: “Antireductionism construes the current division of biology not simply as a temporary feature of our science stemming from our cognitive imperfection but as the reflection of levels of organization in nature”. Similarly, Fodor (1974, 113) writes: “I am suggesting, roughly, that there are special sciences not because of the nature of our epistemic relation to the world, but because of the way the world is put together…”. In other words, these influential antireductionist theses can be read as epistemological theses about intertheoretic irreducibility grounded in metaphysical views about some form of plurality or disunity of the world. They stand in contrast with more modest, targeted antireductionist claims derived from local inspections of the reducibility (or lack thereof) of a given theory to another at a certain stage of development of the corresponding research fields (e.g. Kincaid (1990) and Robinson (1992) in biology, and Hütteman (2005) and Batterman (2006) in quantum physics and condensed matter physics, respectively).

The metaphysical dimension of antireductionism becomes even more explicit in the pluralism of the *Stanford School* and especially in the works of Dupré and Cartwright. The metaphysical basis of Dupré’s antireductionism is provided by his thesis of “promiscuous realism” according to which there exists a large plurality of real kinds, none of which can be considered as more fundamental than others. His rejection of essentialism about kinds allows Dupré to claim that the bridge principles needed for reductive derivations cannot be obtained, hence Dupré’s case for disunity as an inescapable attribute of science (Dupré 1996). Cartwright’s antireductionism also goes hand in hand with pluralist metaphysics. In contrast with “vertical” antireductionism opposing reduction to some more fundamental science, Cartwright’s antireductionism can be described as “horizontal”: it is not primarily concerned with issues of intertheoretic reducibility but with limits of applicability of scientific laws in a given field. In physics for instance, Newton’s laws may apply successfully to orderly systems as the ones we set up in the highly-controlled environments of our laboratories (e.g. a harmonic oscillator), but it would partake of an article of faith to believe that Newton’s laws apply to any real-world system. Making instead the case for a “dappled world”, that is, a world displaying both nomologically ordered systems and unruly ones, Cartwright (1999) invites scientists to resist methodological inclinations for generality and reductionist approaches. Cartwright thus shares with other pluralist proponents of antireductionism (Kitcher 1999, Dupré 2002) a practical concern with the takeover of reductionist methodologies in science.

Controversies about reductionism played a crucial role in the formation of scientific pluralism and served as a focal point for the articulation of general pluralist epistemological and metaphysical frameworks. The fading of reductionism as a general ideology in philosophy of science, however, has also shifted the attention of many pluralists away from intertheoretic reduction towards heterogenous relations between explanations, aims, models, practices, and institutions in scientific practice. In some cases, this shift towards “philosophy of science in practice” (Ankeny et al. 2011) has led to challenges not only of reductionism but also of antireductionism as a general account of the relations between scientific theories. For example, Ruphy (2005) argues for “metaphysical abstinence” not only from reductionists but also from antireductionists. In this sense, she argues that pluralists should make temporally qualified arguments in specific settings of scientific practice rather than formulating pluralism as a general account of the structure of science that is grounded in a general metaphysics of the disunity of science.

2.2 Aims and Models

Pluralist accounts of scientific representation commonly start from the assumption that models, simulations, and related media deliver partial, interest-dependent, hence contingent representations of the world. This pluralist stance is defined by way of contrast with a monist view according to which science ultimately aims at establishing a single, complete, and comprehensive account of the world (Kellert et al. 2006, x). An analogy with maps (Winther 2020) is often employed to explain that such a pluralist stance is compatible with some form of “minimal” realism (Longino 2002a) or “modest” realism (Kitcher 2001). Which aspects of a part of the world are represented by a cartographer depends on the intended use of the map, hence the production of a plurality of maps, whose conformity with the real world can be assessed on pragmatic grounds (being successful when using the map). Similarly, science aims at producing a plurality of partial representations of a given phenomenon, depending on various epistemic and practical interests, whose conformity to the real-word can be assessed on empirical grounds.

This general idea of interest-dependency as a source of representational pluralism has been developed further by specifying the nature of the varying interests. In her analysis of the study of extended extragalactic radio sources, Bailer-Jones (2000) underlines that several models of a radio source are developed, each representing separately some specific features deemed striking or puzzling by the modeller, before being re-united to form an overall model. Parker (2006) emphasizes the variety of modelling tasks (e.g. prediction of global average parameters, simulation of regional climate change) as a source of pluralism in climate modelling. Potochnik (2017) construes situations of representational plurality as reflecting different preferences for tracking certain causal patterns instead of others. In her discussion of scientific inquiries about human behaviour, Longino (2006) emphasizes, as a source of pluralism, differences, from one approach to another, in the weight and strength put on some causal factors compared to others.

A key and open issue raised by these pluralistic situations is the nature of the relationship among the multiple models developed to account for the same phenomenon. In some cases, multiple models appear complementary to each other, to the extent that each represents different features of the target system (as maps do). A less straightforward kind of complementarity is analysed by Morrison (2011), who explains that in turbulence modelling, modellers use different mathematical, idealizing techniques to represent turbulence flows, but that the resulting multiple idealized models can all provide useful information. Multiplicity of complementary models of these kinds is thus deemed epistemically unproblematic since it is compatible with the realist expectation that reliable knowledge about the system under study can be derived from its multiple models.

Epistemologically more challenging is the “problem of inconsistent models” (Morrison 2011, 2015), which refers to the use of multiple idealized models making conflicting assumptions to account for the same phenomenon (Weisberg 2007). In contrast with situations of complementary plurality, the existence of multiple, inconsistent models, directly challenges realist epistemic ambition by yielding incompatible claims about the ontology and causal features of the target system.

Various responses to the problem of inconsistent models have been proposed, reflecting different accounts of the proper epistemic attitude to adopt. Some pluralists (Longino 2006, 2013, Waters 2017) develop an ontologically-laden defence of permanently inconsistent plurality by putting to the fore some features of the world – such as its complexity or lack of ordered structure. Inconsistent plurality, being ontologically grounded, is thus here to stay and one should not expect to overcome it by choosing between conflicting accounts or trying to integrate them. Other pluralists, however, resist appeals to ontology to account for persistent methodological and conceptual divides among research programs regarding the same phenomenon. Potochnik (2017) underlines that persistent different approaches in biology should be traced back to persisting divergent interests rather than conflicting commitments to states of the world. Lenhard and Winsberg (2010) and Ruphy (2011a) explain the persistent co-existence of multiple computer simulations of the same target system (in climate science and cosmology, respectively) through epistemological features of the simulation models, such as their plasticity and their path-dependency.

Recently, a growing body of literature has been investigating whether perspectivism (Giere 2010, van Fraassen 2008, Massimi and McCoy 2020) can provide resources to address the challenges raised by multiple inconsistent models. By developing the notion of a ‘perspectival model’, Massimi (2018) argues that the coexistence of seemingly incompatible models (suitably understood) is actually compatible with realist expectations. Morrison (2011, 2015) stresses the difficulty for proponents of perspectivism to defend the epistemic virtues of having multiple models without adopting an instrumental take on models. Rice (2020) also emphasizes the limited prospects of perspectivism for solving the problem of inconsistent models and appeals to the notion of “universality class” to provide an alternative account of the explanatory virtues of idealized models compatible with realist epistemic expectations toward multiple models. Other authors prefer to address issues of integration on a case-by-case basis by framing multiple models as multiple perspectives - e.g. Plutynski (2020) on cancer research and Chirimuuta (2020) on studies of the motor cortex.

Partly in response to this burgeoning literature on representational pluralism and its problems, some authors have raised questions about the distinguishability of pluralism and relativism. Veigl (2020) discusses various points of friction between epistemic relativism and scientific pluralism and investigates under which conditions the two positions can, or cannot, go together. After delineating a “relativist spectrum”, Kusch (2020) considers various seminal pluralist and perspectivist views (e.g. Feyerabend’s and Giere’s views) and contends that they fall within this spectrum.

2.3 Explanatory Pluralism

Explanatory pluralism can be read as a special case of representational pluralism, whose consequences for research practices are especially important, since the prospects of interdisciplinary approaches are often directly linked to the prospects of relating different types and levels of explanations. The diversity of explanatory strategies in scientific practice is now well-documented in certain scientific fields (e.g. Braillard and Malaterre 2015 in biology; Dale et al. 2009 in cognitive science; Grantham 1999 in paleobiology). This diversity may reflect a diversity of views on what may count as an explanation (see section 4.3 on pluralism about epistemic concepts) or/and a diversity of views on what the proper grain or level of explanation should be.

A common account of the sources of explanatory pluralism is pragmatic: which type, which level or grain of explanation is sought for is often taken to be dependent upon the questions being asked (e.g. van Bouwel et al. 2011, McCauley and Bechtel 2001), which vary with epistemic and practical interests. Sober (1999, 551) goes further by contending that there is no objective reason to prefer macro-explanations over micro-explanations (or vice-versa), such a choice being basically a matter of taste. Reacting to such claims of absence of rules for preferring higher-level or lower-level explanations, Gervais (2014) outlines a general framework to conceive how inter-level causal explanations may relate and argues that heuristics guidelines can be developed to point to preferable levels of explanations.

Widely discussed in the pluralist literature is the key issue of the nature of the relationship between various available explanations of a given phenomenon, and several typologies have been proposed along this dimension. Mitchell (1992) first distinguished between “competitive” and “compatible” pluralism. For proponents of “competitive” pluralism (Beatty 1987, Kitcher 1990), the co-existence of competing explanations is temporary, allowing scientific communities to keep open several lines of research until one of them can be identified as the right one. By contrast, compatible pluralism does not consider the existence of alternative types of explanations a sign of immaturity of a field but as reflecting the complexity of the multilevel, multicomponent target systems, lending themselves to integration rather than competition (Mitchell 2003, 2009). Building on further distinctions developed by Mitchell (2003) and Longino (2013), Van Bouwel (2014) offers a fine-grained typology distinguishing six different types of explanatory pluralism covering various kinds of relationships (or lack thereof) between explanations (anything goes pluralism, isolationist pluralism, interactive pluralism, integrative pluralism, temporary pluralism and explanatory reductionism). More domain specific typologies have also been proposed, such as Marchionni’s (2008) distinction between “weak complementarity” and “strong complementarity” of explanations available on macro and micro levels in the social sciences. To what extent some of these options are exclusive from one another or can be held together depends, not surprisingly, upon the exact content assigned to them. Drawing on a refined notion of “fundamental” level of explanation, Steel (2004) argues for instance that explanatory reductionism, properly understood, can be consistent with some forms of isolationist pluralism.

Given the ubiquitous institutional pleas for more interdisciplinary research, a crucial task for pluralist philosophers is to investigate when interactive and integrative approaches may be more successful than isolationist or reductionist ones. Most attempts at addressing this issue have been domain specific and often push at the end for integration of explanations (e.g. McCauley and Bechtel 2001 on psychology and neuroscience, Kendler 2005 on psychiatry, Mitchell 2009 on social insect behaviour). By contrast, Gijsbers (2016) suggests limitations to integrative tendencies by pointing to the possibility that two true explanations of the same phenomenon available from different disciplines may have inconsistent counterfactual consequences and, therefore, cannot be combined. Muszynski and Malaterre (2020) emphasize that much more philosophical work needs to be done on the notion of integration, what exactly it amounts to in practice and under which conditions it may succeed.

**3 Practices and Methods**

3.1 – Diversity of Scientific Inquiries

While it is a truism that scientists investigate diverse phenomena with heterogeneous methods, pluralism as a methodological thesis articulates stronger claims about the inevitability or epistemic benefits of diverse research methods. In his discussion of maxims about unity of method, Hacking (1996) distinguishes between scientific method understood as logic of justification and scientific method understood as methodology, that is, as a way of finding out about the world. When attacking “the opinion generally accepted that the various sciences named are fundamentally distinct in respect of subject matter, sources of knowledge and technique”, Carnap (1995 [1934], 32) was actually solely concerned with issues of justification. What mattered to him was to establish that everything that can be said in science about the world lends itself to the same type of justification, hence the unity of the domain of the sciences. His motivation for the reconstruction of all scientific sentences within a common linguistic framework was to abolish differences in terms of epistemic access, especially between the human and the natural sciences. As is well-known, Carnap’s project was not successful. More generally, as diagnosed by Earman (1992, x), not much progress has been made since the heyday of logical positivism when it comes to the elaboration of a complete and unified account of empirical justification in science, notwithstanding the much-discussed prospects of the Bayesian approach. Today the debate mainly amounts to assessing the cogency of the quest for a unified analysis of inductive inferences, with philosophers such as Norton (2003) challenging the very project of coming up with a universal inductive scheme.

By contrast, on the methodological side of the notion of scientific method, pluralist approaches have given rise to a multiplicity of concepts aiming at describing and making sense of the diversity of scientific practices. Influenced by “science and technology studies”, “integrated history and philosophy of science”, and “philosophy of science in practice”, many efforts have been made to grasp both the diachronic and synchronic varieties of styles of scientific inquiries, in the vein of classical propositions such as Foucault’s “*épistémé*” (1966), Fleck’s “*Denkstill*’ (“thought style”) (1935) or Kuhn’s “paradigm” (1962). Drawing on the work of the historian of science Crombie (1994), who identified six main “styles of thought”, that is, six main modes of “scientific inquiry, argument and explanation” in the European scientific culture, Hacking (1982, 1992a, 2012) develops the multifaceted concept of “style of scientific reasoning”. His ambition is to provide a concept that combines methodological, ontological and social dimensions in order to account for long-term aspects of scientific development. A style of scientific reasoning is characterized as introducing new kinds of objects, new types of propositions, new types of explanations and is “self-authenticating”, that is, it defines its own standard of validity. Hacking also conceives each style as being both the product of the evolution of human cognitive capacities and the result of specific features of human cultural history. Building directly on Hacking’s work, Ruphy (2011b) analyses the kind of ontologico-methodological pluralism that follows from the current co-existence of different styles of scientific reasoning. Her “foliated pluralism” emphasizes four main properties (transdisciplinarity, synchronicity, nonexclusiveness and cumulativeness) of this pluralism.

Other concepts have been proposed combining to varying degrees epistemological, sociological and historical perspectives. Drawing also directly on Crombie’s work, Kwa (2011) further develops the notion of a style of knowing with special attention to issues of responsiveness of styles to the general and intellectual culture in which they are embedded. Jardine (2000) proposes the concept of “scene of inquiry” and advocates a shift of focus away from scientific doctrines providing answers to issues of accumulation of real questions in science. When introducing the concept of “epistemic culture” grounded in ethnographic studies, Knorr-Cetina (1999, 1) is interested in these “amalgams of arrangements and mechanisms”, which create and warrant knowledge in distinctive ways from one scientific field to another.

What are the relationships between these various concepts attending to the variety of scientific practices? Are they redundant, incompatible or complementary? Chemla and Keller (2017) tackle this issue by providing a collection of case studies that explore, from several disciplinary perspectives, the potential of using concepts of culture to study specific scientific practices. Two lessons are drawn. First, differences in scientific cultures are multidimensional, hence the complementarity of the available concepts. Second, scientific cultures are not fixed and not impervious to external influences; on the contrary, they are open and evolving, being also shaped by their constant interactions with both other scientific cultures and external factors.

Inspired by Feyerabend’s plea for anarchism in science (1975), Chang’s (2012) “active normative epistemic pluralism”, is distinguished by its explicit normative stance, advocating the cultivation of multiple systems of practice and knowledge in each field of study, in order to reap two potential epistemic benefits of plurality, benefits of toleration and benefits of interaction.

3.2 Plurality of Disciplines and Inquirers

The plurality of scientific methods and practices is socially organized through a plurality of disciplines and institutions. Relationships between disciplines may take various forms (multidisciplinarity, pluridisciplinarity, interdisciplinarity, transdisciplinarity), depending on the nature of the connections and the retained degree of autonomy, and have been extensively studied by various fields (e.g. sociology, scientometrics, education, interdisciplinary studies). On the philosophical side, key issues are the benefits of disciplinary integration as well as epistemic, ontological, and social tensions of such integration processes.

Cooperation between scientists was already a central concern in the publication of the *International Encyclopedia of Unified Science*. For Neurath, the motivation for connecting laws of different scientific fields was explicitly practical. Taking the example of the control of a forest fire, he argues that a successful intervention requires connecting chemical, biological and sociological laws, and the unity of the language of science was supposed to facilitate these connections (Neurath 1983). In his contribution to the *Encyclopedia,* Dewey distinguishes between science as a body of knowledge and science as an attitude and a method, and emphasizes the societal need for cooperation between scientists working in different fields, calling for “unifying the efforts of all those who exercise in their own affairs the scientific methods so that these efforts may gain the force which comes from united efforts” (Dewey 1955 [1938], 32). For Dewey, this social form of connection between scientists was more important than unifying their language.

More recently, some authors have focused on what actually connects the works of scientists from different disciplines. For example, Hacking (1992b) points out that scientists primarily share instruments and pieces of knowledge rather than high level theories. Beyond cooperation and sharing of instruments and tools, a stronger form of connection between disciplines is integration, which frequently characterizes interdisciplinarity, by contrast with multidisciplinarity or pluridisciplinarity (Klein 2010).

Integration of distinct disciplines may take various forms, depending on the object of integration: explanations (see section 2.3), models, experimental methods, bodies of data, concepts, theoretical frameworks, etc. (Rueger 2005, O’Malley 2013, Grantham 2004). It is commonly argued that integration constitutes a standard of success of interdisciplinary endeavors (Holbrook 2013). However, this assumption has been challenged on the ground that interdisciplinary success can sometimes be achieved without integration of disciplines. For example, Galison introduces the notion of trading zones to describe spaces in which actors “can hammer out a local coordination, despite vast global differences” (1996, 783). By analysing the emergence of evolutionary game theory and the hyperbolic discounting function, Grüne-Yanoff (2016) shows that genuine interdisciplinary interactions can occur (the identities of the two fields are altered as the result of their interactions) while fields keep developing distinct concepts, methods, explanations, ontologies, etc. He concludes that interdisciplinarity may succeed without integration or even unification.

Another line of debate about interdisciplinary interactions concerns “imperialist” incursions of one discipline into other ones. Dupré (1992) discusses the case of two disciplines – economics and evolutionary biology, which extend their domain of relevance to the study of human behaviour. He characterizes their strategies as “imperialist” to the extent that these approaches claim to provide the essential keys to the proper understanding of human behaviour, thereby disqualifying other approaches. For Dupré, such imperialist tendencies should be resisted on the grounds that they are inadequate and unsuccessful beyond their usual subject domain; instead, “horizontal pluralism”, that is, the peaceful and cooperative co-existence of several disciplines, should be cultivated. However, how scientific imperialism should be identified, understood and assessed is still an open issue (Mäki 2013, Clark and Walsh 2009, 2013). Mäki, Walsh and Fernández Pinto (2017) provides further conceptual clarifications and detailed analyses of various cases of interdisciplinary interactions, discussing their epistemic benefits and harms.

Interactions between academic and non-academic stakeholders have become another growing concern that is reflected in frameworks of transdisciplinarity, citizen science, participatory research, public engagement, open science, and so on. The notion of transdisciplinary emerged in the 1970s (Jantsch 1972) and has been driven by policy demands of research at the interface of science and society. For example, a recent OECD report on 50 years of transdisciplinarity claims a “paradigm shift in research practice” (2020, 9) that orients research towards complex multi-stakeholder interactions in addressing equally complex challenges such as climate change, food security, global health, and sustainable energy production. Philosophers of science have more recently connected debates about scientific pluralism with transdisciplinary appeals to epistemic and social diversity (Koskinen and Mäki 2016). Epistemologically, transdisciplinarity comes with opportunities of accessing novel sources of non-academic expertise but also raises complex questions about vastly different methods of knowledge production between academic and non-academic actors (Bedessem and Ruphy 2020, Gibbs 2015). Politically, transdisciplinarity promises more inclusive research that reflects the concerns of heterogeneous stakeholders but also often reproduces existing hierarchies in the selection of stakeholders and in organizing collaborative processes (Healy 2019, Ludwig and El-Hani 2020).

**4 - Ontologies, Classifications and Concepts**

Diverse scientific practices come with diverse conceptual resources. While philosophers and scientists often aim for conceptual unification, pluralists challenge the need for unification along different dimensions. First, ontological pluralism argues that science does not converge on one absolute conception of the world and that scientific ontologies are inevitably influenced by heterogeneous epistemic and social values of scientists. Second, classificatory pluralism explores the epistemic and pragmatic virtues of classificatory and taxonomic diversity as an integral part of successful scientific practices. Third, pluralism about epistemic concepts challenges the unifying ambitions of philosophers who aim to provide general accounts of epistemic core concepts in science such as explanation, experiment, or objectivity.

4.1 Natural Kinds and Ontological Pluralism

Debates about ontological pluralism commonly depart from wider controversies about metaphysical realism (Nagel 1989, Sider 2009, Williams 1985) and the assumption that science aims for what Williams (1985, 139) has called an “absolute conception” of “the world as it is independent from our experience.” In philosophy of science, metaphysical realism has been commonly formulated in the “tradition of natural kinds” (Hacking 1991). While this tradition is itself multi-faceted, it historically converges with Williams’ ideal (1985, 139) of “a conception of the world that might be arrived at by any investigators, even if they were very different from us.” Natural kinds exist in nature independently from our experience and scientific investigators will therefore ultimately discover the same natural kinds despite different cultural backgrounds, experiences, and interests. For example, anthropologists have argued that communities around the world converge in recognizing the same biological kinds as they discover the same objective discontinuities in nature (Berlin 1992).

In philosophy of science, ontological pluralism commonly departs from tensions between the monist ideal of an absolute conception of the world and the messy plurality of ontologies that are actually employed in science. In scientific practice, ontologies do not converge on one absolute conception of the world but are shaped by heterogeneous epistemic, practical, and social concerns of researchers. The species debate has become a classic case for developing this line of argument. While species have often been characterized as paradigmatic natural kinds, philosophers of biology have argued that the biological world can be divided into species along many different ecological, genetic, morphological, reproductive, and phylogenetic criteria (Kitcher 1984, Dupré 1993, Wilson 1999). Furthermore, the diversity of the biological world (think of bacteria, dinosaurs, mosses) and of biological research programs (think of conservation biology, medical microbiology, phylogenetics) makes it unlikely that scientists will ever agree on a set of criteria for dividing the biological world into species or even taxa more generally.

Beyond this general emphasis of ontological heterogeneity, however, ontological pluralism takes various forms. One area of disagreement is how far the case for ontological pluralism reaches. In the context of biological taxonomy (Ereshefsky 2000), for example, more moderate forms of pluralism only accept species taxa that are monophylectic (Mishler and Donoghue 1982) while more radical pluralist proposals insist on the legitimacy of non-historical taxa (Kitcher 1984) or even of non-academic kinds that divide the biological world along diverse non-historical (e.g. morphological, behavioral, ecological) and pragmatic (e.g. culinary, economic, medicinal, aesthetic) criteria (Dupré 1999, Magnus 2012). For example, more recent debates about indigenous ontologies push the boundaries of ontological pluralism by addressing ontologies that are shaped by epistemic and social concerns of local communities rather than the concerns of academically trained researchers (Kendig 2020, Ludwig and Weiskopf 2019, Robles-Piñeros et al. 2020, Weiskopf 2020).

A second area of disagreement concerns the fate of natural kinds. Many scientific pluralists aim to reimagine the tradition of natural kinds in pluralist terms (Ereshefsky 2018, Kendig 2015, Barberousse et al. 2020). One common strategy departs from a recognition of property clusters (Boyd 2019, Slater 2015) or nodes in causal networks (Khalidi 2015) that shape scientific ontologies. For example, classic examples of natural kinds such as *gold, tiger*, or *water* come with clusters of causally connected properties that make them suitable for scientific inquiry and distinguish them from gerrymandered entities such as the disjunctive kind *gold-or-tiger*. Scientists can learn a lot about gold and they can learn a lot about tigers but there is little to learn about the disjunctive kind *gold-or-tiger.* Current accounts of natural kinds commonly hold that these insights about the cluster structure of the world can be embraced by pluralists while insisting that the prioritization of specific properties and clusters responds to contingent research interests and does therefore not converge on one absolute conception of the world (Franklin-Hall 2015).

However, not all pluralists consider the tradition of natural kinds worth saving. Hacking (2007) influentially suggested that the tradition “is in disarray and is unlikely to be put back together again” and a number of philosophers have suggested to move on without natural kinds (Chakravartty 2017). For example, Ludwig (2018) proposes a multidimensional framework of “non-arbitrary classification” and Brigandt (2020) proposes to avoid natural kinds in favor of an account of kinds that focuses on interaction with human aims (see, however, Conix and Chi 2020, Ereshefsky and Reydon 2019). While these eliminativist proposals eschew natural kinds, they remain committed to the minimal realist assumption that scientific ontologies are shaped by empirical discoveries about the structure of the natural world.

An even more radical departure from the tradition of natural kinds is reflected in constructivist and relativist frameworks in the spirit of Goodman’s (1978) *Ways of Worldmaking*. While few philosophers appeal to worldmaking without further qualifications, criticism of the notion of representation can challenge realist frameworks that treat ontological plurality as representing a shared reality through different conceptual lenses. The critique of representationalism has become especially prominent in the so-called “ontological turn” (Holbraad and Pedersen 2017) in anthropology and science studies. A substantial part of this literature conceptualizes ontological pluralism not in terms of different representations of the world but rather in terms of different worlds (Henare et al. 2017, Viveiros de Castro 2009, Pickering 2017).

4.2 Understanding Classificatory Practices

While the heterogeneity of scientific ontologies raises metaphysical questions about the fate of natural kinds and realism, it also highlights epistemological questions about the role of classifications in scientific practice. A major strand of pluralist literature aims to understand how diverging concepts are productive features of science rather than a problem that calls for unification (Kendig 2015). A large body of literature has emerged that addresses taxonomic plurality in fields such as astrophysics (Ruphy 2010), bioinformatics (Leonelli 2014), cognitive sciences (Ludwig 2015), chemistry (Chang 2012), genetics (Griffiths and Stotz 2013), geography (Winther 2020), microbiology (O'Malley 2014), or psychiatry (Büter 2019).

While this literature emphasizes the productivity of classificatory plurality in science, it also raises complex questions about its functions and limitations. One issue of increasing concern is the role of social and other non-epistemic values in classificatory practice (Ahn 2020, Ludwig 2016, Winther and Kaplan 2013). Much of the older pluralist literature on issues such as biological taxonomies focuses on the heterogeneity of epistemic interests: researchers with different explanatory interests pay attention to different patterns and therefore classify their target domains in different ways. However, explanatory priorities of scientists have non-epistemic grounds and non-epistemic values also often affect more directly classificatory choices. The burgeoning philosophical literature on psychiatric classification can illustrate not only the plurality of classificatory practices but also the entanglement of epistemic and non-epistemic concerns. For example, different iterations of the Diagnostic and Statistical Manual of Mental Disorders (DSM) illustrate the flexible and shifting boundaries of psychiatric categories (Wilson 1993, Tsou 2015, Zachar et al. 2109) through the interplay between epistemic and non-epistemic values. On the one hand, substantial parts of the literature address psychiatric categories as natural kinds (Kincaid and Sullivan 2014) by aiming to identify dysfunctions through epistemic criteria of explanation, prediction, and intervention (Tekin 2016). On the other hand, it has been widely argued that the epistemic and non-epistemic aims of psychiatry are inseparably intertwined (Büter 2019, Cooper 2020, Zachar 2014, Solomon 2020) and that psychiatric classification also responds to more direct pragmatic concerns from applicability in practice to normative concerns about pathologization and medicalization of society.

Negotiating classificatory practices through heterogenous epistemic and non-epistemic values raises complex methodological questions. As Conix (2020) points out, a more restricted pluralism can accept non-epistemic values when epistemic considerations alone are not sufficient to come to a decision. While this “epistemic priority” view of non-epistemic values as tie-breakers follow prominent accounts in debates about theory choice (Steel 2017), one may also adopt a “joint satisfaction” view that conceives epistemic and non-epistemic values equally important in shaping classificatory norms. Cases from the human sciences such as psychiatry may even motivate a more radical “social priority” view that puts concerns such as “human well-being” at the centre of psychiatric classification and integrates epistemic concerns insofar as they contribute to better explanation, prediction, and intervention in the service of socially desirable psychiatric practice.

Another methodological challenge for pluralist accounts of classificatory practice are the virtues of standardization in scientific practice. Ontological pluralism is often embedded in a wider critique of the metaphysical ideal of an absolute conception of the world. The move from ontology to classification, however, introduces further pragmatic considerations about standardization. Even steadfast ontological pluralists need to acknowledge that unified classificatory standards are often of pragmatic value in establishing common frameworks and terminologies (Sterner et al. 2020). For example, debates about “taxonomic governance” are motivated by concerns that the disorder of species classifications affects negatively epistemic progress (Conix 2019) and ultimately reduces “the effectiveness of global efforts to halt biodiversity loss” (Garnett and Christidis 2017, 26). However, attempts to standardize biological taxonomies (and scientific classifications more generally) also come at costs. One crucial benefit of taxonomic plurality is the ability to incorporate diverse epistemic and non-epistemic concerns that can drive different classificatory decisions. Governance of classificatory practices is therefore inevitably political by raising the question whose concerns are authoritative and how tensions are negotiated in the development of standards. One emerging area of research, for example, concerns the plurality of classificatory practices in cross-cultural perspective and the risk of marginalizing locally adapted classificatory practices through dominant standards from biological taxonomy (Robles-Piñeros et al. 2020) to psychiatry (Popa 2020).

4.3 Pluralism About Epistemic Concepts

Debates about ontological and classificatory pluralism are largely concerned with the objects of scientific research such as biological species or mental disorders. A related but distinct debate focuses on epistemic core concepts that scientists use during their investigation: explanation, experiment, evidence, knowledge, model, understanding, objectivity, observation, probability, and so on. Philosophical analysis of such epistemic core concepts is often characterized by monist ambitions of developing general and unified definitions with necessary and sufficient conditions.

History of science has become one of the major sources of destabilization for such unifying ambitions. The project of “historical epistemology” (Feest and Sturm 2011, Arabatzis and Schickore 2012, Rheinberger 2018) aims to historize the epistemic core concepts in science by analyzing their shifting boundaries and roles in scientific practice. Daston and Galison’s (2007) history of objectivity exemplifies this program through a historical series of three core frames from “truth-to-nature” to “mechanical objectivity” to “trained judgment”. Rather than defining objectivity as an ahistorical feature of science, Daston and Galison’s history of objectivity traces different epistemic virtues of science that become emphasized in different historical periods as the attempt to be true to nature through idealization, the goal to purify objectivity through mechanical elimination of subjectivity, and the aim to improve scientific judgment through skills of trained experts.

Scientific pluralism converges with historical epistemology in emphasizing the variability of epistemic core concepts. Objectivity, for example, may not only be historically variable but also have different meanings in different contexts of current scientific practice. Douglas (2004) distinguishes between three dimensions: objectivity1 is conceived metaphysically as a grasp of the real objects in the world, objectivity2 refers to an epistemic position of detachment from personal interests and values, and objectivity3 identifies the social process of organizing science to reduce individual biases and idiosyncrasies. Similar strategies of conceptual diversification are common regarding other epistemic core concepts. For example, the expansive debates about explanatory pluralism (section 2.3 ) suggest that “explanation” does not have one general definition across all scientific disciplines and contexts of application. Instead, philosophical accounts of explanation need to account “for different ideal types of explanation, i.e., different exemplary accounts of what an explanation consists of, which are good as means of classification of different types of explanatory activities that are offered in different domains” (Mantzavinos 2015, 306).

Epistemic concepts such as “explanation” and “objectivity” are embedded in widely different research programs and attempts to provide general definitions run the risk of obscuring this diversity by being biased towards certain domains of research from which the definition is derived. However, pluralism about epistemic concepts is not a truism and can be challenged both from unificationist and eliminativist angles. First, unificationist attempts to develop general definitions may reduce contextual accuracy but come with the benefit of highlighting commonalities of different uses of epistemic core concepts. For example, Koskinen (2018) has argued for a “risk account” of objectivity that is contextual but still argues that the notion of objectivity comes with a unique kind of epistemic endorsement: to call something objective implies to rely on it and to suggest that others should rely on it. Second, pluralism can also be challenged from an eliminativist angle that treats conceptual plurality as evidence of fragmentation that ultimately undermines the usefulness of a concept. For example, Hacking (1999, 24) has challenged what he calls “elevator words” that raise the level of discourse but ultimately becomes “remarkably free-floating” and little more than honorary labels. In the context of cross-cultural research, for example, Ludwig (2017) argues that “objectivity” becomes an elevator word that obscures the heterogeneity of epistemic virtues and vices in producing knowledge about the world.

**5 - The Social Organization of Science**

5.1 Feminist Philosophy of Science and Epistemic Diversity

Feminist philosophy of science has played an important role in the development of scientific pluralism by broadening its agenda towards debates about the relation between epistemic and social diversity in science. Much of the earlier pluralist literature (e.g. Suppes 1978, Fodor 1974, Kitcher 1984) argued for the irreducible plurality of theories, methods, or concepts without relating to the social organization of science. While post-positivist philosophies of the relation between science and society emerged in different academic communities (Canguilhem 1977, Feyerabend 1978, Freire 1970, Habermas 1968, Janich et al. 1974, Klimovsky 1975), they remained largely outside of the mainstream of North American philosophy of science. Feminist philosophers of the 1980s (Harding 1986, Haraway 1988, Longino 1987) challenged this mainstream more successfully by exploring how diverse theories, methods, or concepts relate to diverse social positions and values of scientists. Standpoint theory (Harding 1992, Wylie 2012) and feminist empiricism (Longino 2002a, Anderson 2004) emerged as two major theoretical strands with lasting influence on scientific pluralism.

Feminist standpoint theory can be described as combining a thesis of situated knowledge and a thesis of epistemic advantage (Wylie 2003, Intemanm 2010). First, knowledge is assumed to be situated in the sense that it is shaped by social positioning of actors and their experiences (Haraway 1988). Second, the social positioning of marginalized groups creates epistemic advantages as it can contribute to challenging biases in science (Harding 1992). While the second condition has sometimes been interpreted (and strategically misinterpreted) as making obscure claims about epistemic superiority of women, Wylie (2003) emphasizes that standpoint theory does not attribute automatic epistemic privilege to specific social groups. For example, women do not always know more or better but are often able to bring attention to neglected facts (e.g. about sexual health or labor conditions), to methodological biases (e.g. in survey samples or interview guides) or to fruitful research questions (e.g. about neglected social causes of human behavior or of health disparities) that have been marginalized by dominant actors in scientific practices.

Feminist standpoint theory has been of lasting influence on pluralist frameworks in philosophy of science by contributing to a wide range of research programs that explore the knowledge of marginalized stakeholders and challenge dominant scientific perspectives as being grounded in the standpoints of dominant actors in scientific practice. For example, Wylie’s (2015) work connects standpoint theory with debates about indigenous knowledge in archeological research. As also increasingly recognized in philosophy of science more broadly (Kendig 2020, Ludwig 2017, Weiskopf 2020, Whyte 2013), indigenous people are experts about local environmental and social systems while indigenous knowledge remains widely marginalized both in research and policy. By emphasizing the situated knowledge of indigenous people, philosophers of science have therefore more recently articulated accounts of epistemic injustice in science (Koskinen and Rolin 2019) and explored the challenges of approaching epistemic plurality from a global perspective (Ludwig et al. 2021, Zambrana and Machaca Benito 2014). Harding’s work (2015, 2020) has connected standpoint theory to debates about post- and decolonial perspectives on science that emphasize that situated knowledge in the Global South remains largely marginalized in the mainstream of academic knowledge production (Mavhunga 2017, Mignolo 2010, Santos and Meneses 2009).

Feminist empiricism constitutes another major influence on scientific pluralism (Anderson 2004, Longino 2002, Kourany 2010, Solomon 2006b) that has developed in productive tension with standpoint theory (Intemann 2010). Rather than focusing on the knowledge of specific social groups such as women or indigenous communities, feminist empiricism departs from methodological considerations about the role of social values in scientific practice. Commonly contrasted with the ideal of value-free science (Elliott 2017), feminist empiricists have argued that social values cannot be eliminated from scientific practice including theory choice. For example, Longino (1990) influentially argued that the underdetermination of theories through empirical evidence requires social and other contextual values in theory choice.

While feminist empiricism makes the case for the legitimacy of feminist values in science, it has also shaped scientific pluralism more broadly by fostering a debate about the methodological dimensions of value plurality and dissent in science. Longino (1993), for example, aims to replace the ideal of value-free science with a different set of procedural criteria according to which science should provide (1) forums for criticism that allow the formulation of scientific dissent, (2) uptake of criticism in the sense that dissent is actively discussed in scientific discourse, (3) standards that are publicly recognized and allow for the evaluation of dissenting positions, (4) equality in the sense that different epistemic communities are recognized as having equal authority.

Longino’s criteria illustrate the contributions of feminist empiricism to scientific pluralism beyond explicit concerns with gender by aiming to articulate a general framework for epistemic and value diversity as conditions of successful science. In fact, one of the common criticisms of Longino’s framework has been that it is not feminist at all but rather opens the door for arguments in favor of the inclusion of anti-feminist or otherwise anti-egalitarian voices in research (Crasnow 2013, Hicks 2011, Kourany 2010). As such, feminist empiricism has contibuted to the development of a social epistemology of scientific knowledge production that addresses the complexity of epistemic and value plurality in practice (Grasswick and Webb 2002, Solomon 2006a, Biddle 2007). For example, climate science has become a focus of debates both in relation to the role of values in theory choice and the role of dissenting opinions in scientific practice (de Melo-Martín and Intemann 2018, Keller 2017, Lewandowsky et al. 2018). Biddle and Leuschner (2015) challenge simple narratives about the epistemic benefits of plurality and dissent by arguing that dissenting opinions of climate skeptics are epistemically detrimental to climate research both by forcing engagement with strategically placed but unhelpful objections and by creating a social climate of fear of articulating scientific opinion in public. For scientific pluralists, hard cases such as climate skepticism indicate the need to carefully articulate what types of dissent, disagreement, and diversity are desirable in scientific practice (Dellsén and Baghramian 2020, Hauswaldt 2017, Intemann 2011, Leuschner 2018, Rolin 2017).

5.2 Democratization and Governance of Science

Traditional perspectives on science as self-regulating through politically neutral epistemic norms (Merton 1942) suggest that research requires little governance (Wilholt 2012). For example, Bush’s (1945) government report *Science – The Endless Frontier* has been widely portrayed as a landmark for American science policy after World War II that treated science as a neutral and objective foundation from which applied technologies and commercial innovations derive. While North American philosophy of science largely adopted this depoliticized vision of science (Reisch 2005), pluralist philosophers of science like Douglas (2009), Longino (1990), Harding (2015), and Kitcher (2001) can be positioned in a wider intellectual shift of rethinking the relation between science and society that has been driven by the rapid technological and scientific transformation of post-war societies including their existential risks from industrial disasters in Bhopal or Chernobyl to public controversies about genetic modification or climate change (Macnaghten 2020).

In philosophy of science, Kitcher’s (2001, 2011) model of well-ordered science provides an influential proposal for aligning science and society through democratic negotiation of agenda setting and application. Rather than endorsing direct democratic control of scientific agendas through voting, Kitcher imagines an idealized deliberative process that involves a public that is tutored by the relevant scientific evidence and pluralistic in a fair representation of sometimes incompatible preferences of stakeholders. Well-ordered science therefore aims to articulate a “third way” (Kitcher 2002) between pathologies of direct democratic control of science and an expert-driven technocracy that separates science from society.

Although Kitcher’s moderate pluralism of “well-ordered science” has been widely discussed in philosophy (Brown 2004, Cartwright 2006, Fernández Pinto 2015, Van Bouwel 2009), its highly idealized model of public deliberation has only limited appeal to science governance scholars who have become more closely aligned with science and technology studies (STS) and research on public deliberation under non-ideal conditions (Hagendijk and Irwin 2006, Kearnes 2009). One major contribution from STS is Jasanoff and Kim’s (2009) notion of “sociotechnical imaginaries” that approaches scientific agendas not through ideal deliberation but heterogeneous national cultures of imagining and negotiating futures. In their comparative study of nuclear energy in the US and South Korea, for example, Jasanoff and Kim emphasize that the American imaginary reflects a discourse of containment between the potentials of nuclear superpower and its existential risks, while the South Korean imaginary incorporated nuclear energy into a narrative of scientific and technological progress in the ascent of an underdeveloped nation into a modern society. Thinking about the international plurality of scientific agendas through sociotechnical imaginaries therefore challenges scientific pluralists to address democratization not merely as an ideal in which all preferences and stakeholders are equally represented but as a non-ideal process that unfolds in interaction with heterogeneous discourses, identities, institutions, and technologies.

In science governance, “responsible research and innovation” (RRI) has emerged as an increasingly influential approach for addressing stakeholder plurality and public deliberation under such non-ideal conditions (Doezema et al. 2019, von Schomberg 2013, Wittrock et al. 2021). RRI approaches such as Stilgoe et al.’s (2013) AIRR framework aim to align science and society through governance that is oriented through four dimensions of (A) anticipation, (I) inclusion, (R) reflexivity and (R) responsiveness. For example, anticipatory exercises such as scenario building and reflexive practices such as focus group discussions aim to open-up imagination about different scientific agendas. Inclusion is approached through a wide variety of institutional mechanisms from affirmative action to open access requirements as well as inclusive strategies of organizing research processes through citizen science, participatory research, or transdisciplinarity.

While philosophers of science have increasingly turned to science governance (Douglas 2009, Eigi 2017, Tuana 2010), it remains contentious how far pluralist demands for diversity, participation, and representation should reach. As Macnaghten (2020) has argued, the science governance literature often aims to address the relation between science and society through “grand challenges” or “co-production” models. The “grand challenges” model emphasizes the crucial role of science in addressing pressing societal problems from climate change to food security to public health (Efstathiou 2016). While the grand challenges model aims to include diverse publics in the agenda setting of science, it leaves the epistemic core of scientific knowledge production to scientists as long as they adhere with socially negotiated ethical constraints. Kitcher’s well-ordered science can be interpreted as a philosophical formulation of grand challenges science that articulates a pluralist model for public deliberation for early stages of agenda setting and final stages of application but not for the research process itself. As Longino (2002b, 574) puts it: “Kitcher wants to democratize science policy, not science.”

In contrast, Macnaghten’s (2020) “co-production” model reflects a more radically pluralist tradition in STS that emphasizes the inseparability of epistemic and social orders across all stages of scientific practice. For example, Jasanoff and Simmit’s (2017) co-production model argues that not only scientific agendas and applications but also scientific facts have to be understood as normative in public. According to Jasanoff and Simmit, public facts always interact with social negotiations of whose realities and values matter, what can be contested in a democractic process, and what can be articulated in a given sociotechnical imaginary. While these points resonate with standpoint theory (Wylie 2013) and feminist empiricism (Longino 2002a) as described in the last section, many of these connections remain implicit and point towards a challenge of a more explicit integration of pluralist philosophy of science with interdisciplinary research in science governance.

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