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Science on Trial

ON OCTOBER 22, 2012, in the small Italian town of L'Aquila, seven earthquake experts were convicted of manslaughter and sentenced to six years in prison.[1] The prosecutor claimed that they were responsible for the death of 309 residents in a major earthquake in 2009 due to their failure to adequately assess and communicate seismic risks ahead of time. In the three months preceding the earthquake, the city had experienced an event that experts call a seismic swarm: two or three low-level tremors daily. An additional fifty-seven tremors took place in the five days before. Residents were unnerved and turned to scientists for guidance on whether these tremors signaled a major earthquake, and if so, whether they should evacuate the city. Their worries were exacerbated when a local lab technician named Giampaolo Giuliani began to predict a major earthquake on the basis of his measurement of radon gas levels.[2] The scientific community had repeatedly rejected the reliability of radon measurements for short-term predictions of earthquakes, and Giuliani had been denied funding for his research several times because his work was insufficiently scientific.[3] But this did not stop him from setting up a website to post daily radon readings and sharing his predictions with the locals. A few days before the earthquake, the mayor issued a gag order on Giuliani for fear that his website would provoke panic.

1. Elisabetta Polovedo and Henry Fountain, "Italy Orders Jail Terms for 7 Who Did Not Warn of Earthquake," *New York Times*, October 22, 2012, https://www.nytimes.com/2012/10/23/world/europe/italy-convicts-7-for-failure-to-warn-of-quake.html.

2. Stephen S. Hall, "Scientists on Trial: At Fault?," *Nature*, September 14, 2011, https://www.nature.com/news/2011/110914/full/477264a.html.

3. John Dollar, "The Man Who Predicted an Earthquake," *Guardian*, April 5, 2010, https://www.theguardian.com/world/2010/apr/05/laquila-earthquake-prediction-giampaolo-giuliani.

It was in this context that the Italian Civil Protection Department and local officials decided to hold a meeting with seven seismologists to comment on the probability that the seismic swarm in L'Aquila might precede a major earthquake. The scientific opinion was that this is quite rare. According to the meeting minutes, one of the participating scientists said, "It is unlikely that an earthquake like the one in 1703 could occur in the short term, but the possibility cannot be totally excluded."[4] The meeting was short and followed by a press conference in which Bernardo De Bernardinis, vice director of the Civil Protection Department, announced that the situation was "certainly normal," adding, "The scientific community tells me there is no danger because there is an ongoing discharge of energy."[5] This press conference was the grounds for the charges that led to the scientists' conviction. The charge was not a failure to predict the earthquake, which the prosecutor recognized was not possible, but rather the misleading assurance by a group of respected experts that there was no danger. He claimed that this message had led residents—and especially the younger and more educated ones—to change their plans and stay in L'Aquila, with disastrous consequences.[6]

This small but dramatic episode illustrates some of the key features of the use and misuse of scientific advice in public policy.[7] On the one hand, it shows the dependence of citizens and public officials on scientific expertise on a matter literally of life and death.[8] The residents of L'Aquila turned to science for an explanation in the face of an unusual and frightening natural event. The science was crucial on this issue. Attempting to see the problem merely as a conflict over values, such as whether the residents were the sorts of people

4. Hall, "Scientists on Trial."

5. Nicola Nosengo, "Italian Court Finds Seismologists Guilty of Manslaughter," *Nature*, October 22, 2012, https://www.nature.com/news/italian-court-finds-seismologists-guilty-of-manslaughter-1.11640.

6. Hall, "Scientists on Trial."

7. For a detailed discussion of the role of values and uncertainty in this case, see Melissa Lane, "When the Experts Are Uncertain: Scientific Knowledge and the Ethics of Democratic Judgment," *Episteme* 11, no. 1 (March 2014): 97–118.

8. Deborah Coen argues that historically, earthquake science relied heavily on data provided by local observers. This changed in the twentieth century as a result of what she calls the construction of incommensurability between lay experience and scientific data, but she suggests that the twenty-first century may see another reversal given the increased uncertainty. See Deborah Coen, *The Earthquake Observers: Disaster Science from Lisbon to Richter* (Chicago: University of Chicago Press, 2013).

who would leave their city when faced with an existential threat, would be to miss the point. Factual questions mattered: What was the likelihood of a major earthquake, and what was the risk of harm to the residents in the event of an earthquake?

On the other hand, the incident exposes the limits of decision-making on the basis of scientific knowledge. Like many other areas of science, though more so than most, earthquake science is uncertain and inexact. Scientists have become increasingly capable of predicting the likelihood that an earthquake will strike a given area within a given time period, but there is still no accepted scientific method for reliable short-term prediction.[9] The seismologists who were consulted had some data on the likelihood of a major earthquake in the days following a seismic swarm, but these findings were far from conclusive. Given the uncertainty and limits of reliable knowledge, residents' attitudes toward risk were critical to determining the appropriate earthquake response. Yet ironically, only the lab technician Giuliani seemed to appreciate the power of public fear, while local officials appealed to the authority of science in an ill-conceived attempt to reassure the public.

After the highly publicized trial, scientists and scientific associations around the world protested the conviction on the grounds that it penalized scientists for making a prediction that turned out to be incorrect. The president of the American Association for the Advancement of Science wrote a letter to the president of Italy, arguing that this kind of treatment would have a chilling effect and discourage scientists from public engagement. While the scapegoating of scientists through the criminal system may not have been an appropriate response to what had taken place, it was clearly a reaction to the mishandling of expert advice before the earthquake. The officials had denied the public a chance to understand the content and uncertainty of the science, instead delivering an authoritative judgment with an appeal to the views of "the scientific community." This had created a false sense of security, and deprived citizens of the ability to evaluate the information for themselves, and make up their own minds about how to respond to an unknown and unquantified danger.

The L'Aquila case was a particularly dramatic example of a community's dependence on scientific advice and the disastrous results of bad advice, but it is hardly unique. The COVID-19 pandemic, which started in Wuhan, China,

9. Polovedo and Fountain, "Italy Orders Jail Terms for 7 Who Did Not Warn of Earthquake."

in late 2019, and killed nearly two million people globally within a year, exposed both the dependence of governments on scientific advice and cracks in this relationship on a much greater scale. In the face of a new and catastrophic risk, the lives of billions depended on scientists' ability to study the behavior of the novel coronavirus, provide policy advice to governments, and produce safe and effective vaccines. Governments turned to scientists for help, and scientists delivered remarkable amounts of new knowledge in a short period of time. At the same time, this episode showed the difficulties of using scientific knowledge under conditions of uncertainty and disagreement—and the severe costs of failure. Many governments claimed to be following the science while pursuing wildly different policies. Scientists publicly disagreed among themselves as well as with government policies. The science itself was evolving rapidly. Key aspects of the disease, from transmission and fatality rates to the duration of immunity, were unknown. Scientists and public health officials who appeared on regular press conferences focused on short-term health objectives, while disregarding the economic and social impacts of policies as well as broader conceptions of health. Their assumptions were not always disclosed or scrutinized. As appeals to the authority of scientific models and findings dominated public discourse, rejections and dismissals of scientific authority from politicians and the public also intensified.

The COVID-19 response of many countries involved serious mistakes and with disastrous results. Social scientists, public health experts, and physicians are studying the effects of these policies and trying to explain why some nations fared better than others. It is difficult to diagnose the failure, however, without relying on an account that articulates the sources of tension in the relationship between science and democracy, and examines better and worse ways to mitigate them. This book seeks to offer such an account.

What are the dilemmas of scientific advisory committees and their proper role within broader democratic decision-making procedures? How should the certainty, reliability, and completeness of available scientific knowledge affect the procedures for its use? Is it appropriate to expect citizens to engage with the technicalities of science? How are questions about the use of science in a democratic society influenced by broader decisions about the funding, design, and conduct of scientific research? These are the questions I set out to answer. The answers, in turn, will help us identify the structural tensions in the science-democracy relationship, and distinguish them from contingent problems due

to the moral failings or incompetence of individuals occupying prominent political or scientific positions at a particular time.

Our ability to act on some of the biggest problems of our times, such as pandemics, climate change, biotechnology, nuclear weapons, or environmental issues, requires relying on knowledge provided by scientists and other experts. The modern state has struck an unprecedented partnership with science, taking scientific inquiry as its authoritative source of knowledge and the means for bringing about better policy outcomes. New scientific research determines what we see as our problems and the range of options we have for solving them. Meanwhile, contemporary political life is increasingly characterized by pathological treatments of expertise, with denials of science and distrust of scientists, on the one hand, and appeals to the authority of experts and complaints about the ignorance of the citizenry, on the other. These attitudes are intensified in reaction to one another: frustration with denial and pseudoscience leads to increased appeals to the authority of scientists, which in turn generates resentment—and more denial. It is a vicious cycle.

The partnership between democracy and expertise is intrinsically unstable. Democracy—rule by the people—holds out the promise that the people can shape their collective life by making decisions together, either directly or through elected representatives. Expert knowledge threatens to alter or limit the possibilities for democratic decision-making. It presents a rival source of authority in the public sphere, based on truth rather than agreement. This creates the danger that the authority of experts and their claims to objective knowledge will crowd out the space for democratic judgment about how to shape a collective existence. At the same time, scientific experts have no direct access to political power. The truth of scientific claims may not depend on the number of people who believe in them, but their uptake in politics inevitably requires persuading the many. In the realm of politics, scientists must appeal to people who do not share and may not understand the scientific community's methods for settling the truth. Citizens and their representatives ultimately retain the right to reject scientific knowledge, which is a right that they exercise quite often.

Efforts to eliminate this inherent tension would be problematic for both science and politics. Determining scientific truth democratically would be irrational and dangerous, while justifying democratic decisions by appeal to

standards of scientific correctness would set a standard both impossibly high and inappropriate for politics. The legitimacy of democratic decisions derives not from their scientific credentials but instead from the fact that those who are subjected to them have had a say in the decision process.[10] The challenge, then, is to devise ways for expertise and democracy to coexist productively. Expert knowledge could be used to expand the power of democracy or lead to the alienation of citizens from a politics that seems to defy their control. The success of the relationship between democracy and expertise depends on whether democracies can find ways to use expertise to further their own ends and produce good outcomes. Recent failures in the use of science for political decisions—not only on COVID-19, but on climate change, vaccines, genetically modified organisms (GMOs), and earthquake warnings—suggest that it is necessary to rethink how the relationship between science and democracy should be structured. These are not just failures of political practice; they are also failures of political theory.

The tension between expertise and democracy is not a new problem, but it is important to distinguish between two different forms that the problem has taken historically. The first challenges the justification for democratic rule given the alternative of rule by experts. If there are experts who possess superior knowledge about what is best, the argument goes, then having them rule would be in everyone's interest. Participation by those who know less would simply result in worse outcomes for all. This was one of Plato's arguments for philosopher kings, and it is the main claim in recent arguments for epistocracy.[11] The relevant expertise in this case is knowledge of the good or what would be best for the community; it is a form of moral and political knowledge, rather than scientific or technical. This line of reasoning is usually countered by questioning whether such knowledge exists, whether we can identify or agree on

10. In saying this, I align with the "all-subjected principle" on the boundaries of the people. This principle takes bounded political units for granted, but points out that many resident aliens, migrants, and refugees today are unjustly excluded from the political rights and responsibilities of citizenship in states where they are subject to the laws. For a discussion of the all-subjected principle and its more cosmopolitan counterpart, the "all-affected principle," see Sofia Näsström, "The Challenge of the All-Affected Principle," *Political Studies* 59, no. 1 (2011): 116–34. See also Seyla Benhabib, *The Rights of Others: Aliens, Residents, and Citizens* (Cambridge: Cambridge University Press, 2004); Arash Abizadeh, "On the Demos and Its Kin: Nationalism, Democracy, and the Boundary Problem," *American Political Science Review* 106, no. 4 (2012): 867–82.

11. See, for example, Jason Brennan, *Against Democracy* (Princeton, NJ: Princeton University Press, 2016).

those who possess it, whether a small elite or the demos as a whole is more likely to possess it, and if a small elite, whether it can be trusted to rule incorruptibly.[12] These arguments are about the relationship between knowledge and the legitimacy of democratic authority. I mention these only to set them aside.

The other form of the problem of expertise starts from the premise that democracy is a desirable regime type for a variety of reasons and examines the difficulties posed to democratic rule by its inevitable dependence on expertise in policy making.[13] In this case, the expertise in question is scientific or technical. These experts do not claim that they know what is best for the community but rather that they possess the knowledge necessary for attaining democratically determined goals. This book takes up this second form of the problem, and one specific version of it: the relationship between scientific inquiry and politics, where the experts are professional scientists.

The complexity and institutionalization of scientific bodies offering expertise in politics grew rapidly around the middle of the twentieth century.[14] This was a result of the unprecedented alliance between the state and the scientific community following scientists' contributions to the military effort in World War II and the development of the atomic bomb. This new alliance was cemented with the provision of large amounts of public funds for scientific research. The sophisticated, highly professionalized, and expensive scientific enterprise that was established as a result stood in stark contrast with earlier images of science as a largely amateur project. Thinkers such as John Stuart Mill and John Dewey, who were both concerned with the use of scientific expertise in politics, wrote with a different model of scientific inquiry in mind. Science for them was a private activity for curious individuals. The idea of a

12. David Estlund, *Democratic Authority: A Philosophical Framework* (Princeton, NJ: Princeton University Press, 2008); Hélène Landemore, *Democratic Reason: Politics, Collective Intelligence, and the Rule of the Many* (Princeton, NJ: Princeton University Press, 2008); Samuel Bagg, "The Power of the Multitude: Answering Epistemic Challenges to Democracy," *American Political Science Review* 112, no. 4 (November 2018): 891–904.

13. This version of the problem can also be traced back to ancient Greek democracy. For insights on how the ancients dealt with the problem, see Lane, "When the Experts Are Uncertain"; Josiah Ober, *Democracy and Knowledge: Innovation and Learning in Classical Athens* (Princeton, NJ: Princeton University Press, 2008).

14. Michael Oppenheimer, Naomi Oreskes, Dale Jamieson, Keynyn Brysse, Jessica O'Reilly, Matthew Shindell, and Milena Wazeck, *Discerning Experts: The Practices of Scientific Assessment for Environmental Policy* (Chicago: University of Chicago Press, 2019).

professional scientist was a novelty, and many scientists still lacked any kind of formal training.[15]

Scientists today are distinguished by their membership in a professional scientific community. They owe their status and recognition as experts to a complex credentialing system that requires degrees, publications, institutional affiliations, and adherence to professional codes of conduct. Of course, these cannot ensure that scientists will always be experts in an objective sense, or that they will be the right experts to consult for all problems with a scientific dimension.[16] Whether and when scientists are the right experts in a policy context must be determined case by case. Still, the category of the scientist is meaningful as an object of study in politics since scientists are recognized in policy contexts, serve as expert advisers, and have special standing and authority in the public sphere due to their credentials. The existence of a self-regulating and relatively insulated scientific community whose members can have direct influence over the policy-making process thus lends new and distinctive aspects to the old problem of expertise.

The dominant twentieth-century solution to the problem of expertise, developed mostly in the context of social science and especially economics, was to maintain a division of labor between experts and laypeople, modeled after the Weberian account of the relationship between bureaucracy and political leadership.[17] On this view, experts would provide a neutral assessment of the

15. The term "scientist" was coined by William Whewell in 1833. See Laura Snyder, *Reforming Philosophy: A Victorian Debate on Science and Society* (Chicago: University of Chicago Press, 2006).

16. Alvin Goldman argues that an expert is a person who possesses superior knowledge in a given domain than most people, and is able to deploy this knowledge to answer new questions in that domain. Alvin Goldman, "Experts: Which Ones Should You Trust?," *Philosophy and Phenomenological Research* 63, no. 1 (2001): 85–110. This roughly corresponds to Harry Collins and Robert Evans's notion of "contributory expertise." Harry Collins and Robert Evans, *Rethinking Expertise* (Chicago: University of Chicago Press, 2007). These definitions are about what it means to *be* an expert, which may or may not involve social recognition *as* an expert. By contrast, I am interested in those who occupy the social and professional role of scientific expert, and who are recognized as such in the policy context. Of course, the two definitions overlap in many cases; scientists often are the true experts in the areas they study. But they can also come apart. Scientists may be consulted as experts when they are not, and ordinary people may possess expertise according to the Goldman or Collins and Evans criteria, but will usually not be consulted as experts for policy purposes because of their lack of credentials.

17. Max Weber, "Bureaucracy," in *From Max Weber: Essays in Sociology,* ed. Hans Heinrich Gerth and C. Wright Mills (New York: Oxford University Press, 1958), 196–244.

facts, while citizens and their representatives would supply the values necessary for political judgment. Although Max Weber was pessimistic about the ability of bureaucracies to be truly neutral, he held this up as the ideal to strive for. Isaiah Berlin gave a clear expression of this same view in the opening lines of his famous 1958 essay "Two Concepts of Liberty": "Where ends are agreed, the only questions left are those of means, and these are not political but technical, that is to say, capable of being settled by experts or machines, like arguments between engineers or doctors."[18]

Even Jürgen Habermas, who was deeply concerned with the encroachment of scientific and technical expertise into the political sphere, nonetheless accepted the validity of this division of labor. In *Toward a Rational Society*, he deplored the fact that the exigencies of new technologies were increasingly supplanting the decision-making power of political leaders and value judgments were being displaced by the logic of objective necessity.[19] He was concerned that the rationalization of politics would result in science and technology usurping the realm of ends, such that political power would become an empty fiction and all practical matters would be formulated as problems that experts could solve. His solution to this threat of technocracy was to insist on directing scientific knowledge as a means toward goals chosen by deliberating citizens. But he did not question the assumption that experts could be trusted to settle problems about the means in a purely technical and effective way. Although Habermas acknowledged that science is not value free, his conviction in science's capacity for prediction and technological control played a far more important role in his political theory than thorny questions about the epistemic status of scientific claims, which followed from his own pragmatist conception of truth. His one brief mention of uncertainty in this work is revealing. He argued that the reduction of all practical decisions to choice under uncertainty would be the very culmination of rationalization. He failed to note that choice under uncertainty always requires moral judgment—about the outcomes and mistakes that decision makers want to avoid, and the attitudes they take toward risks, which are morally and culturally determined. Scientific probabilities can never determine choice under uncertainty even if we assume that reliable probabilities are available.

18. Isaiah Berlin, "Two Concepts of Liberty," in *Liberty,* ed. Henry Hardy (Oxford: Oxford University Press, 2002), 166–217.

19. Jürgen Habermas, *Toward a Rational Society: Student Protest, Science, and Politics*, trans. Jeremy Shapiro (Cambridge, UK: Polity Press, 1987). See also Jürgen Habermas, *Knowledge and Human Interests*, trans. Jeremy Shapiro (Cambridge, UK: Polity Press, 1987).

These earlier treatments of the problem assumed an idealized view of expertise and were not attentive to the inner workings of science as a practice. They took for granted that experts were successful at providing accurate predictions that enabled rational control over nature. They saw the modern world as characterized by the reduction of contingency; the truly unforeseeable played no part in these theories.[20] Uncertainty was assumed to be probabilistic and subject to human control; nothing, in principle, was beyond scientific prediction. These accounts were driven by the worry that the inexorable logic of technical necessity would crowd out the space for meaningful political choice.[21] Both the Weberian division of labor and Habermas's pragmatic deliberative theory were solutions that aimed to protect a sphere of value-based political judgment beyond the ever-expanding reach of technical assessment.[22]

When we examine recent controversies around scientific knowledge, however—such as on climate change, COVID-19, biotechnology, or artificial intelligence—we see that they are rarely characterized by the predictable decisions, objective assessments, order, rationality, and efficiency that defined twentieth-century hopes and fears around expertise. To the contrary, each case is marked by uncertainty about future outcomes, expert disagreement over the underlying science, and charges of bias on both sides. Many natural processes—like climate change, earthquakes, floods, and hurricanes—are characterized by radical uncertainty, which defies scientific prediction. Further research in these areas often increases uncertainty rather than reducing it and reveals more about what we do not know.[23] The problems of expertise that we

20. Shalini Satkunanandan, "Max Weber and the Ethos of Politics beyond Calculation," *American Political Science Review* 108, no. 4 (2014): 169–81.

21. Sheldon Wolin points out that "the special irony of the modern hero is that he struggles in a World where contingency has been routed by bureaucratized procedures and nothing remains for the hero to contend against. Weber's political leader is rendered superfluous by the very bureaucratic world Weber discovered." Sheldon Wolin, *Politics and Vision: Continuity and Innovation in Western Political Thought* (1960; repr., Princeton, NJ: Princeton University Press, 2004), 379–80.

22. More recent defenders of the division of labor model include Thomas Christiano, *The Rule of the Many: Fundamental Issues in Democratic Theory* (Boulder, CO: Westview Press, 1996); Philip Kitcher, *Science, Truth, and Democracy* (Oxford: Oxford University Press, 2001); Harry Collins and Robert Evans, *Why Democracies Need Science* (Cambridge, UK: Polity Press, 2017).

23. For descriptions of these trends, see Ulrich Beck, *Risk Society: Towards a New Modernity* (London: Sage, 1992); Ulrich Beck and Peter Wehling, "The Politics of Non-Knowing: An Emerging Area of Social and Political Conflict in Reflexive Modernity," in *The Politics of Knowledge,* ed. Fernando Domínguez Rubio and Patrick Baert (London: Routledge, 2012), 33–57;

encounter in these cases do not fit the conceptualization of expertise in twentieth-century accounts.

This book takes the uncertainty, incompleteness, and fallibility of scientific claims to be central to questions about their political use, rather than taking reliable expertise as a black box and asking how it could be used better to advance collective ends. In doing so, I also depart from treatments of the problem of expertise that start from the question of how to improve the public understanding of science in order to use it more effectively. While the public understanding of science is clearly important, starting from this question presupposes that the appropriate role of nonexperts has already been settled, and the primary goal is to inform and educate them about science.[24] If only citizens and policy makers understood the science, the thinking goes, they would be able to make better decisions. This approach puts laypeople in a passive role with respect to the content of expert claims. I propose instead that we start from the prior question of what role citizens and policy makers should play in decisions involving expertise, and will argue that the answer depends on what we know about the limits of expertise. Once we take these into account, we will also arrive at different answers to questions about how science should be translated and communicated, and what form expert-layperson interactions should take.

My central claim in this book is that paying attention to the uncertainty, incompleteness, and possible biases of available scientific expertise as well as the limitations of the decision contexts in which it is used, should change the procedures and institutions appropriate for democratic decision-making on the basis of expertise. Specifically, it gives us reason to make the use of expertise more democratic, flexible, and attentive to the cost and distribution of potential mistakes. This has implications for striking the proper balance between scientific and democratic authority as well as determining the proper procedures for the funding, production, and use of scientific knowledge. The challenge is in specifying what the relevant limitations are, and how and why they should affect democratic procedures. This is the challenge that I take up.

Silvio Funtowicz and Jerome Ravetz, "Science for the Post-Normal Age," *Futures* 25, no. 7 (1993): 739–55; Sheila Jasanoff, *The Fifth Branch: Science Advisers as Policymakers* (Cambridge, MA: Harvard University Press, 1990).

24. Mark B. Brown argues that Kitcher's project is built on the assumption that public distrust and skepticism of science is due to a lack of understanding. See Mark B. Brown, "Philip Kitcher, *Science in a Democratic Society*," *Minerva* 51 (2013): 389–97.

The upshot of the argument is to redraw the boundaries of the Weberian division of labor. While I still assume that professional scientists will be the primary producers of scientific knowledge in society, and nonexperts should supply the goals and value judgments necessary for decision-making, my goal is to expose the fuzzy middle ground where it would be problematic to adhere to a division of labor insofar as facts and values are impossible to separate.[25] The uncertainty and incompleteness of our knowledge and the constraints on decision-making environments mean that certain kinds of judgment that the division of labor model relegates to the expert domain are in fact value-laden ones under uncertainty, and as such, are appropriately made by democratic procedures. Scientists often make these judgments during research or advisory processes, but in doing so they move beyond what is justified by appeal to their superior knowledge. Leaving these judgments unexamined is a failure to exercise a properly democratic responsibility and encourages its inappropriate exercise by experts themselves. I thus argue that nonexperts must scrutinize expert claims, examine the role of values, background assumptions, and uncertainty in the available scientific knowledge, and deliberate about what counts as reliable expertise in a particular context and for a particular purpose. Such scrutiny will be possible only if there are real opportunities for dissent within the scientific community, and institutions that facilitate the discussion and evaluation of science in the public sphere. This requires imagining institutional reforms to reduce obstacles to scientific contestation and prevent the monopolization of knowledge.

A crucial argument of this book is that focusing only on the decision-making stage would give us a narrow picture of how science shapes society and can be used to pursue democratic goals. The alternatives on the table at the decision stage are largely determined by earlier decisions about which research should be pursued and how.[26] These decisions are typically made by funding bodies, which determine not only the direction of scientific and technological change but also the agenda for future political decisions. Once the impact of

25. In this I go against recent efforts to draw a boundary between the technical and political, thereby restricting the scope of democratic participation. See Harry Collins and Robert Evans, *Why Democracies Need Science* (Cambridge, UK: Polity Press, 2017); Harry Collins, Martin Weinel, and Robert Evans, "The Politics and Policy of the Third Wave: New Technologies and Society," *Critical Policy Studies* 4, no. 2 (2010): 185–201.

26. Kitcher also draws this connection between the funding and use of science. See Kitcher, *Science, Truth, and Democracy.*

scientific findings becomes clear, nonscientists can accept or reject expert claims, but they cannot procure a different kind of science or wish away existing findings. This book therefore examines structures of funding for science, and considers how to strike a balance between scientific and democratic influence over the distribution of public funds for science. Once again, I start from the uncertainty, incompleteness, and fallibility of our knowledge about the outcome of future research. While this indeterminacy is usually taken to ground arguments for the autonomy of science from political influence, I defend the opposite view and maintain that it can actually lend support to certain forms of democratic intervention in the funding process.

Scholars studying the relationship between science and politics frequently draw a distinction between science for policy and policy for science.[27] The former describes science that informs policy decisions, while the latter focuses on the rules and regulations designed to oversee the conduct of science. This book treats the two as interdependent and traces the implications of the same basic argument in both domains. While the political consequences of scientific findings could perhaps be disregarded by scientists pursuing knowledge in complete isolation from society, they cannot be ignored in a scientific community whose activities are publicly funded and whose findings directly inform policy making.

Two important concerns are worth dispelling from the beginning. The first is that concentrating on the uncertainty and limits of scientific knowledge will devolve into radical skepticism about the ability of science to deliver reliable answers. This will blur the distinction between science and politics, and encourage disregarding expertise and replacing it with common sense. It will become clear in the following chapters that this is not my argument. The starting point of this project is that expert knowledge is indispensable to a modern democracy, and experts have superior knowledge and understanding on many crucial questions of fact. The question of how we should respond to climate change, for instance, cannot be settled by our experience of the weather, nor can it be resolved by deliberating about how much we care about nature or future generations. The answer requires knowing how much the earth will warm, and what the impact will be on different regions. We depend on scientists for these answers.

27. Homer A. Neal, Tobin L. Smith, and Jennifer B. McCormick, *Beyond Sputnik: U.S. Science Policy in the Twenty-First Century* (Ann Arbor: University of Michigan Press, 2008); Heather Douglas, *Science, Policy, and the Value-Free Ideal* (Pittsburgh: University of Pittsburgh Press, 2009).

The point of thinking about the implication of the reliability of scientific claims is not to delegitimize them but instead to be clear about why and how citizens must examine expert claims, and what room there is for democratic judgment on scientific issues. We don't need to believe that science is infallible to make productive use of it. My claim is that what we know about the ways in which it is incomplete and biased should influence the appropriate attitude to take toward knowledge claims, and the correct institutional structures for handling them. Taking heed of the limitations of our epistemic situation does not mean that we should abandon informed decision-making. Economist Robert Solow once remarked that realizing that a perfectly aseptic environment is impossible does not mean one might as well conduct surgery in a sewer.[28] But it also does not mean that we conduct surgery as we would in a perfectly aseptic environment. This project considers how we should change the way we do surgery once we realize that the environment is less aseptic than we believed.

The second concern is that even if this book is careful about the status of scientific claims and the proper balance between scientific evidence and democratic procedures, it might nonetheless have the unintended consequence of increasing mistrust of scientists and disregard for evidence. The argument for democratizing the use of expertise inevitably involves drawing science and scientists onto the political stage and exposing their weaknesses. Given the widespread denial and mistrust of science today, this might embolden those who disregard or discredit scientific evidence. Would it not be more appropriate for theorists today to think of ways to shield expertise from politics rather than opening it up to further scrutiny?

This is a serious challenge, especially since I argue in chapter 6 that researchers bear some responsibility for the unintended but foreseeable consequences of their research. Still, I think it is dangerous to respond to pessimism about the current state of democracy and worries about citizens' ignorance by retreating from democratic principles, and thus removing more and more issues from public input. This response avoids dealing with the root causes of the problem and might lead to a backlash against expertise, as the L'Aquila case demonstrates.

People often feel anxious and fearful about scientific or technological developments because they cannot reconcile new truth claims with their deeply

28. Quoted in Clifford Geertz, "Thick Description: Toward an Interpretive Theory of Culture," in *Readings in the Philosophy of Social Science,* ed. Michael Martin and Lee McIntyre (Cambridge, MA: MIT Press, 1994), 230.

held values and cultural commitments. Scientific claims do not intrinsically favor one worldview or set of values over another, but scientists and others who produce and translate scientific findings for use in public life wield significant power in determining which worldviews or values will appear compatible with scientific knowledge. If decisions about which findings are accepted as true for political purposes and what knowledge becomes available for use are removed from democratic influence, citizens might find themselves reduced to a choice between deference to the judgments of scientists and a rejection of the authority of science altogether. This disempowers the public, and encourages unaccountable and irresponsible policy making. Expanding the possibilities for democratic engagement over science is a way to avoid this stark choice and open up more flexible options for reconciling science with politics. This, in turn, can only be done by reinvigorating existing democratic institutions and imagining new ones.

A View of the Theoretical Landscape

The relationship between science and democracy has been examined mostly by scholars in science and technology studies (STS) and the sociology of science along with a few philosophers of science. As a political theorist, what distinguishes my approach is that I place political institutions at the center of my analysis. Scholars in STS have usually avoided thinking in terms of institutions and been particularly wary of taking a normative stance.[29] Similarly, most philosophers of science who have demonstrated how social values shape scientific findings have stopped short of tracing the systemic political implications of these important results. I follow the example of philosophers Philip Kitcher and Heather Douglas, whose pioneering work bridges the gap between the philosophy of science and political philosophy. But they too have largely neglected the dynamics of existing political structures at the intersection of science and policy. While Kitcher develops a highly idealized model

29. See, for example, Jasanoff, *The Fifth Branch;* Sheila Jasanoff, ed., *States of Knowledge: The Co-Production of Science and Social Order* (London: Routledge, 2004); Alan Irwin and Brian Wynne, *Misunderstanding Science? The Public Reconstruction of Science and Technology* (Cambridge: Cambridge University Press, 1996); Bruno Latour, *Politics of Nature: How to Bring the Sciences into Democracy* (Cambridge, MA: Harvard University Press, 2004). For a similar critique of the STS literature for failing to engage with political theory, see Alfred Moore, "Beyond Participation: Opening Up Political Theory in STS," *Social Studies of Science* 40, no. 5 (2010): 793–99.

based on hypothetical discussions between scientists and "tutored" citizens, Douglas examines political problems around science and democracy through the lens of the individual moral responsibilities of scientists.[30]

The distinctive contribution of this book is to develop a theory through the close examination of three types of formal institutions that play a crucial role in the production and use of scientific expertise in democratic societies: scientific advisory committees, small-scale democratic experiments, and funding bodies. I explore their internal dynamics and broader democratic role through the framework of conceptual concerns around authority, legitimacy, equality, freedom, representation, accountability, and inclusion, which are part of the standard vocabulary of political theory. While the thrust of my argument is broadly consistent with works in STS and philosophy that have argued for the need to democratize science, I try to be more precise about what this general claim means for specific institutional bodies and the actors within them. To this end, I articulate specific dilemmas that arise at the intersection of science and democracy—between scientific neutrality and political usefulness, expert knowledge and public participation, scientific autonomy and democratic control, and freedom of inquiry and protection from harm—and reflect on how to resolve them.

The design of institutions requires empirical evidence about performance and information about the particulars of a context, which go beyond the scope of a largely theoretic project such as this one.[31] The same institutions will not be appropriate for all democracies at all times, and we cannot predict the performance of institutions purely from their design. The institutional suggestions I make in this book should therefore not be interpreted as all-things-told prescriptions meant to apply regardless of time and place but rather as practical illustrations of the theory. The aim is to demonstrate that my arguments about the proper relationship between science and democracy *could* be institutionalized, and spell out which institutional forms would better realize them and why. Taking up the challenges of practical specification strengthens a

30. Kitcher, *Science, Truth, and Democracy;* Douglas, *Science, Policy, and the Value-Free Ideal;* Heather Douglas, "The Moral Responsibilities of Scientists (Tensions between Autonomy and Responsibility)," *American Philosophical Quarterly* 40, no. 1 (January 2003): 59–68.

31. For empirical studies of these institutions from a political science / science policy perspective, see David Guston, *Between Politics and Science: Assuring the Integrity and Productivity of Research* (Cambridge: Cambridge University Press, 2000); Roger Pielke Jr., *The Honest Broker: Making Sense of Science in Policy and Politics* (Cambridge: Cambridge University Press, 2007).

theory, even if a gap between theory and practice always remains. In the end, a theory must make some assumptions and idealizations, which place conditions on its applicability to particular contexts. This is a point that I emphasize about the use of scientific models in policy; it is only fair to acknowledge that it also applies to my own theory. I try to respond to this by explaining my assumptions, and supporting their plausibility with relevant evidence and examples where possible.

While other fields have studied the relationship between scientific expertise and democracy using their own theoretical and methodological frameworks, political theorists have largely neglected the subject. My book joins two excellent ones published by political theorists Mark Brown and Alfred Moore in recent years in an effort to establish the problems of scientific expertise as a vital area of inquiry for contemporary democratic theory.[32] Although I agree with many of their points, this book departs from theirs in emphasizing the role of decisions made during the funding and research stages in shaping the political agenda and constraining the possibilities for action. I therefore devote attention to earlier stages of the research process, and argue that the democratization of expertise must be rooted in the democratization of decisions about what kinds of knowledge are pursued and how. My concern with the funding and design choices made at the research stage is absent from these books. I should add that I reject the label of elitism, which Moore uses to describe his theory; to the contrary, I maintain that democracies must find ways to reclaim some of the elite power over agenda setting and decision-making for ordinary citizens themselves.

My position could be described as aiming to democratize the use of expertise, but it is important to clarify how it differs from recent arguments in favor of epistemic democracy and the wisdom of crowds.[33] Unlike scholars in this area, I make no claim that democratic procedures are on the whole more likely to produce "correct" outcomes than decision-making by experts in domains involving complex expert knowledge. The undeniable asymmetries in

32. Mark B. Brown, *Science in Democracy: Expertise, Institutions, and Representation* (Cambridge, MA: MIT Press, 2009); Alfred Moore, *Critical Elitism: Deliberation, Democracy, and the Problem of Expertise* (Cambridge: Cambridge University Press, 2017).

33. Landemore, *Democratic Reason*; Robert Goodin and Kai Spiekermann, *An Epistemic Theory of Democracy* (Oxford: Oxford University Press, 2018); James Bohman, "Deliberative Democracy and the Epistemic Benefits of Diversity," *Episteme* 3, no. 3 (2006): 175–91; Elizabeth Anderson, "The Epistemology of Democracy," *Episteme* 3, nos. 1–2 (2006): 8–22.

the knowledge possessed by a small group of experts and ordinary citizens make epistemic arguments for democracy difficult to carry over to domains of complex expert knowledge.[34] More important, my argument suggests that on issues involving expertise, assessments of the quality of decisions will be determined by the certainty, completeness, and bias of the available expert knowledge. The scientific questions that have been pursued—and how they have been pursued—place limits on the kinds of decisions that citizens will consider possible or desirable on issues where the need for scientific knowledge is acknowledged.

A growing literature on bureaucracies and the administrative state within political theory addresses some problems of expertise.[35] I share this literature's goal of directing theorists' attention to the inner workings of democratic government and administration. Despite some basic similarities, however, the role of science in politics cannot be explained fully by theories designed to analyze the role of bureaucracies. The fundamental worry about bureaucratic domination does not apply well to scientists since they are rarely delegated power to make binding rules. Scientists do not occupy political positions that allow them to exercise arbitrary power over other citizens.[36] The authority they possess is usually epistemic, advisory, or cultural. This does not mean that their authority is unproblematic, but articulating when and why scientific authority becomes a source of democratic concern is a distinct theoretical challenge, which cannot be subsumed under the problem of bureaucratic domination.[37]

34. Landemore defines the scope of her argument as "political decisions," but admits that it is not likely to apply to complex problems such as climate change. See Landemore, *Democratic Reason*.

35. Henry S. Richardson, *Democratic Autonomy: Public Reasoning about the Ends of Policy* (New York: Oxford University Press, 2002); Sabeel Rahman, *Democracy against Domination* (New York: Oxford University Press, 2016); Pierre Rosanvallon, *Democratic Legitimacy: Impartiality, Reflexivity, Proximity*, trans. Arthur Goldhammer (Princeton, NJ: Princeton University Press, 2011); Bernardo Zacka, *The State Meets the Street* (Cambridge, MA: Harvard University Press, 2017); Chiara Cordelli, *The Privatized State* (Princeton, NJ: Princeton University Press, 2020); Leah M. Downey, "Delegation in Democracy: A Temporal Analysis," *Journal of Political Philosophy* (2020), doi.org/10.1111/jopp.12234.

36. Scientists may have arbitrary power over human subjects of research and physicians over their patients unless these relationships are well regulated. I bracket these to focus on the role of scientists in politics.

37. For a defense of the view that scientists do not pose a problem for liberal democracy, see Stephen Turner, "What Is the Problem with Experts?," *Social Studies of Science* 31, no. 1 (2001): 123–49.

The principal-agent framework commonly used to analyze the relationship between bureaucracies and legislatures does not apply straightforwardly to scientists either. Scientists are not the agents of politicians or the public, except when they take up certain advisory offices. Even then, they remain highly independent actors constrained mainly by professional incentives and norms. Their proper role with respect to democratic aims and the extent of their answerability to the public must be theorized rather than assumed. In fact, if the default assumption about bureaucracies is that they ought to be subject to legislative control, the default assumption about scientists is that they ought to be free from democratic control. Of course, this simple contrast misses the complex interdependence between science and democracy that this book examines, but it shows how much variation there is among the democratic expectations from actors loosely categorized as experts.

Scope of the Argument

A few clarifications about the scope of the argument are in order. This project focuses on the natural sciences and largely brackets the social sciences. The distinction is admittedly arbitrary since the philosophical views of science that I draw on challenge the conventional distinction between natural and social sciences as value free and value laden, respectively. It is more accurate to treat the natural and social sciences as continuous rather than different in kind. Still, there are two mainly practical reasons for drawing this line. First, this distinction is commonly made both in theory and practice. Philosophers of science typically concentrate on one or the other, or compare the two with the assumption that they are distinct enough in subject matter and the methodological challenges they face. Political institutions such as legislative committees, executive agencies, advisory bodies, and funding institutions also treat these two areas separately.

Second, even if the natural and social sciences lie on a spectrum, the social sciences lie at the end of the spectrum where predictions are less reliable, well-established findings are fewer, and concept formation and measurement are more difficult. There are well-known methodological challenges specific to explaining and predicting human behavior. On the one hand, these factors might make the social sciences a more fruitful, less controversial, and overall easier target for a book that starts from an epistemological critique to argue for the democratic scrutiny of science. On the other hand, the same reasons make the social sciences a less challenging and rewarding subject for study

because I suspect that few would disagree with the conclusions. If my argument succeeds in the case of the natural sciences, then a fortiori, it applies to the social sciences too.

Another clarification concerns the applicability of the argument within the natural sciences. Is it meant to apply to all natural sciences or only to some? Do we want democratic participation on all issues or can we leave some safely to experts? These questions are more difficult to answer in the abstract because they depend importantly on which scientific issues become politicized and how. The easy part of the answer is that the argument applies to science that has some relevance to policy. It is not concerned with science in the lab that acquires no relevance for public affairs, except for the discussion of funding for basic research in chapter 5. Within areas of science that acquire policy relevance, I think the argument will be most salient on issues that are highly uncertain, with many unknowns and inadequate evidence, and where the political stakes are high. Although we could try to classify sciences according to their level of certainty—with earthquake and climate science, for instance, being less certain than physics or chemistry—it would be a mistake to try to be specific about which particular scientific areas are likely to fall in this category. I do not mean to suggest that every technical issue should be politicized—if a bridge needs to be built, we could safely leave it to engineers—but rather that the question of which issues should or will be politicized is not one that can be specified in theory.[38]

The point about uncertain and high-stakes science suggests another reason why this project is timely: the big scientific problems of our time—COVID-19 and climate change—have been marked from the beginning by a high degree of uncertainty and disagreement among scientists as well as high political stakes. That there is anthropogenic climate change may not be in dispute among scientists anymore, but the key policy-relevant details about how much warming there will be and how it will affect different regions remain unclear. Different climate models prioritize different epistemic values, and make different background assumptions about the historical record, future human behavior,

38. Even bridges can be controversial. The collapse of a bridge in Genoa set off a bitter controversy: Was the accident due to the fallibility of engineering science, or had the management company and Ministry of Infrastructure been negligent? See James Glanz, Gaia Pianigiani, Jeremy White, and Karthik Patanjali, "Genoa Bridge Collapse: The Road to Tragedy," *New York Times*, September 6, 2018, https://www.nytimes.com/interactive/2018/09/06/world/europe/genoa-italy-bridge.html.

and the relative importance of different risks. These features make it clear why democratic engagement must be partly over the content of the science and involve some scrutiny of competing models rather than a debate about moral values that could be addressed independently from the facts. This has not always been the character of the scientific issues that have commanded political attention. The most important scientific issues on the political agenda after the Second World War—the bomb and the space program—were cases where the science was not in dispute. The dilemmas they raised were moral ones about the responsible use of the science. If the division of labor model seemed appropriate for the scientific problems of those times, the more thoroughly democratic model proposed in this project will be more appropriate for ours.

I should add that this book does not focus on the strategic distortion and manipulation of scientific research by corporations, or fabrication of results by individual scientists. These are serious and widespread problems, but they have been documented and analyzed by other scholars.[39] Although more work must be done to reduce their prevalence, I think this work is primarily practical, not philosophical. The problems that I will explore are the ones that remain even when scientists advise policy makers in good faith and intend to solve problems that depend on scientific knowledge. I think this is a realistic description of many expert advisory committees composed of independent research scientists, which are impeded less by deception and fraud, and more by the limits and uncertainty of scientific knowledge and disagreements over values.

Having clarified which kinds of science fall within the scope of this book, I should also say something about how I define democracy. The arguments in this book are intended to be compatible with most widely held normative views of democracy rather than aligning with one specific conception. I take democracy to be a regime characterized by political equality, where collective decision-making procedures are arranged so as to give everyone subject to decisions an equal right to participate in their making.[40] In modern

39. This literature is vast. Highlights include Naomi Oreskes and Eric Conway, *Merchants of Doubt: How a Handful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming* (New York: Bloomsbury Press, 2010); Robert Proctor and Londa Schiebinger, eds., *Agnotology: The Making and Unmaking of Ignorance* (Stanford, CA: Stanford University Press, 2008); Thomas McGarity and Wendy Wagner, *Bending Science: How Special Interests Corrupt Public Health Research* (Cambridge, MA: Harvard University Press, 2008).

40. For similar definitions, see Robert A. Dahl, *Democracy and Its Critics* (New Haven, CT: Yale University Press, 1989); Christiano, *The Rule of the Many;* Niko Kolodny, "Rule over None I: What Justifies Democracy?," *Philosophy and Public Affairs* 42 (2014): 287–336.

representative democracies, this principle is typically institutionalized through free, fair, and contested elections, universal suffrage, guarantees for basic political freedoms of speech, assembly, and association, and popular control over elected representatives.[41] This definition should make my arguments compatible with many liberal, republican, deliberative, participatory, and radical accounts, if not all, but not with elitist theories that view public participation between elections as unnecessary or undesirable. It may also leave out some purely instrumental accounts that take outcome-based criteria to be constitutive of democracy. While my definition of democracy is not an instrumental one, starting from the assumption that modern democracies depend on expertise is to assume an instrumental interest in bringing about good outcomes. The theoretical puzzles in this book do not even get off the ground without this assumption.

It is also worth clarifying the distinction between the role of science in a democracy versus in politics. This book assumes the overall preferability of democracy to other regime types without defending it anew and focuses on the question of how democracies can handle expertise better. Insofar as authoritarian regimes depend on expertise too, some of the answers I provide about the proper division of labor between politicians and experts could be exported to nondemocracies. An example from chapter 3 takes up a gridlock between Napoléon and his main corps of engineers that resulted from a prolonged scientific dispute over the construction of a new canal. The book's main argument, though, has a normative core that does not carry over comfortably to an authoritarian context. It ultimately rests on a view about whose judgments and values should shape the policies by which a community lives. The argument is concerned with the proper source of authority over decisions of a certain kind and the relationship between scientific and democratic authority in decisions that depend on both. These are important in a democratic regime because democracies are meant to be responsive to the values and preferences of their citizens, even if they fall short of this ideal in practice. In authoritarian regimes that make no such claim even in theory, the problem of expertise can be reduced to questions about efficiency and effectiveness. The concern is over how the state can use expertise effectively, and whether decision-making by experts or career politicians produces "better" outcomes. The question of

41. The precise meaning of popular control is controversial. For one answer that I find persuasive, see Sean Ingham, *Rule by Multiple Majorities: A New Theory of Popular Control* (Cambridge: Cambridge University Press, 2019).

which kind of unelected person should make decisions for the public does not have quite the same normative edge; the more pressing question is why those who must obey the state's decisions are given no say at all.

Moreover, the main tensions animating the relationship between democracy and science are due to the existence and social authority of an independent, autonomous scientific community, which is free to pursue knowledge in areas of its own choosing and share the result of its inquiries publicly. Hypothetically, an authoritarian government committed to protecting the autonomy of the scientific community might encounter similar tensions between science and politics. In reality, authoritarian regimes too often lapse into directing, controlling, or repressing the activities of scientists, or worse, silencing, imprisoning, or exiling scientists themselves. The fact that this possibility is widely known in turn determines what scientists dare to do in such contexts, even when the state does not interfere. The interesting tensions in the relationship between science and democracy have essentially been dissolved in nondemocracies in favor of the dominance of politics. The role of science in authoritarianism raises different and interesting tensions of its own. These, however, lie beyond the scope of this book.

Plan of the Book

The book is organized as follows. Chapter 2 develops a taxonomy of the different ways in which the values and purposes of scientists influence their findings, and demonstrates how this affects the practical use of findings later on. Drawing on recent work in the philosophy of science as well as case studies of climate modeling, AIDS, GMOs, medical research, acid rain, and COVID-19, I focus on choices about the formation of concepts, development of hypotheses, construction of models, selection of evidence, and design of experiments. At each stage, scientists make judgments or assumptions about what is significant, useful, or relevant knowledge, and weigh the acceptability of different kinds of mistakes under uncertainty with specific scientific or practical purposes in mind. These judgments favor some perspectives and purposes over others by determining what is known and how it is known. Failure to detect and respond to the way in which these assumptions and values shape expertise will result in democratic policies being influenced imperceptibly by unexamined scientific choices. To address this problem, I argue that democratic institutions that rely on expertise should be oriented toward exposing the assumptions and values driving expert claims, pay special attention to the gaps in the

existing body of knowledge, and be more deliberate about the kinds of new knowledge that should be pursued and used.

Chapter 3 considers the translation of science for use, and the relationship between scientific and political authority by analyzing the role of scientific advisory committees in politics. What I call the paradox of scientific advice consists in the fact that the expectation that scientific committees must be politically neutral is not fully compatible with their fundamental task of providing useful advice to inform policy. To help decision makers set and attain democratic goals, scientific advice must be relevant, compatible with citizens' values and purposes, responsive to preferences over risks and errors, and simplified in ways that facilitate rather than preempt democratic judgment. Converting good science to good advice requires making assumptions about ends and values, and thus violates the neutrality that is the source of the authority of scientific bodies. Scientific committees can respond to this dilemma either by sticking to technicalities and risking irrelevance or making value judgments in the name of other citizens, thereby raising concerns about the inadequacy of their claims to representation. I discuss the shortcomings of both these alternatives and suggest that these tensions could be mitigated by strengthening democratic scrutiny through modes of organized scientific dissent directed toward a public audience.

Chapter 4 develops an institutional proposal to facilitate the kind of democratic scrutiny over expertise argued for in chapters 2 and 3. I highlight three main challenges to democratic debate on complex scientific issues: ordinary citizens cannot set the agenda and terms of the debate, they face difficulties evaluating competing expert claims because of their lack of expertise, and asymmetries in knowledge and authority make deliberation between experts and laypeople unproductive. To address these three challenges, I develop a proposal for an adversarial "science court" that would be initiated by citizens, and where experts would be invited to make the case for different views on a scientific question. A citizen jury would question the experts, and then deliberate and deliver a decision. The outcome of the court would serve an advisory role in the policy-making process and inform public debates. The adversary structure of the proposal is designed to expose the background assumptions, potential biases, and omissions in rival expert claims as well as to clarify the levels of uncertainty. The separation of scientist advocates from citizen jurors avoids the difficulties of mutual deliberation under conditions of unequal authority, while allowing citizens to be active participants despite their lack of expertise. The chapter ends by discussing the court's democratic status and legitimacy, and responding to objections about citizens' competence.

The possible uses of science at the decision stage are shaped by earlier decisions about which research areas should be pursued. Chapters 5 and 6 thus turn to institutions for the funding of scientific research as potential sites of longer-term and more foundational democratic input into the political role of scientific expertise. They focus on how funding decisions for science should be made, and what kinds of political interventions would be justifiable and desirable at these earlier stages.

Chapter 5 asks whether there should be democratic input into decisions about the distribution of funds among scientific projects, and if so, what kind and on what grounds. I develop the argument through an examination of two justifications offered for publicly funded scientific research after World War II. The first is engineer and science administrator Vannevar Bush's vision of the universal material benefits from scientists pursuing basic research. Bush followed scientist-turned-philosopher Michael Polanyi in claiming that these benefits would be best realized if scientists were given a high degree of autonomy to pursue their curiosity. I then turn to John Rawls's more modest justification of public funding for science on the benefit principle, which was intended to ensure that individuals paid only for the benefits they wanted. Despite their differences, both accounts failed to consider the political impact and uses of scientific research. I argue that the close connection between scientific inquiry and truth, and special link between science and policy in the modern state, provide additional reasons for the public funding of science that go beyond those that apply to ordinary public goods such as roads and bridges. I sketch an alternative justification for funding science, rooted in the shared democratic interests of citizens in bringing about good outcomes, setting the political agenda, and acquiring the knowledge and competence to hold policy makers accountable on technical issues.

Chapter 6 ventures into more controversial territory, and asks whether and when democracies may restrict or ban certain kinds of scientific inquiry altogether. My goal is to offer a framework for deciding whether to restrict research under conditions of empirical and normative uncertainty, focusing in particular on the appropriate interaction between expert-led and democratic processes. The argument starts from the ethical framework for the regulation of scientific research with human subjects. It is widely accepted today that research may be restricted if it poses harm to human subjects participating in the research process. Far more controversial is the suggestion that research may be restricted on the grounds that the findings pose a risk of harm to society, even if the research is ethically conducted and the findings are true. I argue

that this boundary is arbitrary from a moral perspective, and consider how the framework's key principles of beneficence and respect may be adapted for the purposes of considering the broader category of harms to society from the use of scientific knowledge and its application in technology. To do so, I defend a more robust understanding of responsibility that is sensitive to the context in which scientific research takes place and involves assigning scientists some responsibility for the foreseeable consequences of their research, even if they themselves neither inflict nor intend harm. I also maintain that a democratic society would be justified in preemptively restricting research on the basis of collective fear and anxiety under conditions of indeterminacy.

Chapter 7 traces the implications of the argument for the public trust in science, science communication, and the role of scientists in public life, and offers concluding reflections. Finally, chapter 8, an epilogue on the COVID-19 pandemic, shows how the questions addressed in each chapter of the book—from the role of values and uncertainty in science to the paradoxes of scientific advice, from the need for public participation to the role of democratic input into decisions to fund science—became salient in the COVID-19 context. It aims to demonstrate the critical and clarificatory power of my arguments for making sense of this episode, while providing concrete illustrations of ideas discussed more abstractly in other chapters of the book. The complex scientific and political dynamics of the COVID-19 pandemic, in turn, allow me to refine the details of my arguments, and add a few nuances and caveats.

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