CHAPTER 12

BUILDING THE SCIENTIFIC MIND

How ordinary humans are transformed into modern scientists through a morally and intellectually violent process

HOLES—EVERY DAY for six weeks, digging holes. That was the agenda for advanced undergraduate students in soil science at the University of California, Berkeley, on a field trip described by Hope Jahren in her memoir *Lab Girl*:

> The average person cannot imagine himself staring at dirt for longer than the 20 seconds needed to pick up whatever object he just dropped, but this class was not for the average person.

After the daily holes were dug, the scientific work began:

> Every feature of every hole was subject to a complex taxonomy, and students would become proficient in recording each tiny crack made by each plant root using the official rubric developed by the Natural Resources Conservation Service.

Such was the training of these aspiring scientists. Their careers might not be any more thrilling: they were for the most part headed not to universities but to "practical land-management jobs" where their expertise in soil analysis would be applied in much the same way as it was during that hot dusty summer in California's Central Valley.

Why did they put up with it? Scientists embrace the tedium of empirical work, I have written, because the iron rule says that's what it is to do science. Every generation of future scientists, however, has to be convinced to subject itself to the rule. For many, perhaps, it is enough that the rule is part of their job description. The undergraduate soil scientists might have seen their holes simply as a route to a steady salary. For that, they would do whatever the *Keys to Soil Taxonomy* told them to do.

But not everyone will be so easy to persuade. The grave-robbing neuroscientist Santiago Ramón y Cajal and the theoretical physicist Steven Weinberg both record a period of youthful excitement about philosophy. In order to win their Nobel Prizes, they needed to turn away from such temptations and to submit to a regime, as Cajal put it, of "indefatigable persistence and enthusiasm for the observation of facts."

It is the job of science educators—high school teachers, professors, mentors, lab directors—to help them do so, taking a sensibility like Cajal's or Weinberg's, thirsty for knowledge from every discipline in every domain, and training it for a lifetime of argument in which appeals to philosophy, to religion, to beauty, to anything but empirical testing, play no part.

The irrationality of the iron rule throws up a formidable obstacle to the process. Consider that reformed philosopher Weinberg again. He is a notable advocate, in his popular writings, of the probative power of beauty: "We would not accept any theory as final unless it were beautiful." This declaration reveals an apparent conviction that ugliness is a decisive falsifier, a beast so rare that even Popper failed to make a con-

firmed sighting. Yet at the same time, Weinberg accepts without comment the scientific orthodoxy that aesthetic appeals should find no place in the official channels of scientific persuasion—that in public scientific argument, only empirical testing counts.

No doubt like many of his colleagues, he thinks that it is sufficient, for the needs of science, that beauty exert its influence behind the scenes, whispering in the ear of any scientist who grasps its intimate connection to truth. But why, of all things, should beauty be condemned to creep around in the shadows? How did such a thoughtful writer make his peace with this perverse demand?

The answer, I believe, is that modern scientists' fidelity to the iron rule is inculcated by a method other than persuasion.

To INVESTIGATE THE dissemination of the iron rule, you might take a scientific approach, carefully monitoring the classroom activities and office hours of science teachers in the schools and universities, tagging along on their hole-digging field trips, and eavesdropping on the advice that senior scientists impart to their underlings over the bustle of the lab bench. I propose, by contrast, a more philosophical approach. Ask yourself: if you had to get the iron rule into the heads and hearts of the next scientific generation, how might you proceed?

Imagine, for example, that you are back in Atlantis. Your mission to bring the intellectual and material benefits of modern science to the Atlanteans is well underway. You have convinced them to abandon their rhyming conception of explanation and to begin to care about causes, valuing hypotheses not for their words' sweet sound but for their ability to tell a detailed story about the production of observable phenomena.

Next you must bring them to care *only* about causal explanation; to agree to conduct their scientific conversation, their collaborations, disputes, and mediations, exclusively in terms of explanatory power; to

publicly renounce many of what they sincerely regard as their most powerful arguments, their philosophical, aesthetic, and religious reasons to believe. You must, in short, induce them to make the irrationality of the iron rule their own.

Perhaps you could explain to them that nonempirical thinking—appeals to metaphysics, God, beauty, and the like—is bad for science. But some of them, like Steven Weinberg, won't believe you, and indeed there is good empirical evidence for the efficacy of nonempirical reasoning in science. A sense of theoretical symmetry or elegance, in particular, has been crucial at various points in the history of scientific inquiry.

Better, then, is an iron rule that doesn't apologize, doesn't explain—that simply puts its foot down and insists on compliance. Science educators might, in the words of one of Thomas Kuhn's more controversial papers, recognize a vital role for dogmatism in imparting scientific habits of thought.

To implant a dogma in a critical young mind is not, however, entirely straightforward. Even if the iron rule goes, by professorial edict, unquestioned in the classroom, there will remain the temptation to cheat after hours, philosophically or aesthetically circumventing its directives. To curb such desires, you might steal two ideas from the rough trade of politics—morality and simplemindedness. The moral strategy: convey a sense that thinking that draws on philosophy or faith or beauty violates the sanctity of science. The simplemindedness strategy: deprive your students of the ability to think philosophically, theologically, or aesthetically at all.

Moral training first. You want your novitiates to feel bad, feel guilty, feel corrupt pursuing anything but empirical reasoning in science. You cannot create a moral intoxicant from nothing and expect it to have psychological force. Draw, then, on ingredients already known for their power to bring the ego to heel: purity, humility, restraint, asceticism. School your pupils in the following precepts:

> The purity of scientific reasoning must not be adulterated by nonempirical strains of thought.
>
> The scientist approaches nature with the utmost modesty; they do not presume to dictate terms, but rather respectfully listen to what she has to say.
>
> Philosophical speculation in science is self-indulgence, abandoning the discipline of empirical testing for the extravagance of speculation.
>
> The scientific life is one of sacrifice; the scientist is prepared to give up almost anything of value to gain knowledge of the natural world.

Don't try to rationalize these rules; let them stand alone as moral absolutes; they are to be preached rather than to be justified or explained.

To that end, equip Atlantean science with a cadre of spiritual leaders to extol the value of empirical testing and to dismiss or denigrate other routes to knowledge of the natural world, such as philosophical reasoning. These moralizers should hold up science as an institution with a privileged connection to the truth: not just the best method of inquiry, but the only proper method of inquiry.

So indoctrinated, the Atlantean scientists will perhaps be better able to resist their higher urges—to forgo the grand project of drawing together all the threads of human reason, philosophical, artistic, empirical, political, and spiritual, to form a greater whole. It is easiest to follow the dictates of a moral system, however, in the absence of temptation.

Thus, the complementary element of Atlantean science education: to foster simple minds. Why furnish a future scientist with all the protocols of philosophy, the paraphernalia of art, only to tell them not, under

any circumstances, to be seen putting these accoutrements to use? They make the student a more fully realized person but quite possibly a worse scientist. Better not to take the risk. Therefore, remove such things altogether from the scientific syllabus. To build the surest, purest empirical minds, equip students of science with only empirical modes of reasoning and only empirical knowledge; give them the capacity for empirical thought alone. The belief that they follow the one true way—rightful and uncorrupted—should be satisfaction enough.

THE DYSTOPIAN INDUCTION of young Atlantean scientists into some high church of empiricism couldn't bear any resemblance to science education in the real world today—could it?

It is in fact not so difficult to discern a moral quality in contemporary science's empiricist strictures. Most striking to those in my own profession is the scientific high and mighty's continual denunciation of philosophy.

Stephen Hawking and Leonard Mlodinow's 2010 book *The Grand Design* opens by announcing:

> Philosophy is dead. Philosophy has not kept up with modern developments in science, particularly physics. Scientists have become the bearers of the torch of discovery in our quest for knowledge.

Apparently, Hawking himself had not kept up with modern developments in philosophy: there are philosophers who specialize in the prospects of string theory, the implications of cosmology, and the vicissitudes of quantum gravity, some working at Hawking's own university at the time he wrote these words. But the facts were irrelevant. Hawking was delivering a sermon, not a seminar. The take-home message: philosophical thinking has no place in science.

The astrophysicist Neil deGrasse Tyson mused along similar lines in a 2014 podcast interview:

> My concern here is that the philosophers believe they are actually asking deep questions about nature. [But in fact they are not] productive contributor[s] to our understanding of the natural world. . . . So, I'm disappointed because there is a lot of brainpower there, that might have otherwise contributed mightily, but today simply does not. It's not that there can't be other philosophical subjects, there is religious philosophy, and ethical philosophy, and political philosophy, plenty of stuff for the philosophers to do, but the frontier of the physical sciences does not appear to be among them.

Philosophy, in other words, should stick to gods, morals, and government.

The physicist Lawrence Krauss clarified in an interview for *The Atlantic*:

> Philosophy is a field that, unfortunately, reminds me of that old Woody Allen joke, "those that can't do, teach, and those that can't teach, teach gym." And the worst part of philosophy is the philosophy of science. . . . It has no impact on physics whatsoever.

Numerous outraged commentators have fought back on philosophy's behalf: "It's shocking that such brilliant scientists could be quite so ignorant." But to contest the fairness or veracity of scientists' antiphilosophical remarks is to miss the point. Their function is exhortatory: *Young scientists, shun philosophy and all its ways.* Hawking, Tyson, and Krauss are not cultural commentators with any knowledge of or interest in philosophy; they are holy men chanting empiricist invocations, laying down the credo that shapes and inspires their order of truth seekers.

As a last example, take this 2014 tweet from the biologist Richard Dawkins:

> Philosophers' historic failure to anticipate Darwin is a severe indictment of philosophy. Happy Darwin Day!

On the surface, Dawkins's remark makes no sense at all. No one anticipated Darwin; that is precisely what makes for a scientific breakthrough. For every great discovery, there is a parade of past thinkers who failed to make it—a parade that includes philosophers, but also everyone else. In the wake of what appeared to be a staggeringly ill-considered outburst, many criticized Dawkins for not thinking straight. But this was not supposed to be thinking; it was supposed to be incantation. Science soars only once it jettisons the dead weight of philosophy; congregants, lift up your empirical hearts and rejoice!

Besides morality, the other underhanded Atlantean strategy for cultivating the iron rule was miseducation. That method, too, seems not to have been neglected in the real world.

All through the 1990s, in universities across the West, there blazed a high-end cultural and intellectual dispute known to its protagonists as the "science wars." A familiar array of questions constituted the battlefield: whether scientists' professional decisions were affected by personal allegiances or cultural background; whether there is any objective element in scientific reasoning; whether science reveals facts about an observer-independent reality.

In the most famous engagement of the conflict, the physicist Alan Sokal submitted to the postmodernist journal *Social Text* an article investigating the liberating potential of the quantum physics of gravity. After the piece was published, Sokal revealed that it was a hoax, an experi-

ment intended to answer the question: "Would a leading North American journal of cultural studies . . . publish an article liberally salted with nonsense if (a) it sounded good and (b) it flattered the editors' ideological preconceptions?" And he reported the result: "The answer, unfortunately, is yes." The topic of the issue in which Sokal's essay appeared was, aptly, the science wars themselves. Afterward, the "Sokal affair" was widely discussed in newspapers and magazines and spawned a number of books by Sokal and others.

Strangely enough, scientists themselves did not seem aware that a battle was raging around them. Stephen Jay Gould recounted his efforts to clue them in:

> Tell most scientists about the "science wars"—and I have tried this experiment at least fifty times—and they will stare back at you with utter disbelief. They have never encountered such a thing, never read anything about it, and don't care to interrupt their work to find out.

What could explain their ignorance? Do scientists consider their humanist colleagues' concerns to be unworthy of their attention?

No, writes Gould; the explanation is not arrogance but "philistinism lite." Most scientists do not notice anything much outside science. Or more exactly, while they may pay attention to the news, to sports, to music, to church, to their families, they know and care little about the many forms of thought that intersect with scientific inquiry—such as philosophy, theology, and the history and sociology of science. It is not that they understand the nature of the claims made, that they appreciate the relevance of these other intellectual pursuits but, like compartmentalizers such as Newton and Whewell, they plug their ears for the greater good of science. Rather, they are barely aware that these ways of thinking exist.

It is straightforward to isolate empirical thought from what's in the

other compartments when the other compartments are empty. And so the Baconian prescriptions of empirical science—refer in public discourse to the data, all the data, and only the data—are supremely easy for the average scientist to follow. They don't know how to do otherwise. As E. O. Wilson remarks, "So many scientists are narrow, foolish people."

As he does not remark, that is the secret to their success. An inability to think outside the box funnels all of a scientist's mental and physical and emotional energy into the box itself and thus into the empirical investigation of a single question, the exploration of a single structure, the fabrication of a single substance. It is through this concentration that the iron rule gives the knowledge machine its laser-like power to cut to reality's quick.

You might justly say of many great contemporary scientists what Tolstoy's Prince Andrei says in *War and Peace* about military brilliance:

> A good commander not only does not need genius or any special qualities, but, on the contrary, he needs the absence of the best and highest human qualities—love, poetry, tenderness, a searching philosophical doubt.

It seems apt that Andrew Schally, who together with Roger Guillemin won the Nobel Prize for discovering the structure of the hormone TRH, compared his scientific endeavors to Napoleonic warfare.

THE PROGRAM OF MORALIZING and miseducation that I have sketched in this chapter is not prescribed by the iron rule itself. The rule imposes narrowness on scientific argument and dialogue as it passes through official channels, but as you now know well, it puts no constraints whatsoever on a scientist's private thoughts and feelings.

Indeed, among successful scientists there are extraordinary people who conform to the iron rule in their technical writing but are in no

way narrow. They have wandered far outside the boundaries of conventional scientific training and delight in what they find there. They pay little attention to Hawking's or Dawkins's provocations; they take gleeful advantage of the latitude allowed by the iron rule and follow their own tastes and inclinations wherever they lead.

Among them you might encounter "philosopher-scientists," such as Albert Einstein and the eighteenth-century physicist, mathematician, and social thinker Émilie du Châtelet (who translated Newton's *Principia* into French), or thinkers as familiar with history and literature as they are with the technical apparatus of their craft, such as Stephen Jay Gould and Murray Gell-Mann. They may write books about beauty in nature that celebrate the ideas of Pythagoras and Plato, like the theoretical physicist Frank Wilczek. They may champion the aesthetic and moral importance of natural diversity, like Rachel Carson and E. O. Wilson. They may explore the implications of human cognition for life and history, like the psychologists Alison Gopnik and Steven Pinker. These thinkers are, precisely because of their expansive interests, far more likely to be known to most readers than the great, silent, scientific majority upon whose minds scientific training has fixed ponderous iron clamps.

The clamps are, however, the norm. They are the twentieth and twenty-first centuries' standard mechanism for turning out new scientists, instilling the iron rule by psychological stratagems rather than by enlightenment or persuasion.

What a contrast this makes with the first modern scientists, the inheritors of the Newtonian method in the seventeenth and eighteenth centuries. They followed the iron rule, but they were not its captives. Engaging in public argument, they would perform the role of "the empiricist" in the same way that Newton performed the roles of the mathematical physicist, the alchemist, and the scriptural exegete. Outside that context, in their private scientific thought worlds, they would

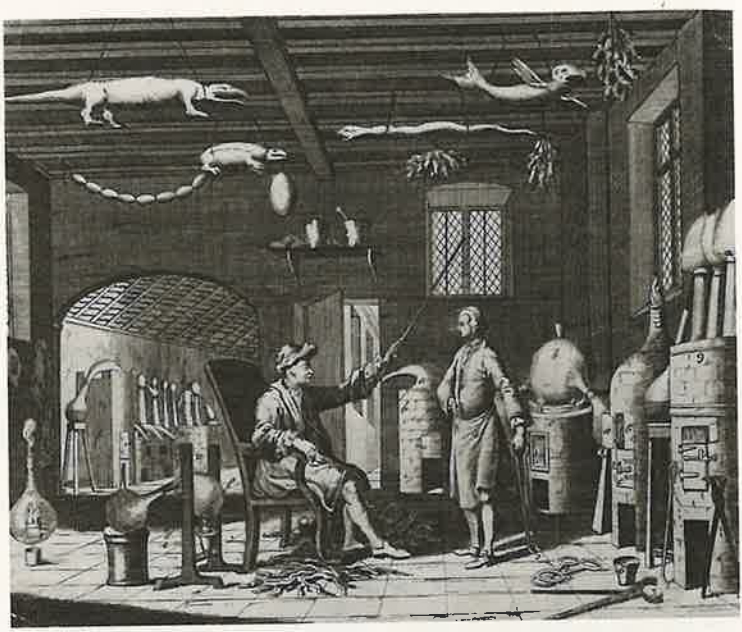

Figure 12.1. The empiricist.

put away the rule and open their minds to whatever seemed pertinent and compelling.

The European seventeenth century excelled in producing minds ready to pull off this theatrical feat. Deeply experienced with exacting or arbitrary rules of public engagement, such minds were able to play their scientific parts to perfection, becoming—while strutting the empirical stage—for all intents and purposes deaf to a chorus of urgent philosophical demands and numb to their most deeply held spiritual beliefs. They thrived within the harshest official strictures, inhabiting their characters not reluctantly or reservedly or half-heartedly or merely dutifully, not rebelliously and not (too) subversively, but with a fervent desire to succeed, taking the framework seriously without forgetting its mere conventionality, putting all of their heart into a role without letting the part engulf their soul.

For that sort of temperament, the ongoing, everyday public performance of narrow and unrelenting empiricism does not pinch off the interior philosophical, spiritual, and aesthetic conduits. Although such a performance must be the centerpiece of the scientific life, what is excluded from the performance does not atrophy but waits patiently in reserve, ready to take back control behind the scenes and between one show and the next.

Oppression and bloodshed were the conditions under which these protean, multifarious minds evolved. We are—most of us—fortunate not to live in such dangerous and trying circumstances. Across the richer half of the globe, humanity enjoys a great degree of tolerance and openness in matters of religion, politics, and philosophy. Consistency between outer actions or words and inner beliefs can be attained without sanction, even without great effort.

And such consistency should be among our highest goals, we moderns tend to believe. Authenticity is a cardinal virtue of our age:

> Resolve to abide by your own deepest promptings. (D. H. Lawrence)

> To be nobody-but-yourself—in a world which is doing its best, night and day, to make you everybody else—means to fight the hardest battle which any human being can fight. (E. E. Cummings)

> In this ever-changing society, the most powerful and enduring brands are built from the heart. . . . The companies that are lasting are those that are authentic. (Starbucks founder Howard Schultz)

To conform to such precepts makes for a purer and more perfect realization of our ideal of what it means to be human. But at the same time it produces minds that are ill suited to the theatricality and normative

compartmentalization that keep the iron rule in its proper place. The highest expression of liberal democracy undermines, in other words, the cognitive, emotional, and social skills needed to maintain a science that is both widely receptive—tuned in to the universe at every frequency—and intensely empirically focused.

The focus is essential; without it, the knowledge machine loses its traction on the world. So we build scientific minds that are empirical in thought as well as in words. That makes for scientists better able to live authentic lives, realizing their empirical values personally and professionally, in private and in the wider world. It empowers science to make all lives better materially and intellectually. It makes peace with what we consider to be a far better polity: we would much prefer to live in a liberal democratic regime than to negotiate the complexities and rigidities of seventeenth-century civic, religious, and social life. From an intellectual and cultural standpoint, however—and perhaps a moral standpoint, too—it makes for a less agreeable science. The knowledge machine, in its contemporary realization, is highly effective at advancing human goods, but it is not a high expression of what is humanly good.