Invisible Science

Steven Shapin

There's a McDonald's restaurant near where I live in Cambridge, Massachusetts. Roughly equidistant from Harvard and the Massachusetts Institute of Technology and close to one of the beating hearts of modern science and technology, the restaurant sits across Massachusetts Avenue from a nondescript building full of entrepreneurial electronic gaming companies. Walk a little toward the MIT end of the avenue, and you pass major institutes for bioinformatics and cancer research, at least a dozen pharmaceutical and biotech companies, outposts of Microsoft and Google, the Frank Gehry–designed Stata Center, which houses much of MIT's artificial intelligence and computer science activities (with an office for Noam Chomsky), and several "workbars" and "coworking spaces" for start-up high-tech companies. You might think that this McDonald's is well placed to feed the neighborhood's scientists and engineers, but few of them actually eat there, perhaps convinced by sound scientific evidence that Big Macs aren't good for them. (Far more popular among the scientists and techies is an innovative vegetarian restaurant across the street—styled as a "food lab"—founded, appropriately enough, by an MIT materials science and Harvard Business School graduate.)

You might also assume that, while a lot of science happens at MIT and Harvard, and at the for-profit and nonprofit organizations clustered around the McDonald's, the fast-food outlet itself has little or no significance for the place of science in late modern society. No scientists or engineers (that I know of) work there, and no scientific inquiry (that I am aware of) is going on there. And yet there is a sense in which such places *are* scientific sites, touching our lives in ways that bear comparison with the science that happens at places like Harvard and MIT.

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Right: *In Orbit*, 2013, by Tomás Saraceno, installation view, Kunstsammlung Nordrhein-Westfalen, K21 Ständehaus, Düsseldorf; courtesy the artist; Tanya Bonakdar Gallery, New York; Andersen's Contemporary, Copenhagen; Pinksummer contemporary art, Genoa; Esther Schipper, Berlin; © photograph by Tomás Saraceno, 2013.

If no science is going on at the McDonald's, much of what happens in it has passed through channels carved out by scientific and technological expertise. Any McDonald's restaurant is a site of *embedded science.* The products that are its reasons for being have been subjected to extensive scientific and technical inquiry and assay, and whatever products come to be added to them, or to replace them, will be subjected to further inquiry and assay. The electric wiring, the lighting, the heating, the ventilation, the air-conditioning, and the refrigeration systems—all have been designed, tested, and monitored for efficiency and safety by legions of technical experts, as have those of public buildings throughout the city and nation. Standards for the safety of the food, its storage and preparation, are set and monitored by scientifically informed government expertise. The McDonald's is one of very many late modern "Pasteurian" places, where nineteenth-century "old science" provides a foundation for the latest findings about, for example, strains of bacteria and the toxins they may produce or about the physiological effects of trans fats, sodium, and high-fructose corn syrup. The nutritional content of the food is displayed near the counter and on the company's website—so many calories, so much fat (saturated and otherwise), so much fiber—the constituents tallied according to the federal government's ever-changing assessments of the physiological effects of and requirements for different nutrients.

McScience—Billions Served

McDonald's, and other purveyors of fast food, have been targeted by activists concerned about the epidemics of obesity and type 2 diabetes sweeping the nation, knowledge of which is produced and circulated by government and nongovernment scientific bodies. In the United States, professional and government organizations—the American Heart Association, the American Cancer Society, the federal Centers for Disease Control and Prevention—pore over fast-food menus to identify causes of epidemic ill-health. In New York City, a regulation limiting the size of sugary drinks sold in restaurants went into effect in 2013, promoted by the experts of the municipal board of health. That statute was struck down in 2014 by the New York State Court of Appeals, in a decision that has implications for the authority of expertise in relation to individual choice. The critics have, nevertheless, continued the fight, mobilizing new science and proposing a "Healthy Happy Meals" bill to limit the calorie content and sugar, fat, and sodium content of meals marketed to kids.

Any McDonald's restaurant is a site of embedded science.

The local McDonald's is a business: It sells food to customers, and it succeeds or fails according to whether its products find favor. That business sucks in huge amounts of scientific and technological expertise. Science is omnipresent in the corporation that owns or franchises this particular restaurant. Science is outsourced when McDonald's draws on the expertise of the Marine Stewardship Council to choose the Alaskan pollock for its Filet-O-Fish sandwiches, or the US Department of Agriculture to inspect and grade the beef for its burgers, or the nonprofit Stanford Research Institute to find environmentally friendly food-packaging techniques. Science is massively deployed in the company's food laboratories and among its technical consultancies, where standards are maintained and innovative new foods are prepared and tested. Flavor scientists devise new ingredients and combinations; sensory scientists and sociologists tweak and test proposed new menu items with individual consumers and focus groups under rigorously controlled conditions. The stability of foods is constantly monitored; preservative chemicals are obtained, and more effective ones constantly sought. Possibilities are researched to better satisfy consumer demand and to generate new demand. Test markets are located, and the results of tests are statistically processed. The design and placement of restaurants is informed by systematic studies of customer preferences and behaviors. Customer demographics and purchasing patterns are compiled and data-mined for information. Employee efficiency, motivation, turnover, and responses to various pay rates and incentives are minutely studied and assessed for their impact on corporate profitability.[1] So while it may appear that no science at all happens in the McDonald's, practically everything that goes on there is saturated with science—condensed, refracted, and embedded in a commercial enterprise that we rarely think of in association with late modern science and that many people might even consider to be inimical to the methods and findings of legitimate science.

Recovering the Visibility of Science

When some people say that McDonald's products represent bad science or the perversion of science, or that those products manifest a cynical disregard for science, they are talking a kind of sense, but it's a sense that derives from prior judgments about what should count as scientific knowledge and as scientific practice. And that is why I chose my local McDonald's as a starting point to revisit the question of what and where science is in late modern society. I want to provoke reconsideration of the place of science and the conditions of its visibility *as* science.

We tend to think of science happening in a small number of special places, purposely set aside for scientific inquiry and instruction, but there's a case for saying that science is now everywhere, and that understanding its pervasiveness is important to describing both late modern science and late modern society. I have just offered some anecdotes to suggest that ubiquity, but there is quantitative evidence too. In the United States, many relevant statistics have been compiled since the 1970s by the National Science Foundation, data that are routinely tabulated and published in the NSF's annual *Science Indicators*. Consider, for example, the number of scientists and engineers applying their knowledge and skills in various settings, a number that has been rapidly rising. These figures show that there are now just short of six million workers in what are called S&E (science and engineering)

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Untitled by Darrel Rees, Heart Agency; courtesy of the artist.

occupations, compared to 1.1 million in 1960. The absolute number of S&E personnel has grown fivefold during those decades, now making up 4.1 percent of the nation's work force—up from 1.6 percent in 1960.

Most S&E workers are not to be found in institutions such as Harvard or MIT or, indeed, in research universities. About 70 percent of this work force is employed in the business sector. Government (federal, state, and local) employs 11 percent, and educational institutions (of all sorts) employ only 19 percent. Less than a half of the S&E workers in education are in four-year institutions, and S&E specialists, like higher-education teachers in general, typically work in two-year community colleges or other educational institutions where research isn't a priority.[2]

Floating on a Sea of Science

These and similar statistics have two aspects. Most obviously, they *represent* states of affairs; they are facts about the makeup of the country and the activities, locations, and identities of categories of people in the country. The figures are compiled because of state concerns: They allow the state to know how it is doing and how it might do better—in this case, to produce what are considered to be the right number and right sorts of scientists and engineers, workers whose activities are sometimes reckoned to be in the national interest. Less obviously, statistics like these are the facts of the matter with which I am concerned. They are *about* science, and they *are themselves* science—reflexive evidence for the pervasiveness of the science that remains largely invisible as such.

Statistical practices are one way the state knows itself and makes itself legible—that is, after all, how "statistics" acquired its name toward the end of the eighteenth century. They are important aspects of what Michel Foucault called *governmentality*. The modern state floats on a sea of science: Since at least the seventeenth century, the state has mapped itself through cartography; its lands and seas are inventoried through the natural history sciences; its weather is tracked by meteorology; it knows and represents production, trade, the distribution of wealth, state expenditures and income, the security of the financial system, and much else through economics. The modern state learned how to finance itself significantly through customs and excise taxes, and these involved assay techniques to determine the amount of alcohol in beverages, the authenticity and quality of tea, tobacco, fuels, and other goods. And, pervasively, the state has learned how to count: It counts how many people there are in the country, what they own and what they owe, where they are located and housed, how they move around, what they do, what diseases afflict them, and what they die of. The sciences of risk were pioneered by insurance companies, but they eventually became government concerns as systems of social security, health care, emergency planning, and military strategy emerged in the twentieth century. The sciences of counting, accounting, surveying, assaying, and estimating are so integrated into the practices of government that you could plausibly say that the state would be unrecognizable absent its scientifically derived inventories and representations of itself; its scientifically based systems of surveillance, control, administration, and communication; its scientifically grounded predictions of the future, a future the state may do something to bring about, prevent, or provide for.

It is now better appreciated that the state mobilizes science and technology in its exercise of power. The twentieth-century relationship between physics and the atomic bomb has become emblematic, though it is less well understood that state power has *always* drawn on scientific and technical expertise: Oppenheimer, Teller, von Braun, Turing, and Berners-Lee are at one end of a genealogy that extends back to Archimedes and that includes Galileo, William Petty, Edmond Halley, Pierre-Louis Maupertuis, Joseph Banks, Alexander von Humboldt, Louis Pasteur, and Fritz Haber. In all historical periods, both the external projection and the internal exercise of state power have called on scientific and technological expertise; the only thing that is relatively new is the formalization of this connection and its importance for the conduct of many sorts of science.

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And yet so much of this science isn't widely recognized as science at all. It *should* be. The invisibility of embedded science is an apparently paradoxical, but reliable, index of the significance of science for everyday life—for government, for commerce, and, not least, for our sense of self. So how is it that when many people talk about science, they seize on just a small fraction of it, while the rest—like the underwater mass of the proverbial iceberg—remains invisible?

The visibility of embedded science in the late modern world is unequally distributed. Some institutions, and some people, have acute and systematic understandings of its pervasiveness. The NSF knows how much science there is. So does the US Bureau of Labor Statistics. So do similar bureaucratic arms of many other countries and international bodies such as the United Nations, the European Union, the Organization for Economic Cooperation and Development, and the World Bank. And while such agencies tabulate the different sorts, specialties, and qualifications of practitioners, they tend not to be much bothered about policing the boundaries between scientists and engineers, between "pure" and "applied" scientists, between those with doctorates and those without, between research and development. They are well aware of such distinctions, but they neither insist on demarcations between science and technology nor assert the special competences of PhDs when they compile these figures. That isn't the point of these exercises. From the end of World War II (with some precedents in the first decades of the twentieth century), government and nongovernment agencies generally adopted categories that merged activities and personnel, categories previously thought of as distinct: The notions of R&D (research and development), of S&E (science and engineering), and of the QSE (qualified scientist and engineer) then emerged as routine statistical categories. These usages reflected heightened state and commercial concern for the ultimate material utility of what had been called pure or basic research. This running together of fundamental and undirected research, on one hand, and materially goal-directed research, on the other, ran roughshod over the long-standing evaluative *academic* insistence on essential distinctions between such categories.

Ivory Tower Science

What do *laypeople* believe about what and where science is? There are, of course, outcries about "public ignorance" of science, and these seem to be well-supported. Significant portions of the modern public know next to nothing about, for example, the differences between viruses and bacteria, and many are unsure whether the earth orbits the sun or the other way around, while biologists' complaints about public ignorance of the facts of evolution are particularly vehement. But there are few systematic opinion surveys of what people think about what *counts as* science, how science is done, in what sorts of settings it happens, and what its goals may be.[3] There's not a lot about these questions circulating in the public culture, and it's unlikely that they occupy much lay attention.

What do laypeople *believe about what and where science is?*

We do, however, know a fair amount about how science is *represented* to the public in the media; so there is justification for inferring *something* about public belief.[4] And what we might infer is that the bits and pieces of lay thinking form a patchwork of notions, some of which are evidently inconsistent with others. There are widely distributed portrayals of "ivory tower" scientific unworldliness—a disengagement that is sometimes respected, more often sneered at, by politicians, funding agencies, university administrators, and business people.[5] At the same time, there is some evidence that the public accepts the notion that the emergence of valued technologies *depends upon* the findings of scientists who do not themselves have instrumental intentions.[6] Francis Bacon famously claimed that power is a test of reliable knowledge and that genuine science *should* display its truth in useful technologies. Late modern laypeople probably find the Baconian sentiment congenial, and it's common enough to hear smartphones, cancer cures, and GPS devices celebrated as Miracles of Science. Yet what fascinates the public, and the media, about technology is *innovation*—the new things, those that often come surrounded by wild claims about their "world-changing" power, and especially those with digital bells and whistles attached. Several aspects of technology, however, still tend to remain invisible in public culture: There is *old* technology, the sort of devices and processes that have *already* "changed the world," whose users now take them for granted, whose inner workings are of little interest, and that rarely attract notice as technology—things like refrigerators, kitchen ovens, rifles, shipping containers, bathroom scales, synthetic ammonia fertilizers. Then there are the sorts of embedded technologies that go into making a Big Mac and making it profitable.[7]

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From early in the nineteenth century, leading spokespeople for science argued that the ultimate utility of pure science made it a worthy recipient of state patronage and an essential tool for sound government. (While only some scientists totally accepted these arguments, others realized that such justifications were simply the most effective way of securing resources in democratic societies.) Sometime between the military mobilization of chemistry in World War I and the spectacular successes of physics and cryptography in World War II, the state and much of the commercial world were decisively persuaded. Science, even in its purest forms, did produce useful outcomes. Many sorts of science—physics, of course, but chemistry, mathematics, biology, psychology, and linguistics too—seemed to deserve substantial state support, and the once vigilantly policed distinctions between the pure, the applied, and the technological were progressively elided. In the new way of thinking, science was technology at one remove, and science was to be valued insofar as it laid technological Golden Eggs—more power, more profit, more abundant and cheaper food, more effective cures for dread diseases.

Technoscience and Science-in-Industry

Yet if science in this inclusive sense became clearly visible to the late modern state and to much of the business world, science "in the round" has remained largely invisible in the academic disciplines whose purpose is not *doing* science but *understanding* science—philosophically, sociologically, and historically. True, there are studies of *technology* in all these academic genres, but largely taken-for-granted distinctions among pure science, applied science, and development persist in humanistic and social science disciplines concerned with science and technology. (The recent vogue of the term *technoscience* has not yet done much to efface those distinctions.) In fact, research, writing, and teaching in academic studies of science are substantially defined by those bits of it that happen in research universities and their historical antecedents. So far as the great majority of historians, sociologists, and philosophers are concerned, science stops being science—and places itself largely outside their domain of interest—precisely when it becomes embedded in the modern institutions of government, production, and, to a lesser extent, war. The study of science-in-industry, for instance, is most commonly handed over to economic and business historians, whose concern is often to work out "best practices" for how corporate research is to be managed, how it is to be costed and its benefits assessed—not to describe the realities of its role and management.

The academic invisibility of embedded science is an effect whose cause involves the *evaluation* of science as a cultural practice. For a very long time, disinterested scientific inquiry enjoyed greater prestige than its utilitarian forms. Applied science and technology were seen as straightforward deductions from basic science—as if, once you had the theory of nuclear fission, the task of building an atomic bomb was mere hack-work.[8] Some commentators—from Max Weber to Thorstein Veblen to Robert Merton to Michael Polanyi—simply withheld the designation of *science* from whatever took place in industrial facilities, even as science-in-industry was being enthusiastically celebrated in the public culture during the first decades of the twentieth century. Neither the philosophers of the Vienna Circle nor Karl Popper or Thomas Kuhn wrote as if science was anything other than inquiry into nature's fundamental workings, rationally driven and autonomously conducted for its own sake. (Possible exceptions were mid-twentieth-century Marxist writers on science and a few reflective directors of industrial research, but the former had only a fleeting impact on Western academic understandings of science and the latter had almost none.) Anything other than disinterested scientific inquiry was not worthy of the name *science*. Academic theories of science, invocations of "the Scientific Method," and accounts of "the normative structure of science" had little or nothing to say about nonacademic science, or treated it as a denial of the fundamental values—openness, free criticism, autonomy—that were considered to define science.[9]

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Historians often derive their status from the prestige of the matters they study, and the academic history of science is no exception. But the location of scientific prestige changes. So from about the 1930s to the 1960s, scholars concerned with the "modernity-making" seventeenth-century Scientific Revolution were cocks of the walk; later, the study of modern physics ruled the departmental roost; now, the academic history of science (and Science, Technology, and Society departments) scramble to recruit scholars of modern biomedicine and of information technology, finding that these are in short supply. At the bottom of the pecking order are two categories of scholars—specialists in the history of the human sciences and an ill-defined, but tiny, group of researchers concerned with what I've called embedded science.

Broad and restrictive conceptions of science currently coexist. Conceptions differ according to the different purposes—practical and evaluative—that inform them. Yet the inclusive sense—recognizing both the invisibility of much late modern science and the paradoxical significance of invisible science—has something to recommend it. It takes seriously the argument made for generations, even centuries, by the scientific community itself: namely, that scientific inquiry, even in its purest forms, has useful outcomes and should be valued and supported for that reason. It would be curious if the spread of embedded science—which is an index of that argument's success and the fulfillment of many scientists' aspirations—were deemed unworthy of attention by scholars studying the changing cultural and social place of science. To disregard embedded science, or to treat it as beneath scholarly dignity, would mean that academic students of science would be focusing their attention on just those bits of science that have not *yet* been enfolded in civic institutions and practices—and however much that may seem correct or self-evident, the propriety is myopic and the legitimacy isn't obvious.

Embedded Science: Soft-as-Hard

Embedded science is pervasive, but no kind of science is more thoroughly baked into quotidian late modern life than the human sciences—psychology, sociology, anthropology, and, most notably, economics. The institutions of government and commerce want to understand, and perhaps to change, how people behave and what they believe. Laypeople also draw on human sciences expertise to understand themselves, to give accounts of themselves, to justify, criticize, or change themselves. If the human sciences are, as is often said, "soft" compared to the "hard" natural sciences, then it's an odd sort of "softness" that is so ubiquitous and so consequential. One long-established sense of the "hardness" of some sciences points to the degree of *certainty* attached to them; a less familiar, but justifiable, sense of "hardness" might point to the extent to which some sciences permeate the culture. In this latter sense, there are sciences reputed to be very "soft" that could be redescribed as very "hard" indeed.

> *There are aspects of embedded sciences—both human and natural—that are especially revealing of the "soft-as-hard" notion.*

Science is everywhere in late modernity, but the human sciences have a special claim to recognition. The sciences dealing with human action and behavior are enlisted in selecting the "canned music" that attracts certain sorts of customers to certain sorts of stores, that improves their mood and their disposition to buy. Psychologists, sociologists, and anthropologists are engaged by online dating companies to understand patterns of intimate human behavior and to design algorithms that allow people to connect more or less successfully. The Pentagon and the CIA draw on a range of academic human sciences to try to comprehend the mentality of suicide bombers. Experts on "human factors" and "ergonomics"—with a range of human science backgrounds—are employed in physical product design, in assessing communication in airplane cockpits, and in developing routines to minimize medical mistakes. Designers of speech recognition systems work with applied linguists and social scientists who know about naturally occurring human speech, about its conditions of intelligibility, and about meaning in context. Computational linguistics is layered on human linguistics. The "sciences of taste" are all over the late modern world, their practitioners wanting to construct robust, "objective" accounts of people's tastes—what they like and what their likings are like; what disposes them to consume, to buy, or to bond; how they communicate to others the private subjectivities of taste; how, if possible, tastes can be changed.[10] A catalogue of embedded human sciences would be immensely long. And, everywhere, commercial and political enterprises seeking to understand who communicates with whom enfold social science expertise, one of whose tasks is reflexively to make new social science from the massive quantities of data thrown up by electronic social networks that social scientists have themselves helped to design.[11]

Forms of embedded technical expertise have rightly been pointed to as the "scientization" of the ordinary, and many cultural critics urge its rejection in favor of some type of humanism.

Finally, there are aspects of embedded sciences—both human and natural—that are especially revealing of the "soft-as-hard" notion. These are the sciences whose findings and practices infiltrate and inform late modern senses of the self. Our notions of who we are, of what other people are like, of what explains human behavior, emotions, and thought—indeed, of *how* these things are to be described—are all as soft and subjective as anything can be: No one else knows what it's like to be you and to think, feel, and perceive as you do. Yet the resources available to construct senses of the self vary by time, place, and cultural position—and some of these resources have passed into the vernacular from the domains of scientific expertise. Some people are accounted "charismatic"; some people identify, explain, and excuse themselves because they are "a bit Aspie" or have "ADHD"; some refer their personalities to parentally induced sexual traumas of early childhood; some describe themselves as "type A personalities," some as having "multiple personalities"; some people have an IQ of 135 and a consequent sense of satisfaction; some have a BMI of thirty-one and a consequent sense of dread; many others now send swabs of their saliva to the genomics company 23andMe to get an online report of the genes that make "one unique you." All of these—and many other—ways of describing, explaining, accounting, and justifying belong to late modern vernaculars. Their origins are in human sciences expertise, but they wind up being aspects of what it's now like to be a person.[12]

Scientization of the Ordinary

These forms of embedded technical expertise have rightly been pointed to as the "scientization" of the ordinary, and many cultural critics urge its rejection in favor of some type of humanism. That response is intelligible and often attractive, but it tends to miss the possibility that the embedded science of which you happen to be skeptical will often be opposed by *different* science. Academic and journalistic attention can help make embedded science visible, and one of the possible advantages of a momentarily enhanced visibility might be more effective ways, if you are so minded, to push back. The science of McDonald's is already opposed by the science of Marion Nestle and the Center for Science in the Public Interest; definitions of autism in the *Diagnostic and Statistical Manual of Mental Disorders* are opposed by "neurodiversity" movements and sympathetic psychiatrists; the neoliberal economics embraced by many Western governments is opposed by Paul Krugman, Amartya Sen, and strands of behavioral economics; and genetic determinism is opposed by the emerging science of epigenetics. Science often speaks with more than one voice, and embedded science is no exception.

The bad news for humanists is that science at times seems close to becoming the only game in town; the good news is that science is more heterogeneous than some humanists have been led to believe. The heterogeneity of many forms of science not only gives humanistic impulses a point of entry; the credibility of these forms *requires* them. As David Hume wisely and provocatively wrote, "Reason is, and ought only to be, the slave of the passions, and can never pretend to any other office than to serve and obey them."[13] Only now, we must acknowledge that there are sciences that aim to describe and explain the passions.

It would be tempting to say that we don't see "science everywhere" in the same way that we don't see the nose in front of our face, but it would be better to say that science is just the face of modernity. It's what we see when we look in the mirror.

Endnotes

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