"An intellectual thrill ride. . . . [A] memorable mosaic, a big picture that illustrates how human progress is half a matter of striding and half of stumbling. . . . Illuminating reading."
—*The New York Times Book Review*

OUR OWN DEVICES

HOW TECHNOLOGY REMAKES HUMANITY

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ALSO BY EDWARD TENNER

Why Things Bite Back:
Technology and the Revenge of Unintended Consequences

Tech Speak

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Preface

TECHNOLOGY APPEARS to have become a synonym for electronic systems. It should not be so. Just because microprocessors are all machines does not mean that all machines, even all important machines, are built around chips and circuits. In fact, in the early 1990s the economist Edwin Mansfield found that improved thread and stain removers had done more for America's productivity than personal computers. The time is right to think again about technology, and to start with some of the simplest forms.[1]

In *Why Things Bite Back: Technology and the Revenge of Unintended Consequences*, I defined technology as the human modification of the natural world. This book is about the changes we have made in ourselves: how everyday things affect how we use our bodies—how we sit, stand, walk, and communicate. And it is about their symbolic side: how they affect our images of each other. They are, literally, our own devices. Though people have been able to do surprisingly well without them, these everyday things are today part of a technological treadmill from which it is difficult to step down.

I started to consider these themes after participating in an on-line forum on technology and design sponsored by the Discovery Channel's Web site in 1996. The other guests were the cognitive psychologist Donald Norman and the civil engineer and historian of technology Henry Petroski, both of whom had written important and insightful studies of everyday objects. It was the best kind of discussion, and I regret that it is no longer available on the Web. One of the things I learned from our agreements and disagreements was that nobody had yet looked at ordinary things as the outcomes of a ceaseless interplay of technology, economics, and values.[2]

An engineer can look at the proliferation of tableware in the nineteenth century, for example, and consider the mechanics of producing and using specialized knives, forks, and spoons. A food chemist can evaluate the appropriateness of glassware shapes for wines and spirits. But science-based analysis does not tell us why men and women of one period were paying for proliferating variety. Some social historians believe that the Victorian upper classes were making daily rituals as complex as possible to intimidate and entrap upstarts. Likewise, paper clips could probably have been made in the eighteenth century; it was not only new metalworking machinery but mountains of new paperwork that hastened their development. Technology, often regarded as a prime mover of change, is also a response to long-standing trends.

A psychologist can identify many ways to make objects easier to use. Many tools could still be improved by scientific study. But performance is not the only measure of value. Our needs are complex and sometimes paradoxical. One of the most popular fields for awards of U.S. patents is new golf equipment, yet the U.S. Golf Association maintains a large, professionally staffed laboratory that rejects many of these innovations, not because they fail to work or are difficult to use, but because they are too effective or too easy to operate. Golfers, like other sports participants, must balance the search for a technological advantage with the prestige that comes from learning a difficult technique. In *Why Things Bite Back* I considered how innovation can maintain or undermine the challenge, the artificial difficulty, that underlies sports. Even the most fervent technology enthusiasts have not (yet) proposed to turn golf and other sports over to robots whose progress can be observed on monitors at the clubhouse bar. Manual skills have not declined; they have been migrated from work to hobbies and sports.

The line between manufactured things and information is also arbitrary. Our knowledge is filtered through objects. A second inspiration for this book came during a question-and-answer session after a lecture I gave in 1997 in the Urania-Gesellschaft in Berlin, one of the world's oldest and liveliest adult education centers. One member of the audience, an older man who (to judge from my hosts' disapproving glances) liked to confront the speakers, challenged me to name the most important invention in history. I thought for a moment and replied, "Eyeglasses, so as many people as possible will buy my book," breaking the tension but also provoking myself to think more about the body as information system. The questioner, who himself was wearing glasses, joined in the approving response. Perhaps there is such a thing as constructive heckling.

This book looks at everyday objects through a pair of terms: *technology* and *technique*. The first consists of the structures, devices, and systems we use; the second, of our skills in using them. Historians of technology customarily focus on the devices themselves, if only because user habits are poorly documented. Designers—often rightly—aim to make some skills obsolete. What virtue was there in trimming a wick, cranking an automobile, tuning a crystal radio set, or even (for casual amateurs) focusing a camera manually?

In fact, technique is much more important in our lives than we realize. Many things seem to act almost magically on their own. We can sustain this illusion at length, but sooner or later we need an expert urgently to correct an "automatic" system gone awry. The zero-insertion-force floppy drives of older Macintosh computers—before Apple turned against the floppy disk on principle—were such a technology. They swallowed disks gracefully after only a gentle nudge. Unlike the IBM-compatibles, they released them again by software control from a pull-down menu on the screen, not with a vulgar spring-loaded button. But the drives were still machines, and the disks sometimes stuck. A simple technique was needed: straightening a paper clip and poking it in a discreet little hole with a recessed switch. Even users of well-designed objects need to know a few tricks.

The interplay of technology and technique is literally at our feet. The shoelace can encapsulate the themes of this book. For all the embrace of advanced materials in athletic shoes (which we will explore in Chapter Three), shoe fastening has changed little for two centuries or longer. The obsessive protagonist of Nicholson Baker's novel *The Mezzanine* observes, "Shoes are the first adult machines we are given to master." Generations of inventors have proposed alternative fasteners, and many children today begin with the interlocking fabrics trademarked as Velcro. But sooner or later, just about every child in the world's wealthier countries learns to tie his or her own shoes. Few of us remember studying the procedure, yet it is complex enough to justify manufactured learning aids for teachers and parents and extended Internet discussions of methods. Try, without manipulating an actual pair of laces on shoes, to write a paragraph explaining to a novice—and there must be at least a billion or two around the world—how to tie the knot. If you can do that in your mother tongue and are proficient in another, try to explain the procedure in your second language. You will probably find it easier to restate the ontological argument for the existence of God, or any other philosophical or theological idea. Tacit knowledge, what we can do but seldom explain, is essential. The special vocabulary of the everyday is obscure. How many people know the proper words for the plastic- or metal-bound ends of shoelaces, *aglets* or *tags*?[3]

Baker's narrator could have discovered even more about shoelace technique. Simple objects can call for a surprising level of skill. Henry David Thoreau, for all his acuteness as an observer of nature, took some time to understand that his leather laces were constantly coming undone because he was tying granny knots rather than square knots. Subcultures have their own shoelace techniques, sometimes highly refined. In his memoir *The Duke of Deception*, the writer Geoffrey Wolff recalls learning only one useful thing from his detested maternal grandfather, a mean-spirited, self-made officer: the navy method of tying shoelaces so they would not unravel. Soccer players knot their laces on the radial (outer) side of the foot to avoid interference with kicking. Experienced hikers can adjust lacing patterns to terrain, keeping the toe box loose and the ankle tight uphill (to prevent twisting) and reversing the pattern on the way down (to protect the Achilles tendon), using a double-twisted knot to separate the two parts of the lace. Still another lacing can seat the heel firmly in the back of the boot. A skilled hiker can skip eyelets and use other lacing tricks to improve performance and prevent blisters. Athletes in other sports too learn to adjust lacing patterns. Joe Ellis, a sports podiatrist, has published instructions for varying laces to stop heel slippage, improve midsole flexibility, and protect tender toes and insteps. Many manufacturers, beginning with Nike, have even introduced variable-width lacing with alternating inner and outer rows of eyelets to permit wider and narrower fittings of shoes made on the same last. (Most wearers still use all the eyelets.) Even for the less active elderly, orthopedists recommend laced shoes over slip-ons because they better accommodate orthotics and swollen feet. In fact, experienced shoe fitters can show people of all ages how to use lacing patterns borrowed from hiking to compensate for mismatches between shoe shapes and individual feet. They warn that "advanced" shoes with loops instead of eyelets and round laces may cut into the foot.[4]

Old technologies, then, stay alive by assimilating new techniques as well as materials. But they also confer symbolic meanings. Shoelaces have an important cultural side, even religious implications. In most traditional Islamic societies they were avoided as inconvenient in removing and replacing shoes at the entrances to mosques. Slip-on footwear is obviously easier to use wherever custom dictates removing shoes at entrances to private homes. Social class also helps define closures. In 1666, King Charles II of England began a new fashion when, according to the diarist John Evelyn, he "put himself solemnly into the Eastern fashion, changing … shoe strings [forerunners of laces] and garters into buckles, of which some were set with precious stones." Through the eighteenth century and until around 1820, gentlemen in Europe and America used buckles on their shoes, not laces. When Thomas Jefferson adopted shoelaces at the beginning of the nineteenth century, he was defying criticism to embrace a democratic fashion he had observed as a diplomat in Paris at the eve of the Revolution.

Laces also represent group identity. In North America, Europe, and Asia, school authorities occasionally ban colored laces for their association with gangs. Leaving laces threaded but with ends untied has been an emblem of youthful rebellion. Not wearing them at all with lace-up shoes has, like baggy trousers, been part of inner-city prison chic. (At the other extreme, Lord Baden-Powell established a "Scout's way" of tying laces that concealed both the knot and the end of the string.) And even among conservatively dressed adult males there are notable differences in shoelace technique. Europeans tend to tie parallel laces across the instep, using hidden offset zigzags; Americans prefer the crisscross like a series of X's. Nobody knows when and why these patterns diverged. In the British army in World War II, soldiers were taught parallel lacing to aid medics in cutting to remove the boots of the wounded, but the custom is probably much older. Some American commanders have ordered troops to lace each of two pairs of boots with a different style, as a reminder to alternate them. Once I observed that a visiting European colleague had used a different pattern on each shoe. (The American method uses slightly less lace, according to the mathematician Ian Stewart.)[5]

In social interactions laces are no mere symbols. They serve as invaluable props. A loose shoelace justifies a time-out, the interruption of a conversation, the chance to observe. A London journalist reported that a financier she was interviewing would begin to adjust his eyeglasses and untie and retie his shoelaces when questions became uncomfortably personal. Viewers of *Dr. Strangelove* will recall the Soviet ambassador stooping to retie his laces at the apocalyptic end for a last bit of clandestine photography of the War Room. In fact, the shoelace enables many a devious maneuver. Cheaters in marathon races wait on the sidelines, bend to tie their shoes when the pack passes, then rise to join it in the excitement. During the 1992 Barcelona Olympics, the Cuban baseball team used frequent shoelace-tying to slow down the game and defeat their American opponents—at least, so U.S. journalists saw it.[6]

Finally, shoelaces show the power of technological improvisation, our ability to find unexpected uses for familiar things. Flat, strong, braided thread is easy to knot. In its benign aspect, a shoelace is a wonderful tool wherever a flexible cord is needed, for example, looped to make it easier for people with disabilities to open doors with knobs, or as an emergency tourniquet. It also has sinister uses, ranging from the concealment of crib sheets by students to suicide and murder. Prison and mental hospital authorities the world over often confiscate shoelaces from new inmates. (Airport alarms are tripped by metal arch reinforcements, but laces raise no questions.) Like clothespins, paper clips, and duct tape, shoelaces are technologies that leave especially ample room for new techniques elaborated by our imagination.[7]

Laces show that a simple body technique can be so valuable that changes become incremental rather than revolutionary. Production of shoelaces has long been automated, down to the attachment of the plastic aglets—quite a technological feat because laces are braided from multiple strands that must be woven together much as hanks of hair are braided, but on a minute scale. The only important recent innovation has been elastic laces that eliminate the need for knotting and make removal and replacement of shoes easier for people with disabilities and for those living in societies where shoes are for street wear only.

But fashion can make unexpected demands on technique. When shoe manufacturers began to turn to neat-looking but slip-prone round synthetic laces for a sleeker appearance in the 1990s, wearers complained. A winning New York Marathon runner from Kenya sponsored by Nike failed to break a record after his round nylon Air Streak Vengeance laces came untied three times, costing him crucial seconds. (Speaking of technological revenge, Nike paid him the $10,000 bonus he would almost certainly have won had the laces held.) Yet some shoe executives insisted that with proper knotting skills the laces would stay put.[8]

The manufacturers of nineteenth-century laced footwear and shoelaces could scarcely have foreseen the variety of motor and symbolic skills their innovations would unleash. They no doubt were thinking of more comfortable, flexible, and fashionable alternatives to buckles, buttons, and slip-ons. Communities of users—athletes, young people, criminals—developed new techniques for manipulating laces. Of course, new technology could in turn serve these trends: braiding machines with today's sophisticated controls can produce patterns in laces, including ways to identify corporate and school affiliation. Technique and technology reinforce and modify each other, coevolving unpredictably and endlessly. Building on the ideas of the architectural theorist Christopher Alexander, the writer and designer Stewart Brand has illustrated how structures "learn" by absorbing the additions, subtractions, innovations, and restorations of successive owners. Adaptability is equally vital in designing the smaller things in life. What Brand writes about buildings, that each is a prediction and a wrong one, applies to our tools as well.[9]

Our Own Devices is thus an exploration not only of inventive genius but also of user ingenuity. It explores why we experience so many positive as well as negative unintended consequences. In *Why Things Bite Back*, I identified a class of problems that I called revenge effects, the side of technology that undermines its reason for existence. Some computer programs designed to prevent crashes, for example, have been known to cause them. But technologies can have equally unexpected benefits. Apparently frivolous ideas can have productive consequences. The chemistry of attaching oxide particles to magnetic tape was a by-product of efforts in the Weimar Republic to bind gold leaf more effectively to fashionably decadent black Russian cigarettes. More recently, the control room of a major neutrino experiment at the particle research center Fermilab near Chicago was inspired by the round subterranean den of the *Teletubbies* children's television series, familiar to parents and grandparents among the laboratory's staff. Scientists at Silicon Graphics have trained digital cameras on the circulating blobs in Lava lamps to generate truly random numbers, which are essential to many computer tasks but cannot be produced by computer circuits alone.[10]

This book starts by looking at how objects complement body techniques (as the French anthropologist Marcel Mauss originally called them), arguing with examples from warfare to music that some of the most important innovations have been less in the invention of things than in the development of new usages.

The core of the book considers body techniques and technologies through history, starting with the first technology most people encounter, infant feeders. It then starts, literally at the ground, by examining the simplest form of foot covering, the sandal—specifically, the thong sandal familiar to antiquity and spread around the world from Asia after World War II. It continues with the twentieth century's most characteristic footwear, the running shoe, and its association with styles of movement. The following chapters move to the back and its relationship to seating. The chair is an originally Mediterranean and Middle Eastern creation that has displaced older forms of seating only recently in most of the world. The idea of designing a chair for work emerged only in the nineteenth century and is still one of the greatest challenges for designers. Reclining chairs, the subject of the next chapter, are not always fashionable but are usually well designed for what they do. The chapter on them shows how a technology first associated with aristocratic leisure and then with high modern style and health became a symbol of self-indulgence and obesity in popular culture.

The breakthrough technology for the hands in the last two centuries has been the keyboard, which has not only displaced the pen and the pencil as a writing instrument but has changed human control of many other processes. The chapter on the musical keyboard looks at how styles of playing and the principles of making instruments interacted. Its counterpart on the text keyboard shows how typists contributed as much as the original inventors to the definition of the technology.

What the piano did for music and the hands in the nineteenth century, mass-produced spectacles did for the eyes. The chapter on eyeglasses explores how their existence depended less on the understanding of optics than on the needs of society's growing literacy; yet the explosion of reading material in the nineteenth and twentieth centuries has in turn made us increasingly dependent on eyeglasses. The helmet, which started the first arms race in the ancient Middle East, is now as much an athletic as a military object, and is even an orthopedic appliance for babies.

The epilogue considers trends in body technology. Wearable and implantable devices have lost some of their cachet since the late 1990s; even a pioneer of the cyborg lifestyle has misgivings. Direct modification of the body itself—through exercise machinery, diet, medication, and in the future even regeneration of teeth and organs—is a possibility. And mobile devices are promoting the humblest digit to a new dignity, suggesting that there can be happy unintended consequences, too.

Like *Why Things Bite Back*, this book is not mainly for specialists in the history, philosophy, or sociology of technology. It is an exploratory work for all who are curious about familiar things. My goal is to provoke new ways of looking at the commonplace. For I agree with Oscar Wilde that the true mystery of the world is not the invisible but the visible.

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Edward Tenner

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CHAPTER ONE

Technology, Technique, and the Body

IN A GARY LARSON cartoon, a number of dogs are tinkering with building hardware at laboratory workbenches. The caption explains that they are striving to improve canine life by mastering the Doorknob Principle. What makes this funny is partly the idea of pooch scientists standing on their hind legs, manipulating screwdrivers and even microscopes. It recalls the long-discarded notion that we humans are the only tool-using animals. It points indirectly to the unique versatility of the human hand, with its range of grips, and the relative specialization of other creatures' paws and claws.

There is something even stranger than Larson's image, though. Other animals have a surprising ability to manipulate human technology. Not all understand what people do with things, but they develop ways to work with human-made objects, and they transmit this knowledge socially. At the dawn of industrialization, the rats of early-nineteenth-century London, with no direct auditory or visual cues, had long known that water flowed through the lead pipes servicing houses. When sufficiently thirsty, they gnawed right through them.

Unfortunately, by the 1830s the pipes sometimes contained gas; the holes left by the disappointed rodents added to the risk of explosions. (Rats also loved the wax covering early matches, brought them back to their dens, and ignited the phosphorus with their teeth, causing still more fires.)[1]

Bears in Yosemite National Park have learned to twist open screw-top jars of peanut butter, to break into food lockers with a combination of paw and snout, and to raid Dumpsters through supposedly protective slots. Bears cooperate to defeat other human technology; sow bears appear to send cubs into branches to dislodge carefully cached food, and young bears learn from observation how to break open automobile doors and penetrate the flimsy barrier separating the backseat from the food the owners thought they were protecting in the trunk. According to park rangers, who call the practice clouting, bears recognize specific brands and models, for example Honda and Toyota sedans, that are most vulnerable to attack, and use similar techniques on each model. When a particular model and color yield a rich cache of food, bears begin to attack similar vehicles every night. Mother bears show cubs how to pry open rear side doors by bending the door frame with their claws until it becomes a platform for reaching the backseat and trunk partition. Bears also brace themselves against neighboring cars to break the windows of vans more readily.[2]

Zoo officials "never use the words *can't* and *orangutan* in the same sentence," according to the comparative psychologist Benjamin Beck, a specialist in animal survival skills. A young orangutan in the San Diego Zoo became famous for unbolting the screening of his crib, removing the wires, and moving through the zoo nursery, unscrewing lightbulbs. According to Beck, an orangutan, unlike other great apes, understands what a tool like a screwdriver means in the human world and given the opportunity could use it to take its cage apart and escape.

Other orangutans have learned to distinguish the faint sounds made by electrified barrier systems and to escape when they detect that the power is off.[3]

It should not be surprising, then, that dogs also learn the Doorknob Principle. An innocent resident of Takoma Park, Maryland, was allegedly mauled by a Prince George's County police dog in her own bed after it was sent in to look for a burglar in her basement apartment. It had gained access by turning a doorknob, which the woman has since replaced by a latch. Bizarre as these anecdotes appear, they make an important point. Those who create things, whether doorknobs or gas pipes, can only begin to imagine how they will be used. If we define *technology* as a modification of the environment, then we must recognize the complementary principle of *technique:* how that modification is used in performance. New objects change behavior, but not always as inventors and manufacturers imagine. And changes in behavior of people, as of bears and dogs, inspire new hardware, which in turn engenders more innovations.[4]

TECHNOLOGY = TECHNIQUE?

In many European languages the same term— *la technique; die Technik* — describes both things and practices. One of the most incisive and influential critics of technology, Jacques Ellul, argued powerfully that modern humanity is enmeshed in such omnipresent, interlocking technological institutions that technology and technique are inseparable. Ellul begins his most important work, *The Technological Society*, by insisting, against Lewis Mumford, that the machine is only a result of technique, not its source. Mumford established historical periods based on energy—hydraulic, coal, electrical; Ellul sought to understand the spirit behind the power sources and machinery. For him, technology was the product of the ancient Near East; in Western antiquity and medieval Christianity, it was always subordinated to other principles. Even the Renaissance and the seventeenth century pursued humanistic universality rather than technical proficiency; many supposedly practical books of this period lose the modern reader in digression and speculation. The universal application of technique began only with the eighteenth century and the French Revolution. Mechanization was only one consequence of "systematization, unification, and clarification," equally reflected in the suppression of customary law by the Napoleonic Code. History and philosophy as we know them emerged as intellectual techniques. In fact, Ellul argues, industrialization followed rather than preceded these intellectual and cultural transformations. With the rapid industrial development of the nineteenth century—which Ellul does not attempt to explain—came a new relationship of technique to society: "a reality in itself, self-sufficient, with its own laws and determinations." Political control of technique is an illusion. It is irreversible, "beyond good and evil," not merely morally neutral but "the judge of what is moral, the creator of a new morality" and thus of "a new civilization." Humanity has become "a slug in a slot machine," setting it in motion without controlling its outcome.[5]

Ellul's arguments are trenchant, brilliantly argued, and often persuasively illustrated. His focus on mental processes and habits as the foundations of technology is especially apt. And Ellul probably would agree that other organisms, including bears and dogs, become subject to the same technological regime. But there is strong evidence for the power of technique well before the revolutionary era. In fact, for better or worse, the dominion of technique is an ancient one. For Ellul, the Greeks simply despised technique and exalted pure theory. He cites Archimedes' destruction of the models that he used to construct his theories, once he had demonstrated his proofs geometrically. He also suggests that Greek ideals of harmony and moderation held back the development of technique. But there is no opposition between aesthetic ideals and the development of techniques. Experience and skill are hardly neglected in the Hippocratic writings in favor of abstract thought.[6]

Ellul also underestimated the power, even “autonomy” in his terms, of military technology before the eighteenth century. Swordsmanship and other martial arts were cultivated and transmitted by generations of medieval and Renaissance masters. But only in early modern Europe did the distinction between technology and technique become apparent. Between 1594 and 1607 Maurice of Nassau, Prince of Orange, showed how technique could transform technology. Matchlock muskets were heavy and dangerous. Soldiers had to hold their weapon in one hand and a lighted fuse in the other. While some hunting weapons already had spiral grooves in their barrels for greater accuracy, this delicate rifling needed more careful loading and maintenance than rough and dirty military field conditions could afford. Thus the military musket was inaccurate as well as awkward to handle. Maurice’s genius was to see that organization and synchronized motion could make the crude musket an effective weapon. Inspired by an idea of his cousin William Louis, he assigned another cousin, Maurice’s adjutant Johann, to break down the cycle of preparing, loading, aiming, and firing muskets into discrete steps. Johann of Nassau had a series of forty-three plates engraved, each illustrating one stage. It was no longer enough for drillmasters to teach the operation of the musket. Soldiers now had to be able to march forward, rank on rank, as they prepared the weapons for firing when they advanced to the front rank, then countermarch to repeat the process. Only with precision and strict discipline could they avoid serious injury to themselves or their comrades. But once the process—the technique—was mastered, the troops could lay down repeated, formidable volleys. An intense field of simultaneous fire could be effective, even with many shots going wide of the mark. Maurice and Johann's manual, *Weapon Handling* (1607), with its elegant illustrations by Jacob de Gheyn, transformed battle throughout Europe, especially through the victories of Gustavus Adolphus of Sweden two decades later. The press was a technology, and the printer's art a technique, that accelerated the diffusion of countless others.[7]

Here was technological synchronization three hundred years before Henry Ford. Some readers will insist that the musket itself, as a technology, somehow dictated the technique of drill. Certainly, battlefield experience determines which innovations spread and which are abandoned. But techniques do not create themselves, and neither operators nor their supervisors initially understand the full possibilities of devices. Ellul wrote in the shadow of a modernism that still sought a single best way to do everything, and for which (as the architectural critic David Heathcote recently remarked of the British official-planning mentality of the 1960s) "design is the search for the Platonic ideal and … variety is symptomatic of an unsolved problem." Ellul was right to underscore the constraints of technique, but wrong to deny its creative and improvisational side. In fact the two complement each other. Just when a technique seems to have proved itself inevitable and universal, an individual may develop and spread an alternative method. Organizations and professional groups codify best practice. Gifted individuals from time to time challenge the textbooks, often failing but sometimes revising them.[8]

Ellul, like most analysts of technology, believed in a radical discontinuity between the industrial world and nonindustrial societies. An older French contemporary, the anthropologist Marcel Mauss, illuminated a side of technique that Ellul thought was too restrictive and unrelated to modern societies: the role of physical habits, which Mauss called body techniques. Ellul was correct in arguing for a concept of technique that included mental and social practices, but he ignored how important simple body techniques can be even in complex societies.[9]

Mauss introduced the idea of body technique almost casually, in an article in a French psychology journal published in 1934. He identified a set of human practices as “effective” and “traditional,” and at the same time “mechanical, physical, or physico-chemical.” These were the ways people learned to do things with their bodies. These patterns of motion were not haphazard; they were produced and inculcated by an entire society. They formed a framework of conduct. He coined the word “habitus” for these socially produced behaviors, which varied systematically “between societies, educations, proprieties and fashions, prestiges.” Prestige was, for Mauss, essential to human body technique. Children imitate the actions of their elders, especially those with formal authority. The learning of body techniques is at once social, psychological, and biological. Mauss gave examples from the dances and rituals of the native peoples of Australia and New Zealand. But some of his most interesting cases are taken from the early-twentieth-century history of sports, and from his own experience.[10]

Mauss remembered learning to swim first, then to dive. He also recalled being taught to dive with eyes shut, opening them only after immersion. By the 1930s, when his study of body techniques was emphasizing mobility and flexibility. It must have been the difference in marching instruction rather than body proportions that frustrated the Worcester Regiment.[14]

WALKING AS A TECHNIQUE

Mauss had no idea how rich in meaning even a single body technique could be. Cultures can suppress certain techniques; for instance, in Mali, as the anthropologist Katherine Dettwyler found during her fieldwork there, some groups do not allow children to crawl, apparently because of hazards on the ground. At the other extreme, Western technology to accelerate walking may actually impede development. Up to 92 percent of families with babies have infant walkers, wheeled seats that let children move about before they can even crawl. Yet experiments have shown that infants using them sit and crawl one month after those who do not use them, begin to walk two months later, and score lower in mental tests. The walkers are thought to restrict the ability to explore and interact with the infant's environment. That is certainly consistent with the reports of many creative adults that locomotion promotes reflection. The writer Evan S. Connell once observed that great ideas come to people in transit, especially walking; Joyce Carol Oates has celebrated the stimulation of running and walking, citing Wordsworth, Coleridge, Thoreau, and Dickens.[15]

In adults, the range of walking styles has a history that would have fascinated Mauss. In ancient Greece, bold steps were associated with warriors and rulers. In Homer's epics, Ajax, Odysseus, and other heroes move "with long strides." (Females, women and goddesses alike, take dainty steps.) For the Athenians of the fifth century B.C., the waning of aristocratic power brought a new and more moderate male ideal, neither swaggering nor timid but graceful and dignified. The freeborn man of leisure moved calmly. In the *Nicomachean Ethics*, Aristotle observes that the *megalopsychos*, the great-souled man, moves unhurriedly. Deliberate walking was the mark of leisured men also for the Romans. Strides were broad and both feet probably remained on the ground for longer intervals than they do now. In Roman comedy, slaves ran about, possibly in a scrambling, Keystone Kops fashion. The American orthopedist Steele F. Stewart recalled that the norm for himself and other presumably middle- and upper-class children about a hundred years ago was a “mild Chaplinesque shuffling gait.” It might have been a reaction to the clomping, clodhopping stride of assertive lower-class youth, but we can’t know for sure; the body techniques of the poor are even harder to reconstruct than those of the affluent.[16]

Westerners and non-Westerners have long noticed each other’s distinctive gaits, not always admiringly. The Bengali Brahmin polymath Nirad Chaudhuri recalled in *The Continent of Circe* that his Indian contemporaries seemed to move “like swaying trees”; in turn, young and old compatriots mocked Chaudhuri’s walking style, which he learned from the British, shouting “Left-Right!” and “Johnnie Walker!” as he came down the street. (Indeed, the immense success of the international whiskey brand may have owed much to the bold tread of its booted, ruddy-cheeked Regency figurehead and his invocation of masculine ambition and self-assurance.) Until the middle of the nineteenth century, according to the anthropologist Masaichi Nomura, Japanese children learned to walk with the “namba” gait. It can be seen in old woodblock prints. Arm swing was limited, and each arm moved forward with the corresponding leg instead of with the opposite leg, as is usual in both Japan and the West today. To assure a more level platform for archery, some horses were even trained to move namba-style, with right and left legs synchronized. Japanese ethnologist today find a wider variety of gaits than in the West, but note that the Japanese still use less arm motion and that fewer Japanese than Americans or Europeans strike the ground with their heels as opposed to their toes or entire foot surfaces. Another cultural anthropologist, Tim Ingold, has observed that before their country was opened to the West, Japanese children learned to "walk from the knees," moving the hips as little as possible, whereas European and North American children are trained to "walk from the hips," maintaining their culture's prized erect posture by keeping the legs straight. For Ingold, the skill of walking is not just the addition of culture on top of a genetic capacity; it is the result of a developmental program that includes an entire society's technologies and techniques. For example, traditional Japanese walking gave a good footing on the often uneven local landscape; it was linked with the Japanese method of transporting heavy things by tying them to shoulder-borne poles. Yet the Japanese also have adopted some Western walking techniques with delight. An American named Frances Caldwell Macauley is said to have introduced skipping to Japan in the late nineteenth century, when she demonstrated it to her class of prospective kindergarten teachers in Hiroshima. It spread so fast that she soon saw an aged couple skipping down the street. In Chapter Three we will see that even in our own times, Japan's distinctive footwear has continued to influence gait.[17]

Some traditional walking techniques, long considered merely exotic, are biomechanically stunning. Women of the Kikuyu and Luo tribes of Africa, according to an international team of scientists who studied their performance, can carry up to a fifth of their body weight balanced on their heads at no additional metabolic cost—in energetic terms, for nothing. With heavier loads, up to 70 percent of body weight, their method is still more efficient than a military backpack.

In our normal gait, the body acts as an inverted pendulum, regularly converting potential energy to kinetic energy and back, with the foot as the pivot and the body itself as a moving bob. Somehow the women are able to move so that a moderate weight makes the transfer of energy more efficient, canceling out the extra energetic cost of moving the weight. Sherpas have a similar load-bearing style especially suited for heavier weights. It was not until the year 2000 that a new computer program showed how potential and kinetic energy were exchanged in the African women's walk. Still unknown is how certain Africans, Nepalese, and other peoples around the world acquire this skill, possibly in childhood.[18]

Mauss's insights into body technique can be extended well beyond gait and gesture to technological and medical procedures. When Mauss first published his study, he noted that French telephone linemen were still using only crampons to climb poles. Only a year or two later did they begin wearing belts that looped around the poles, a method Mauss believed was in universal use among "so-called primitives." The Greeks and Romans treated burns effectively with cold water, yet for thousands of years doctors were taught to use oils instead (or sometimes simply to apply bandages), especially after the introduction of petroleum jelly in the late nineteenth century, a technology that actually set back burn treatment. Only in 1953 did a Los Angeles surgeon, Alexander G. Schulman, impulsively plunge his own grease-burned arm into a tub of cold water and discover that after an hour he could remove it with little pain. His further research and publications brought back a technique abandoned for over a millennium.[19]

Other doctors of our own time have discovered apparently original techniques that needed no medical theory of technology. Consider the Heimlich maneuver. Because choking fatalities have been documented at least to the time of Emperor Claudius, and because airway obstruction can be fatal in five or six minutes, it is remarkable how long it took physicians to develop a standard emergency technique. Well into the 1980s, for example, the American Red Cross still recommended slapping the victim's back—probably a less effective treatment than the medieval method of rolling him or her over a barrel. It was a single Cincinnati physician, Dr. Henry Heimlich, who in 1974 proposed that the best way to dislodge food from the airway is to compress the diaphragm by standing behind the victim, placing a fist between the navel and the rib cage, and jerking it upward with both arms. The back slap, he maintained, could easily lodge food more deeply in the throat. While the Red Cross and the American Medical Association continued to recommend back slaps as a first resort (at least until the then Surgeon-General C. Everett Koop took Dr. Heimlich's side in 1985), the procedure was estimated to have saved more than 9,000 lives in its first decade and 20,000 by 1990. By the mid-1990s, it was credited with 4,000 to 5,000 rescues annually.[20]

The Heimlich maneuver is pure technique. It needs no medication or apparatus; the inventor decided against using special hardware because precious minutes would be lost in deploying it. (After World War II, Heimlich had developed and patented a now-standard chest drainage valve, for treatment of collapsed lungs, from a 25-cent rubber toy that sounded Bronx cheers.) Yet the method is simple enough that many people who have used it successfully probably have had no more training than seeing a demonstration on television or on a restaurant poster. Much of its power comes from the fact that in a public setting, at least one or two onlookers are likely to be familiar with it. Victims can apply it to themselves, and the method can be modified for very large people, pregnant women, and unconscious people. A four-year-old boy used it to rescue his two-year-old brother.[21]

But is technique really abolished, or only relocated? Think again of the automobile. Fewer American drivers are buying manual transmissions, not only because new automatic designs are smoother and more economical than their predecessors, but because motorists have embraced a new and potentially hazardous technique: traveling while cradling and speaking into a portable cellular telephone. An air bag seems to be the ultimate passive device, but even it has implications for how we use our bodies. The American Automobile Association now recommends keeping hands on the steering wheel at the 9 and 3 o'clock positions, or even as low as 7 and 5 o'clock, instead of at the former driver-education-course standard of 10 and 2 o'clock, to reduce the risk that the air bag will burn the driver's hands or propel them up at the face. Advocates also say the new grip allows a fuller rotation of the wheel in emergencies without removing the hands. And some experts now believe that traditional hand-over-hand technique, while efficient in tight cornering, not only exposes arms to air bag explosions but promotes dangerous oversteering under stress. Children in the backseat are to be directed to sit up straight and not lean to the side if their cars are equipped with the new side-impact air bags. And skill is required to install rear children's seats safely; the U.S. National Highway Traffic Safety Administration (NHTSA) estimates that in 90 percent of cars, either the seat or the child is improperly secured. New safety devices thus may require us to spend hours changing the very techniques that were once taught for safety, and acquiring entirely new ones.[25]

Few drivers receive formal training in emergency handling of their cars, especially in snow and ice, and places for safe practice of these maneuvers are rare. Yet antilock brake systems (ABS), traction control, and other innovations may encourage drivers to venture out in conditions where these special skills are necessary, even with the new technology. And there is an element of technique even in the use of automatic devices: because ABS is unlikely to be universal in the near future, every driver has to be aware of how to handle a skidding car: the pumping action formerly recommended for the traditional brake, or the steady pressure needed by ABS. (To make matters still more confusing, it is not clear whether pumping is a more effective way to halt a skid or merely a relic of the days before disk brakes, when fade was a serious problem.)

Making inherently dangerous things easier to use creates other problems. The 9-millimeter pistol shows that simpler construction may demand more skill. In the 1980s, many American police departments began to replace their service revolvers with these semiautomatic weapons, made by Beretta, Glock, Ruger, and other companies, for more rapid firing against drug dealers' automatics. Originally temperamental, the semiautomatics now are more reliable and easier to use and maintain than revolvers. But it is precisely this simplicity that makes technique more complex. When the city of Washington, D.C., adopted the Glock 17 in 1988, officials especially liked the absence of an external safety lock. The Glock 17 has three mechanisms to prevent accidental discharge, but squeezing the trigger releases each of them. One of the internal safeties is intended to add an additional pull on the trigger before firing, but in the streets many officers may activate it early to be ready to fire instantly.[26]

The military works hard to prevent premature engagement by achieving "fire discipline." In Washington, there were over 120 accidental discharges of the new pistols in the first ten years, leading to settlements of over $1.4 million in just three months of 1998 alone. The Glock, according to its many admirers in police circles, is inherently safe. One simply needs special training to know exactly when to begin fire when the finger is kept on the trigger. (Because it will fire a round from the chamber even after the magazine has been removed, the Glock 17 also demands more careful maintenance procedures.) The simplicity and ease of firing, then, demand more rather than less training in technique.

Other sophisticated, seemingly transparent technologies also call for unexpected manual skills. The magnetic-striped MetroCards used by the New York Metropolitan Transportation Authority must be passed through a slot at subway turnstiles in a firm, fluid, even manner not easy for all riders to master. (Bus fareboxes swallow the card and return it, provided it is inserted in the single correct direction out of four.) A failed “swipe,” as the motion is called, must be repeated at the same turnstile; otherwise the system temporarily invalidates it. Sometimes several passes are required before the card is read.

In at least one of the advanced research laboratories I have visited, technicians were on call to untangle the serpents’ nests of cords and wires that accumulate behind and beneath equipment. Their specialty has a name, cable management, and pays salaries high enough that a representative in one laboratory apologized for the mess with the explanation that untangling would have strained the unit’s budget.

At the level of individual users, the mouse was heralded as an unproblematic intuitive device but often demands either reprogramming (for acceleration or double-click speed, for instance) or adjustment of the user’s technique. It clogs readily with dust and only the most thorough cleaning restores its responsiveness. And some ergonomists believe that, used improperly, it can be a greater health hazard than the keyboard.

Technique has a history even without changes in equipment. It is too bad that Mauss did not pursue his analysis of swimming history, because the sport showed the importance of culture for performance. It was a kind of aquatic marching, at first taught mainly by military instructors. The breaststroke that Mauss and his contemporaries had learned was favored by European and North American swimming teachers in the nineteenth century despite its obvious disadvantages: as the name implies, the full breadth of the chest pushes through the water, and the arms and legs also increase resistance as they return to the beginning of a stroke. Yet it was an intuitive and natural motion, and it helped keep weapons dry. Europeans as early as the seventeenth century studied the frog kick to prepare themselves for the water, and live frogs were even kept at London's Serpentine for swimming instruction in the early nineteenth century. England was the center of Western swimming, and English athletes had refined the breast-stroke so thoroughly that other styles could not compete for decades.[27]

The more efficient crawl did not originate with the masters of the breaststroke, who had no incentive to abandon the style they had perfected. Two Native American swimmers, Flying Gull and Tobacco, had demonstrated their overarm style in London in 1844, and Flying Gull was able to cover a 130-foot pool in only thirty seconds, but their apparently thrashing style was condemned as "un-European." In fact, many peoples of the Americas, Africa, and Asia had been swimming hand-over-hand. European techniques, the dog paddle and the froglike breaststroke, were the exceptions. But the American Indian style, effective as it was, needed a European smoothness if it was to compete. It was the most distant European outsiders of the nineteenth century, Australians, who supplied the missing bits of technique. Observing the stroke of South Sea Islanders, they made the kick more pleasing to

Europeans. They needed no devices for this they were pure innovators of technique, as were the Swedes who discovered that the springboard—an early-nineteenth-century innovation of the German founder of modern gymnastics, Friedrich Ludwig Jahn— could be not just an entry platform to the pool but the basis of an independent athletic performance. Throughout the twentieth century, gifted swimmers and coaches have been developing the crawl and other strokes. Often it is swimmers like the backstroke specialist Allen Stack and the butterfly expert Mary T. Meagher whose intuitively shaped motions transform practice. Today, athletes and coaches are also using imaging technology to study the techniques no longer of frogs, but of marine mammals, birds, and flying insects.[28]

SPORTS AND THE FRONTIERS OF TECHNIQUE

The transition from military to recreational swimming instruction illustrates another displacement of physical technique: from work to leisure. Learning any sport is a conscious apprenticeship, or trial-and-error self-tutorial, in the controlled use of the body. Even if technique really is becoming less important on the job, more of it than ever is apparent at play.

Playful does not mean inconsequential. To the contrary, part of growing up is learning graceful motion. Throwing a baseball is a surprisingly complex learned behavior. Consider the phrase "throwing like a girl," directed at Hillary Rodham Clinton after she ceremonially opened a Cubs baseball game at Wrigley Field in Chicago in April 1994. The writer James Fallows dissected the First Lady's offending stance and found three elements that distinguished it from proper baseball style: she faced the target rather than positioning her trunk perpendicular to it and then rotating back to amplify the pitch; she kept aerodynamic advantage over the Ordinaries, finally stabilized (to use Bijker's expression) the bicycle as we know it. Because the skills of riding the Ordinary no longer bought superior speed, they disappeared.[33]

PULLING TOGETHER

The interaction of inventors (who may or may not be athletes) with participants (who may or may not have technical skills) allows technology and technique to produce striking results envisioned by neither designers nor athletes. Rowing, fencing, speed skating, bowling, and bicycling show five outcomes of the interaction of technology and technique. In rowing, an innovation forgotten since antiquity was independently revived in the nineteenth century, but it took outsiders nearly a hundred years to refine a style that exploited it fully. In fencing, hardware innovation at first upset traditional technique, then rapidly reached a new equilibrium with it as both equipment and behavior changed together. In speed skating, a design from the 1890s was ignored for a century, then swept the field when athletes finally adjusted their technique. In recreational cycling, an alternative design helped change the nature of the sport itself, appealing to new riders with a different attitude. And in bowling, new equipment has altered the definition of winning technique.

Technology and technique were linked in the early history of rowing, when it was a vital military skill rather than a sport. The sliding seat was first used by rowers of the ancient Greek triremes. Their leather cushions and low-level seating, lubricated by fats, promoted more efficient motion with a sliding stroke that exploited leg power. Most rowers were free citizens, and the sliding stroke, then as now, required practice, so twelve thousand men were paid to train this principle in the 1870s—using seat mountings first of bone sliding on brass and ultimately of wheels in vulcanite grooves—some conservatives resisted. Even if the innovation made rowing more efficient and speedier, they objected, it was a labor-saving idea of professional scullers, and put a premium on fast entry and leg power rather than a hard “catch” powered from the shoulders and upper body. Motion from the hips and lumbar region was no longer paramount. Letters objecting to the sliding seat and its associated technique appeared in the London *Times* as late as 1933. Because of this aesthetic model of proper use of the rower’s body, coaches and athletes revised their style only slowly. At the most important English regattas, Henley and Oxford-Cambridge, speed records actually declined after its introduction. Even after the sliding seat’s acceptance, the fixed seat remained a norm for training in England and the basis of a style called English Orthodox that persisted well after World War II. An observer in the 1880s reported that Oxford crews were not synchronizing slide and swing but delaying the use of the slide until their bodies were upright, as though they were still using fixed seats.[35]

As in swimming, it was an Australian who began a revolution of technique, and at about the same time. (The American Orthodox style was only a modification of English Orthodox.) In the early twentieth century, Steve Fairbairn (1862–1938), the coach of Jesus College, Cambridge, introduced a revolutionary call to use the body’s weight, and especially the legs rather than the shoulders, to move the boat. His crews’ successes were the first major challenges to Orthodoxy. The next great innovations, building on Fairbairn’s ideas, came in the 1960s. A club in the north German town of Ratzeburg at last developed an alternative method, now known as International Modern. By accelerating the slide in its approach to the front stop, the coach Karl Adam was able to assure a steadier hull speed, help the West

Marvin Nelson, a veteran fencer, official, and coach, deplored the "sloppy, pig-sticking" style that flourished as officials allowed fencers to maintain attacks when procedural rules ("right of way") should have given the touch to the other side. The flashing light overrode their knowledge of the rules. Meanwhile, the flexible weight-tipped blades whipped away from targets. Nelson recalled that he, like others, "was forced to fence with absence of blade and reduce my game to much more simple actions."[39]

These problems passed. Suppliers introduced better points and stiffer blades. And technique changed as well. Competitive fencers practiced with foils simulating the feel of the electric models. In fact, by the mid-1970s Nelson noticed a more vigorous game: "Fencers are 'carrying' the weapon more effectively—showing an improvement in awareness of the different parts of the blade. Thrusts or actions are being made from positions not usual in standard foil or in the first period of electric foil.… Foot movements are increasingly efficient." Still, these more sophisticated techniques have brought other changes in technology, notably grips with small projections for more secure finger holds. Introduced as "orthopedic" grips for fencers with missing fingers or other disabilities, these are now widely used as "pistol" grips. They promote a more vigorous style at the expense of lightness and flexibility and have been labeled by one authority as "this monstrous brood." And electric scoring demands self-discipline, as some athletes focus their attention so much on the gratification of a light or buzzer that their minds wander from the bout itself, letting their opponent score the touch.[40]

A second group of sports changed significantly in the last century thanks to new materials and manufacturing processes. In these cases, too, the crucial change was not so much the new equipment as the development of body motions to optimize it. Most skating remains relatively conservative in equipment despite countless refinements of skates and great improvements in ice conditioning equipment in recent years. Speed skating, too, changed little until very recently. In 1488, Leonardo da Vinci studied it but lost interest after failing to create a new design. Four hundred years later, in 1890, a Canadian and a German independently developed and patented a skate hinged at the toe and spring loaded, so that the boot could separate temporarily from the blade. Neither model appears to have gone into commercial production.[41]

Gerrit Jan van Ingen Schenau, a professor of biomechanics at the Free University of Amsterdam, originally wanted to design a safer skate, not necessarily a faster one. He told a journalist from a Japanese news service that from the early 1980s, many skaters had complained to him of pain in their shins. "I then realized that skating is a uniquely unnatural movement—different from walking or running—because the heel does not rise freely in motion." The lever mechanism let the skater lift one leg at a time, the one not doing the pushing, while keeping the runner on the ice, in principle reducing strain on the calf muscles. At some point his team noticed that speed skaters kept their ankles locked and pushed off their heels—unlike jumpers, who extended their ankles and pushed off their toes. The hinged skate in principle allowed the ankle to move with the blade still fully on the ice, using the calf muscles for a longer stride.[42]

As with the clap skate, a new generation of competitors forced the established champions to adapt their technique to the new equipment. Not all succeeded. But to many veteran instructors and pros, the loss has been collective as well as individual. In their view the urethane ball threatens the game's integrity by upsetting the historic balance between strikes and spares. "With today's balls," says one, "you don't have to make a good shot to knock down 10 pins; you pay $160 [for a bowling ball], hit the pocket, and you strike." And another observes that "[l]ots of dedicated people practice. But most of them practice just to strike," instead of studying how to achieve spares as well.[48]

While the cultivation of some techniques has declined in the United States, other techniques have flourished as Asia has embraced the game. In the 1980s, players in Taiwan began to develop a radical new style of delivery. Using balls typically weighing eleven pounds rather than the sixteen pounds customary for Western men, they gripped them from above and used their thumbs to impart a rapid backward horizontal rotation to the ball, strong enough to continue down the lane like a top, scattering the pins with explosive force. (In the epilogue we will consider the thumb as the Cinderella of the hand.) With proper spin, hitting the 1–3 pocket precisely becomes unimportant. A ball aimed at the head pin can miss by as many as seven boards on either side, giving the spinner or helicopter ball a fourteen-board strike zone rather than the Western three-board zone. Some Taiwanese bowlers wager on their ability to roll "perfect" strikes, not just toppling all the pins but removing them from the deck. This technique of the lighter Asian players not only has surprised Western pros but has taken world titles, first when You-Tien Chu of Taiwan won the AMF World Cup in Mexico City in 1983 and most recently in November 1998, when Cheng-Ming Yang, also of Taiwan, won the AMF Bowling World Cup competition in Japan. Unlike other bowling techniques, the Taiwanese almost anything can be made better by user experimentation. There is a benign and positive side to the unintended. Inventors also can scarcely foresee the changes in values that will give new meanings and techniques to what they have produced. Some of the most common things in everyday life reflect not only the ingenuity of the original producers but the experiences of generations, sometimes millennia, of users. When we use simple devices to move, position, extend, or protect our bodies, our techniques change both objects and bodies. And by adopting devices we do more. We change our social selves. In other species, natural selection and social selection shape the appearance of the animal. In humanity, technology helps shape identity. Our material culture changes by an unpredictable, dialectical flux of instrument and performance, weapon and tactic.

shaping of the human body. Genetic manipulation may ultimately reduce the frequency, at least in certain populations, of genes responsible for certain birth defects. It may also promote other genes that are culturally held desirable, governing body type, appearance, and intelligence test scores. Neither most advocates nor most opponents of these techniques have fully thought out the implications of calling them "engineering." Civil engineers—as Henry Petroski has argued in a series of books—advance through mistakes and even disasters, but misdesigned people cannot be rebuilt as failed bridges, collapsed tunnels, and failing roads may be. At the very least, in vitro fertilization may actually help increase the incidence of infertility, as we have seen that genetic testing can inadvertently spread genes for hereditary diseases while preventing their expression in a given family. Over the coming century, for an increasing number of couples, parenthood might require medical assistance. Already one in six American couples receives some kind of fertility treatment. It is easy to imagine that this proportion might increase.[1]

As common as prenatal tests have become in industrial societies, they have a small effect on the human body compared with those of an older form of intervention in our development: bottle-feeding. For the majority of people in the developed world, infant formula and its physical apparatus of bottles and nipples is the first technology. And its effects, if usually subtle, are lasting.

THE SKILL TO BE NATURAL, THE WILL TO BE ARTIFICIAL

Human nursing is different from the lactation of other mammals, even of other primates, because (as part of the price of our hyperdeveloped brains) the human infant is uniquely dependent. Other primate infants are born as vigorous little individuals who know how to look out for themselves. They need no help in finding and latching on to the mother's nipple. Other primate mothers do have infant care skills to learn, and second infants are easier for them, but by the time they are ready to nurse they have learned what they need, and the infant does the rest. By contrast, the human infant needs its mother's body not just for nourishment and shelter but for immunological protection; it has been called an "external fetus."[2]

Once more, human performance requires technique, as breast-feeding advocates are the first to acknowledge. Being a baby can be hard work. While sucking is a reflex, an infant must use sixty-three different nerves to suck, swallow, and breathe, according to lactation specialists, and about one in ten has some difficulty. Maternal behavior, too, has to be learned. New mothers are not innately prepared for many contingencies: insufficient or excessive breast milk, cracked nipples, and a great variety of infant behaviors. In the words of an African infant nutrition activist: "We make the mistake of believing breast-feeding is natural, an intuitive thing. But it's a learned behavior passed on from generation to generation. In the old days, the older women would sit there and encourage and tell you to do this and that—it was part of education." Now breast-feeding advocacy organizations and lactation consultants have taken the place of grandmothers.[3]

Humanity has a long history of feeding arrangements for mothers unable or unwilling to nurse their own children. Of course, the great majority of mothers did so, if only because there was no available alternative. In Greece and Rome the affluent often employed wet nurses, free as well as slave. Wet nursing was a thriving profession in the Middle Ages, a specialty of whole districts like the Casentino and Valdarno valleys in Italy, whence young married women and their

127–43; Peter T. Ellison, "Breastfeeding, Fertility, and Maternal Condition," in ibid., 305–45; Jelliffe and Jelliffe, *Human Milk*, 117–19.

33. *Womanly Art of Breastfeeding*, 161–73; Baumslag and Michels, *Milk*, 31–32, 23–26; Lastinger, "Re-Defining Motherhood," 613; Marylynn Salmon, "The Cultural Significance of Breastfeeding and Infant Care in Early Modern England and America," *Journal of Social History*, vol. 28, no. 2 (Winter 1994), 247–69.

34. Alan S. Ryan, "The Resurgence of Breastfeeding in the United States," *Pediatrics*, vol. 99, no. 4 (April 1997), E12—E16; Marc Kaufman, "What's in Infant Formula?" *Washington Post*, June 1, 1999.

35. Kaufman, "Infant Formula," 13; Marc Kaufman, "Baby Formula Fight Puts Fat Under Fire," *Washington Post*, June 1, 1999.

36. Karen Goldberg Goff, "To Baby's Health," *Washington Times*, August 18, 2002; Isadora B. Steylin, "Infant Formula: Second Best but Good Enough," *FDA Consumer*, vol. 30, no. 5 (June 1996), 17–20.

37. Alan Lucas, letter, *British Medical Journal*, vol. 317, no. 7174 (August 1, 1998), 337–38; Glen E. Mott et al., "Programming of Cholesterol Metabolism by Breast or Formula Feeding," in *The Childhood Environment and Adult Disease* (Chichester, Eng.: John Wiley & Sons, 1991), 56–76; Golden, *Wet Nursing*, 206; Janet Raloff, "Breast Milk: A Leading Source of PCBs," *Science News*, vol. 152, no. 22 (November 29, 1997), 344.

38. Jill Nelson, "Mr. Mom Finally Gets It All," *Washington Post*, September 27, 1987.

39. On the technology and politics of contemporary breast-feeding, see Linda M. Blum, *At the Breast: Ideologies of Breastfeeding and Motherhood in the Contemporary United States* (Boston: Beacon Books, 1999); for a new feminist interpretation, see Alison Bartlett, "Breastfeeding as Headwork: Corporeal Feminism and Meanings for Breastfeeding," *Women's Studies International Forum*, vol. 25, no. 3 (May—June 2002), 373–82.