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Eighteenth-Century Wetware

To be a machine, to feel, think, know good from evil like blue from yellow . . .
—Julien Offray de La Mettrie, *Man a Machine* (1747)[1]

"WETWARE" IS THE NAME that computer scientists and engineers give to the human brain and nervous system, to contrast them with computer hardware and software. Rudy Rucker, a popular science writer, novelist, and mathematician in the Department of Mathematics and Computer Science at San Jose State University, coined the term to serve as the title of a 1988 novel in which he defined "wetware" as referring to "all [the brain's] sparks and tastes and tangles, all its stimulus/response patterns—the whole biocybernetic software of [the] mind."[2] Rucker's definition makes manifest the dual action of his new word. Even as it distinguishes animal from artificial machinery, "wetware" also unites the two, and has in fact come to be used in ways that undermine the contrast between animals and machines: for example, when it is used to refer to artificially intelligent systems that are modeled closely upon human neurology, or to systems that incorporate biological components, or to those that resemble biological systems in texture and substance, or any combination of these ("biomimetic" or "chemomechanical" systems made of polymer gels, for instance).[3]

"Wetware," then, with its Silicon Valley derivation and its cutting-edge applications, is the expression of a particular moment, the turn of the twentieth to the twenty-first century. The neologism voices one of the organizing ambivalences of the current moment: we believe that the processes of life and consciousness are essentially mechanistic and can therefore be simulated, and yet we are equally firmly persuaded that the essences of life and consciousness will ultimately be beyond the reach of mechanical reproduction.

Although the conflicting assumptions expressed in the word "wetware" and the machinery to which it refers seem utterly specific to the present, they were in fact also characteristic of another moment, the second half of the eighteenth century—decades that saw the emergence of artificial life in a flurry of attempts to simulate

ABSTRACT This essay explores a similarity between the way people approached the relation of life to machinery during the second half of the eighteenth century, and the way they have been exploring this relation during the second half of the twentieth century and turn of the twenty-first. The essay describes a moment of intense interest in producing artificial life, from the 1730s to the 1790s, examines what set the projects of this moment apart from previous and subsequent ways of conceiving the relations between animal and artificial machinery, and closes with some speculation about the similarity between the two epochs in the history of artificial life, then and now. / Representations 83. Summer 2003 ISSN 0734-6018 pages 97–125.

with machinery the physiological processes and cognitive behaviors of living creatures. I mean in this essay to explore a similarity between the way people approached the relation between life and machinery then and the way they have been approaching it recently.

Here and throughout, I use the word "simulation" and all its forms in their modern sense, which originated around the middle of the twentieth century, to refer to an experimental model from which one can discover properties of the natural subject. This epistemological entity came into existence, as I argue elsewhere, and as I hope will also become clear over the course of this essay, two centuries before the coining of the modern term "simulation," around the middle of the eighteenth century.[4] At that time "simulation" meant artifice and had a negative connotation, implying fakery, and I have not found any eighteenth-century applications of the term to automata. However, the practice of using machinery to approximate nature, then experimenting on the model and drawing conclusions about its natural prototype—in short, "simulation" as we now mean it—originated then. Thus, I employ the term here despite the anachronism in order to convey the pivotal role that eighteenth-century projects in artificial life played in the history of attempts to simulate (in its modern sense) life processes.[5]

The first designers of artificial life intended their projects to resemble natural life in texture and substance, sometimes even making use of biological components. The resulting simulations, like present-day "wetware," made manifest both their makers' assumptions about the differences between animals and machines, and their impulse to undermine these differences. Part of the surprise and the interest in this similarity between late-eighteenth- and late-twentieth-century approaches to artificial life is that there was a long intervening period, during the nineteenth and early twentieth centuries, when people thought very differently about the possibility of simulating life.

This conspicuous changeability, over the past two and a half centuries, in how designers of artificial life have conceived of their project has been strangely absent from recent discussions of their early productions. For example, Gaby Wood's *Edison's Eve* treats Descartes's animal-machine, the clockwork androids of the mid- to late eighteenth century, the mechanical tricks of the magician Jean-Eugène Robert-Houdin during the mid-nineteenth century, and the robots currently inhabiting the Massachusetts Institute of Technology's Artificial Intelligence Laboratory all as expressions of the same impulse, a sort of rationalism gone mad. Wood describes this mad-scientist impulse as also always provoking the same response, from the journalists who gave effusive accounts of a set of Swiss mechanical musicians during the 1770s, to the lady-spectators who crossed themselves and fainted during exhibitions of the notorious Chess-playing Turk of the late eighteenth and early nineteenth centuries, to E. T. A. Hoffmann's mystical treatment of artificial life in "Die Automaten" (1821): in each of these instances, Wood discerns the Freudian "uncanny."[6]

Here I will suggest, in contrast, that the project of artificial life, and also the surrounding cultural representations and assessments of that project, transformed foundationally from each generation to the next. The story of the origins of modern artificial life lies, not in a changeless quest emerging from timeless human impulses, but rather in the experimenters', philosophers', and critics' continually shifting understandings of the boundary between intelligent and rote, animate and mechanical, human and nonhuman. In what follows, I describe the intense interest in the eighteenth century in producing artificial life as a discrete and *sui generis* moment, examine what set it apart from previous and subsequent ways of conceiving the relations between animal and artificial machinery, and close with some speculation about the similarity between the two moments in the history of artificial life, the second half of the eighteenth century and the second half of the twentieth.

The emergence of artificial life in the mid-eighteenth century was crucially informed by a particular philosophical development, namely a materialist, mechanist understanding of life and thought. Materialists repudiated Descartes's separation between mind and body, and insisted that all the functions that might be ascribed to mind and soul actually resided in the stuff of which living creatures were made. Mechanists argued that interaction among the body's parts, animal machinery, was directly responsible for all vital and mental processes. These materialist and mechanist accounts of life worked in both directions. Not only did they shape how people thought about living creatures but, reciprocally, they also changed how people thought about matter and mechanism. If life was material, then matter was alive, and to see living creatures as machines was also to vivify machinery.

Thus materialism and mechanism were themselves transformed during the second half of the eighteenth century by their application to the explanation of life. Materialists began to invoke a vital property of matter called "sensibility" that, many physiologists believed, was inherent in organic substance. Mechanists began to draw upon such qualities in their explanations and, therefore, to throw off the restrictions of seventeenth-century mechanism, no longer confining themselves to the primary qualities of size, shape, state of motion, number, and solidity. The altered, eighteenth-century meanings of materialism and mechanism obtain in works such as Julien Offray de La Mettrie's *L'Homme-machine*, the title of which could be misleading, since the book does as much to animate machinery as it does to mechanize life. La Mettrie's human machinery senses and feels, and is in fact eroticized. La Mettrie writes: "if what thinks in my brain is not a part of that vital organ, and consequently of the whole body, why does my blood heat up when I am lying tranquilly in bed thinking[?] . . . Why does the fever of my mind pass into my veins?"[7] He knows that thinking is carried out by his machinery because of the sensual agitations produced by thought.

The mechanists and mechanicians of the eighteenth century described animal machinery that was sensitive and passionate. Seeing animals as machinery, they

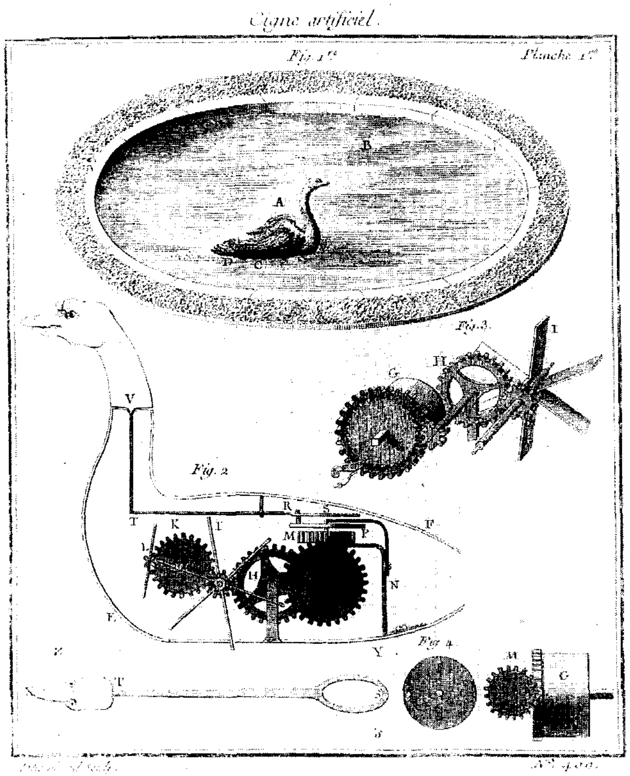


FIGURE 1. Maillard's artificial Swan, from "Diverses machines inventées par M. Maillard. Cygne artificiel," in M. Gallon, ed., *Machines et inventions approuvées par l'Académie royale des sciences depuis son établissement jusqu'à present; avec leur Déscription* (Paris, 1735–77), 1:133–35. Courtesy of Department of Special Collections, Stanford University Libraries.

began also to see machinery as animal, and to design machines accordingly. The results, like modern "wetware," called attention to certain differences of texture, substance, and mode of action between animal and artificial machinery and simultaneously worked to undermine these differences. It is because of their dual function that I call these machines "eighteenth-century wetware."

One species of such machines was composed of automata: mechanical figures of people and animals. During the mid- to late eighteenth century, a particular style dominated their design. Eighteenth-century designers tried to simulate life's textures and substances, and even physiology, making automata from this period look very different from those of the previous or subsequent periods. Mechanical animals of the previous period, the seventeenth and early eighteenth centuries, present artistic renditions of animal movements but make no attempt to imitate physiological processes. Consider, for example, an artificial swan (fig. 1), presented to the Paris Academy of Sciences in 1733 by a mechanician named Maillard. The swan paddled through the water on a paddle wheel while a set of gears swept its head slowly from side to side.[8] It was intended to represent, rather than to simulate, a natural swan.

Strikingly, the very pinnacle of mechanist physiology in the mid-seventeenth century did not correspond with attempts to simulate animals using machinery. Seventeenth-century mechanist physiologists drew analogies between animals and machines, but they did not use machines to simulate life. Descartes compared animals to automata and even built automata himself, but he did not design these as physiological simulations.[9] His philosophical heirs, though, did try to simulate life. This disparity shows up the crucial divergence between analogies and simulations, two conceptual devices that function quite differently: analogies work by preserving a certain distance between the two things being likened, whereas simulations operate by collapsing that distance. The period between the 1730s and the 1790s was one of simulation, in which mechanicians tried earnestly to collapse the gap between animate and artificial machinery.

The period of simulation was surrounded on both sides by contrasting moments in which analogies between life and machinery were rife, but simulations rare. Nineteenth-century automata, like their seventeenth-century ancestors, were not simulations but instead were artistic renditions of animal and human activities. Indeed, in the nineteenth century there was a great proliferation of such renditions. Particularly after midcentury, when automata began to be mass produced, they were suddenly everywhere. To get a sense of the transformation, consider that during the 1840s automata sold in Paris for thousands of francs, whereas in 1868, one could buy an automaton for 8 francs, 50 centimes.[10] Mechanicians began to design very complicated displays, ultimately filled with the preoccupations of the Belle Epoque: dandies, circus- and street-performers, magicians, workers at work, schoolchildren at their lessons, and shopkeepers in their shops. But despite their elaborateness, these nineteenth-century automata were markedly less ambitious than automata of the preceding century. Or, more precisely, their ambition was not to simulate. Once again, philosophers, physicists, physiologists, and engineers drew analogies, particularly during the second half of the nineteenth century, between human and animal bodies on the one hand and machinery on the other, often resting upon the new concepts of energy and work.[11] But, by and large, those who drew such analogies did not use machinery to simulate living beings; indeed, they tended explicitly to reject the idea of simulating life. The second half of the eighteenth century was an exceptional moment, then, for the very literal way in which it construed the similarity between animal and artificial machinery.

The difference between eighteenth- and nineteenth-century approaches to artificial life is encapsulated in the contrast between *Pierrot écrivain* (fig. 2), a late-nineteenth-century automaton by Gustave Vichy, one of the most successful designers of the period, and the Writer (fig. 3), built during the early 1770s by a Swiss clockmaking family named Jaquet-Droz.[12] Whereas Pierrot did not actually write, but merely waved his pen over his paper in rough imitation of writing, the Jaquet-Droz Writer not only wrote but also could (and can) be programmed to write any message of up to forty characters. He remains in working condition at the *Musée d'art et d'histoire* in Neuchâtel, Switzerland, where he is accompanied by a Draughtsman

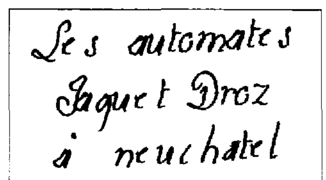


FIGURE 2. Gustave Vichy's *Pierrot écrivain*, from a postcard of the (now closed) Museum of Automata, York, England.
FIGURE 3. The Jaquet-Droz family's Writer, from a postcard of the Musée d'art et d'histoire, Neuchâtel, Switzerland. At right is a sample of his work.

(fig. 4) who uses a bit of charcoal to draw four pictures and by a Lady-musician (fig. 5) who plays a harpsichord, following her hands with her eyes as she plays.

The Jaquet-Droz automata do not just carry out the processes of writing, drawing, and playing music, they are also anatomical and physiological simulations. Their skeletal structures were likely designed with the help of the village surgeon.[13] Both the Lady-musician and the Draughtsman also breathe. The Draughtsman periodically blows the charcoal dust from his paper and surveys his work, and the Lady-musician sighs in time to the music. Her breathing was what spectators most often commented upon. It made her seem not only alive, but emotional. She appeared moved by the music she played.[14]

Breathing automata were quite popular in the late eighteenth century. They originated with Jacques Vaucanson's android Flute-player of 1738, who needed to

FIGURE 4. The Jaquet-Droz family's Draughtsman, from a postcard of the Musée d'art et d'histoire, Neuchâtel, Switzerland. At left is a sample of his work.

breathe in order to play his flute. He was the first automaton musician actually to play his instrument, rather than being a music box with a decorative figure on top, and he had three sets of bellows giving him three different blowing pressures. In addition to breathing, the Flute-player also had lips that he could flex in four directions, a supple tongue, and fingers made with a skin of soft leather.[15]

Physiological correctness, then, was a new and pervasive interest on the part of automaton designers of the mid- to late eighteenth century. Automata of this period were physiologically correct sometimes to the point of being scatological. The leading example is Vaucanson's defecating Duck of 1738. In addition to cavorting with its bill and wings, bending its neck, and flexing its feet, the mechanical Duck digested its food—or so Vaucanson claimed—by means of a "Chymical Elaboratory" in its stomach. It swallowed bits of grain, and, after a moment, it excreted

FIGURE 5. The Jaquet-Droz family's Lady-musician, from the author's own photograph.

them at the other end in an altered state.[16] This was the main attraction that drew people from all over Europe to see it. The digestion was later demonstrated to be fraudulent (instead of being digested, the grain was caught in a reservoir at the base of the throat, while the rear-end was loaded before the demonstration with fake excrement), but that does not detract from the interest of Vaucanson's choice of subject.[17] Why a defecating duck? Because Vaucanson, in each of his projects, sought subjects that seemed as distant as possible from mechanism. What could be more unlike machinery, more messily organic, than defecation? Hence the snooping protagonist of Jonathan Swift's 1730 poem, "The Lady's Dressing Room," gradually discovering that his true love's beauty is a triumph of art over nature, has a final epiphany when he discovers her chamber pot: "Thus finishing his grand survey, / disgusted Strephon stole away / repeating in his amorous fits, / O Celia, Celia, Celia shits."[18] Here was the most natural of products, the antithesis of art.

Eighteenth-century projects in artificial life produced machines with soft skin, flexible lips, and delicate, jointed fingers. These machines not only wrote, drew, and played musical instruments but also breathed, ate, and defecated. They performed functions, in other words, that their designers took to epitomize the animate and the organic.

One function that many took to epitomize the organic was spoken language. The materialist-mechanist understanding of intelligence operated at its most literal in the widespread consideration of speech, the defining function of human intelligence, as an essentially physiological process. Eighteenth-century designers of artificial life assumed that the sounds of spoken language depended on an organic structure in the throat and mouth, and it was this dependence that provided the interest in designing speaking machines. The assumption that a talking machine required simulated speaking organs had not always dominated thinking about artificial speech. In 1648, John Wilkins, the first secretary of the Royal Society of London, described plans for a speaking statue that would synthesize, rather than simulate, speech by making use of "inarticulate sounds." He wrote, "We may note the trembling of water to be like the letter L, the quenching of hot things to the letter Z, the sound of strings, to the letter Ng [*sic*], the jirking of a switch to the letter Q, etc."[19] But in the eighteenth century, builders of speaking machines mostly assumed that it would be impossible to create artificial speech without building a talking head: reproducing the speech organs and simulating the process of speaking.

Throughout much of the century, there was a great deal of skepticism about artificial speech on the grounds that the human larynx, vocal tract, and mouth were too soft, supple, and malleable to be simulated mechanically. Around 1700, Denys Dodart, personal physician to Louis XIV, presented several memoirs to the Paris Academy of Sciences on the subject of the human voice, in which he argued that the voice and its modulations were caused by constrictions of the glottis, and that these were "inimitable by art."[20] Bernard le Bouyer de Fontenelle, who was then Perpetual Secretary of the Academy, commented that no wind instrument produced its sound by such a mechanism (the variation of a single opening) and that it seemed "that Nature had the design of placing [the instruments of the voice] altogether outside the realm of imitation. . . . Nature can use materials that are not at our disposal, and she knows how to use them in ways that we are not at all permitted to know."[21]

In 1738, following the public presentation of Vaucanson's automata, the abbé Desfontaines predicted that, despite these triumphs in artificial life, the mechanical imitation of speech would be impossible because of the inimitability of the "larynx and glottis . . . the action of the tongue, its folds, its movements, its varied and imperceptible rubbings, all the modifications of the jaw and the lips."[22] And in 1775, Antoine Court de Gébelin maintained, "The trembling that spreads to all the parts of the glottis, the jigging of its muscles, their shock against the hyoid bone that raises and lowers itself, the repercussions that the air undergoes against the sides of the mouth . . . these phenomena" could only take place in living bodies.[23]

However, during the last three decades of the century, several people took on the project of simulating the organs and process of speech. The first was Erasmus Darwin, who in 1771 reported that he had "contrived a wooden mouth with lips of soft leather, and with a valve over the back part of it for nostrils." Darwin's talking head

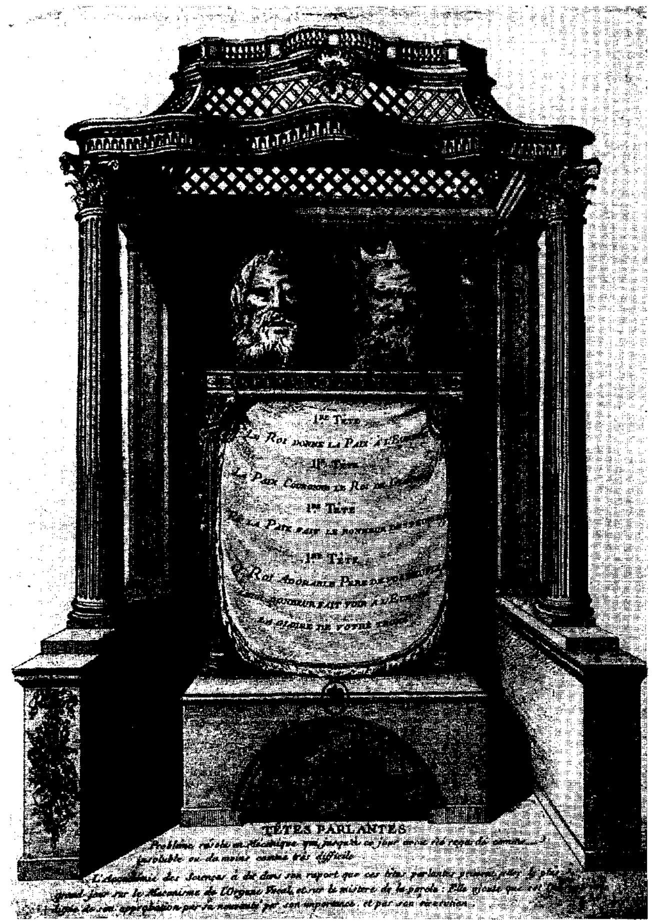


FIGURE 6. The abbé Mical's Talking Heads, from André Chapuis and Edouard Gélis, *Le Monde des automates* (Paris, 1928), 2:205.

had a larynx made of "a silk ribbon . . . stretched between two bits of smooth wood a little hollowed." It said "mama, papa, map, and pam" in a "most plaintive tone."[24]

The next to simulate speech was a Frenchman, the abbé Mical, who presented a pair of talking heads to the Paris Academy of Sciences in 1778 (fig. 6). The heads contained several "artificial glottises of different forms [arranged] over taut membranes." By means of these glottises, the heads performed a fairly insipid dialogue in praise of Louis XVI: "The King gives Peace to Europe," intoned the first head; "Peace crowns the King with Glory," replied the second; "and Peace makes the Happiness of the People," added the first; "O King Adorable Father of your People their Happiness shows Europe the Glory of your Throne," concluded the second head. The Academicians appointed to examine Mical's talking heads emphasized that their enunciation was "very imperfect," but granted their approval to the work anyhow because it was done in imitation of nature and contained "the same results that we admire in dissecting . . . the organ of the voice."[25] Several more people built talking heads before the turn of the century, among them a Hungarian engineer named Wolfgang von Kempelen, who claimed to follow nature "absolutely" in designing his speaking machine. The resulting apparatus had bellows for lungs, a glottis of ivory, a leather vocal tract with a hinged tongue, a rubber oral cavity and mouth whose resonance could be altered by opening and closing valves, and a nose with two little pipes as nostrils.[26]

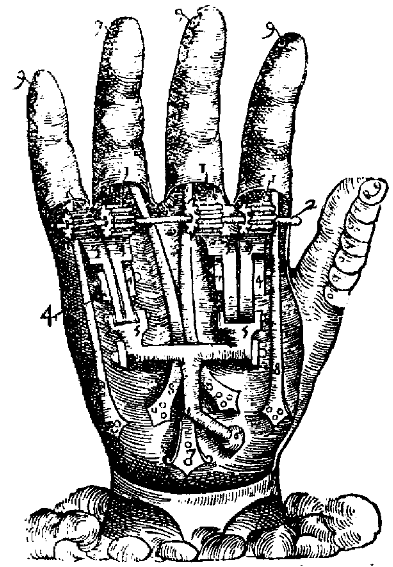
After this flurry of activity in the 1770s, '80s, and '90s, there was a marked decline in interest in speech simulation. A few people over the course of the nineteenth century, including Charles Wheatstone and Alexander Graham Bell, built their own versions of Kempelen's and Mical's speaking machines and of other talking heads from the earlier period.[27] But for the most part, designers of artificial speech turned their attention once again to speech synthesis.[28] In 1828, Robert Willis, a professor of applied mechanics at Cambridge, wrote disparagingly that most "writers who have treated on the vowel sounds appear never to have looked beyond the vocal organs for their origin. Apparently assuming the actual forms of these organs to be essential to their production . . . [they have considered] vowels in fact more in the light of physiological functions of the human body than as a branch of acoustics." In fact, Willis argued, vowels "are not at all beyond the reach of human imitation in many ways, and are not inseparably connected with the human organs."[29] In addition to promoting synthesis over simulation, many also returned to the conviction that simulation of the vocal organs was impossible. Around 1850, Claude Bernard wrote in his notebook, "The larynx is a larynx . . . that is to say . . . [its] mechanical or physical conditions are realized nowhere but in the living organism."[30]

Disenchantment with speech simulation was so pronounced that when a German immigrant to America named Joseph Faber designed quite an impressive talking head in the late 1840s (figs. 7 and 8), he could not get anyone to take notice of it. Faber's talking head was modeled on Kempelen's and Mical's, but was far more elaborate. It had the head and torso of a man dressed like a Turk, and inside were bellows, an ivory glottis and tongue, a variable resonance chamber, and a mouth cavity with a rubber palate, lower jaw, and cheeks. The machine could pronounce all the vowels and consonants, and was connected by way of levers to a keyboard of seventeen keys, so that Faber could play it like a piano. He first exhibited the machine in New York City in 1844, where it aroused very little interest. He then took it to Philadelphia where he had no better luck. P. T. Barnum found Faber and his talking head there, renamed the machine the "Euphonia," and took them on tour to London, but even Barnum could not make a success of it. Finally the Euphonia was exhibited in Paris in the late 1870s, where it was mostly ignored, and soon thereafter all traces of it disappear.[31] The moment for talking heads had passed.[32] In the early part of the twentieth century, designers of artificial speech moved on from mechanical to electrical speech synthesis.[33] The simulation of the organs and process of speaking—of the trembling glottis, the malleable vocal tract, the supple tongue and mouth—was specific to the last decades of the eighteenth century.

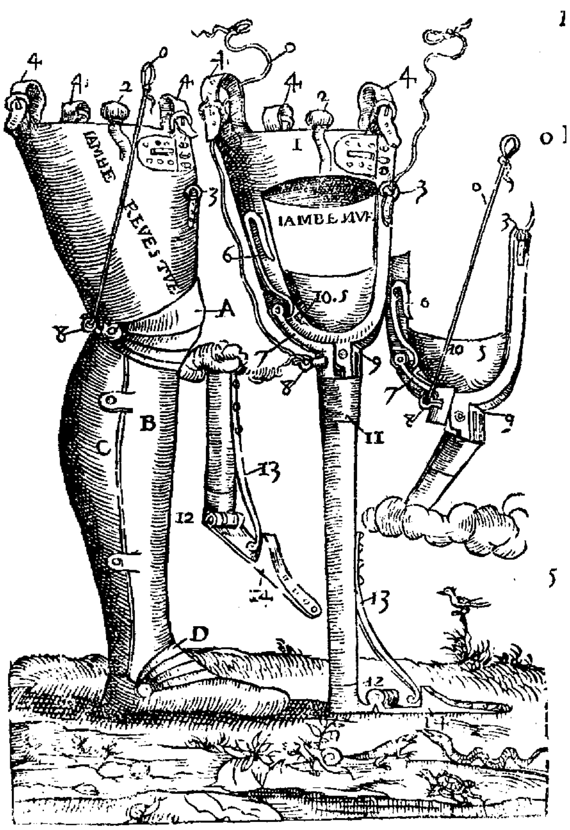
FIGURES 7 and 8. Joseph Faber's Euphonia. Circus World Museum, Baraboo, Wisconsin.

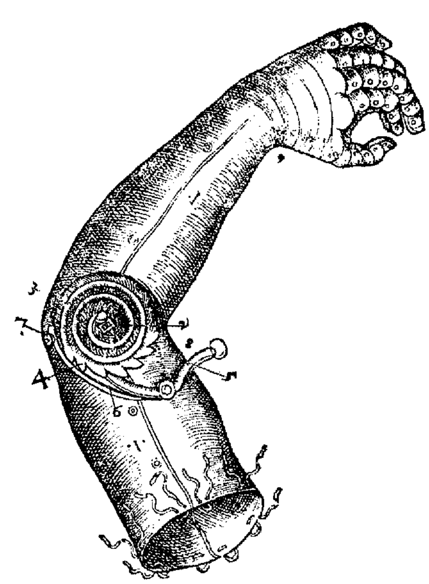
At that time, speaking, like defecation, seemed a quintessentially natural act, and this was what provided the interest of trying to simulate it. The next step was to reproduce the body itself, and in fact, prosthetic devices underwent a major transformation in this period. The change was largely in materials. Mechanical prostheses had originated in the sixteenth century as heavy, cumbersome, iron things with very limited movements. The hands designed by the French surgeon Ambroise Paré worked by springs and catches, and he also built a leg with a knee-lock that could be fixed in either the standing or sitting, equine position (figs. 9, 10, and 11).[34]

During the first decade of the eighteenth century, a mechanician to the French court named Sébastien designed two artificial hands for a Swedish military officer named Gunterfield who had lost both arms above the elbow. These hands had flexible fingers that Gunterfield could control using his stumps by means of a network of threads. The finished product enabled him to don and doff his hat. But the things were uncomfortable and awkward, and he decided he would rather do without.[35] In 1732, an inventor named Kriegseissen applied for and received the approval of the Paris Academy of Sciences for an arm and hand made of copper leaves (fig. 12). The contraption was designed for a below-the-elbow amputee. The amputee's upper arm fitted into the hollow upper portion of the artificial arm, and the movements of the wrist and hand were controlled by means of pullies fastened on either



FIGURES 9, 10, and 11. Ambroise Paré's prosthetic hand, leg, and arm, from *The Collected Works of Ambroise Paré* (New York, 1968), 881, 882.





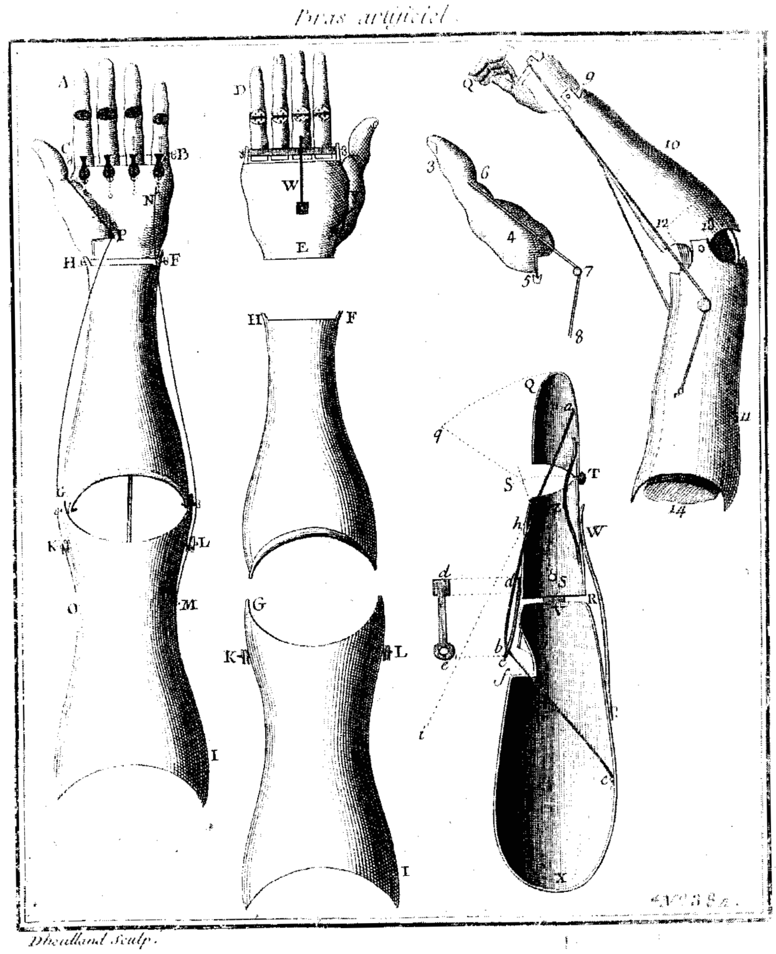
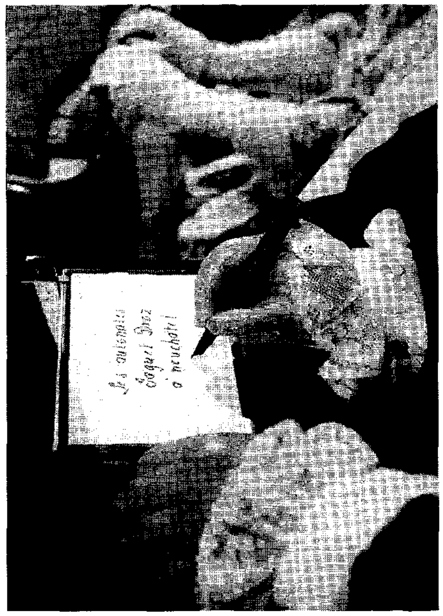


FIGURE 12. Kriegseissen's copper arm, from Gallon, *Machines et inventions approuvées par l'Académie des sciences*, 6:71–73. Courtesy of Department of Special Collections, Stanford University Libraries.

side of the elbow and cords of catgut passing through them to the thumb and fingers. By using his own elbow to bend the lower arm in toward the upper arm, the wearer tightened the two cords on either side, which curled the whole hand inward into a fist. Springs on each joint of each finger and the back of the thumb restored them to their straight positions.[36] Next, around 1760 a mechanician named Laurent received a knightship for improving upon Kriegseissen's design so that it could be used by an above-the-elbow amputee. The beneficiary of this improved copper arm was reportedly able to write "very legibly" with it.[37]

The major innovations in the field of articulated prosthetic limbs came in the

FIGURE 13. The hands of the Jaquet-Droz family's Draughtsman. All photos this page from the author's own photographs.
FIGURE 14. The hands of the Jaquet-Droz family's Lady-musician.
FIGURE 15. The hands of the Jaquet-Droz family's Writer.



1780s and '90s, at the hands of the Jaquet-Droz family, the automaton designers. After the success of their automata, they were asked by a tax farmer named La Reynière to design two artificial hands for his son, who had lost his own in a hunting accident. The result was a pair of prostheses made from the same materials that the Jaquet-Droz family had used in their automata: leather, cork, parchment, and papier-mâché on a steel frame (figs. 13, 14, and 15). They were very light, about 480 grams, and reportedly very versatile. The Jaquet-Droz operation continued to design prosthetic hands and arms of this sort through the 1790s.[38]

In the same period, anatomical models for teaching underwent the same transformation as prosthetic devices. They became less like models and more like simulations, reproducing their organic subjects in texture and substance. For example, the king's midwife, Mme. du Coudray, whose life story is told in a recent biography by Nina Gelbart, designed a "birthing machine" to use in teaching midwifery (fig. 16).[39] This machine, of which du Coudray produced many copies to send to midwives and surgeons all over France, had skin and soft organs made from flesh-colored linen and leather, some dyed redder and some paler, and stuffed with padding. The earlier models were built on pelvic bones taken from real skeletons; many of the later ones used wood and wicker. As a "supplement" to the machine, one could buy "liquids," an opaque red fluid and a clear one, along with a set of sponges. The sponges, saturated with the fluids, were to be planted inside the birthing machine by the demonstrator and made to release their fluids at the appropriate moments.[40]

The birthing machine, like the Jaquet-Droz artificial limbs with leather skin, the talking heads with tongues and glottises, and the automata that breathed and defecated, all reflected the assumption that an artificial model of a living creature should be soft, flexible, sometimes also wet and messy, and in these ways should resemble its organic subject. This was the flip side of a materialist-mechanist understanding of life. If living creatures were simply the matter and moving parts they were made of, then artificial creatures could potentially be very much like them.[41]

The "wetware" approach to artificial life was exemplified, finally, in the work of designers of so-called moving anatomies, mechanical models of physiological processes. The phrase "moving anatomy" was Vaucanson's. He used it to refer to his initial project (before the Duck and the Flute-player), which he described as a machine containing "several automata, and in which the natural functions of several animals are imitated by the movement of fire, air, and water." Very little is known about this first machine except that Vaucanson took it on a successful tour of France.[42] Later he returned to his moving anatomy project, and in 1741 he presented to the Académie de Lyon his plan

> to create an automatic figure whose motions will be an imitation of all animal operations, such as the circulation of the blood, respiration, digestion, the movement of muscles, tendons, nerves and so forth. . . . [B]y using this automaton we shall be able to carry out experiments on animal functions, and . . . draw conclusions from them which will allow us to recognize the different states of human health.[43]

This machine seems never to have been finished. But more than twenty years later, still in pursuit of his "moving anatomy," now in the more modest form of a hydraulic model of the circulatory system alone, Vaucanson applied to Louis XV for support. The king approved Vaucanson's request to have the machine built in Guyana, where he proposed to use "elastic gum" to make the veins. These veins would have been the first flexible rubber tubes.[44] Again the project lapsed, but its conception is another example of the new interest in using lifelike materials to imitate animal

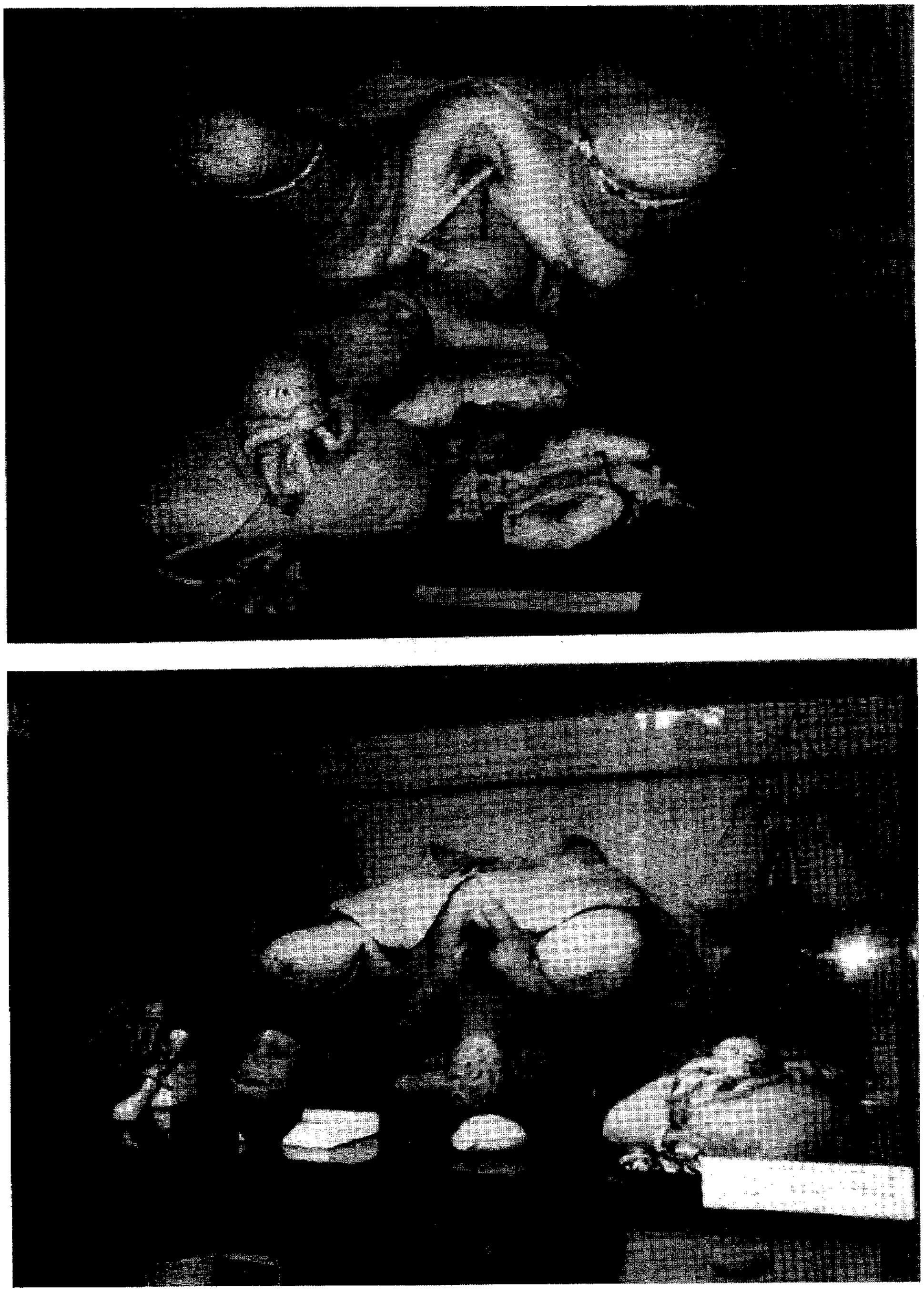


FIGURE 16. Mme. du Coudray's birthing machine, from Nina Rattner Gelbart, *The King's Midwife: A History of Madame du Coudray* (Berkeley, 1998), 62.

and human parts. The difference between a model of the circulatory system with metal tubes and one with rubber veins, like the difference between an artificial arm made of iron and one made of cork and leather, was not just the materials but the concept, the idea that a machine could—and should—have a lifelike texture. Vaucanson's anatomical and physiological projects were also all conceived as wet machines: they centrally involved fluids acting either chemically or hydraulically.

Along with being soft, moist, and malleable, the substances from which moving anatomies were made were also lifelike in that they seemed to act purposefully. Fluids and airs tended to maintain a balance, to fill a vacuum, to equalize pressures. These active and purposeful tendencies seemed to designers of moving anatomies to be crucial to the operation of animal machinery, and they were crucial also to the way in which they understood their artificial machines. An example is the moving anatomy designed by the French surgeon François Quesnay. Like many of his contemporaries, he believed that the source of motion in animal bodies was a fluid principle so volatile that "a mere nothing excites and puts [it] into action." This fluid, sometimes called "animal spirits" or the "vital principle," was "distributed by means of the threads of the nerves" all throughout the animal. As to its mode of action, it "extraordinarily confused Physicists," because it could only be comprehended by "recourse to active Elements"—that is, by its own property of activeness.[45] Quesnay also appealed to the active properties of ordinary fluids, in particular their striking tendency to seek an equilibrium. He emphasized that bleeding did not diminish the amount of blood in a given vessel, because when a surgeon depleted the blood in one of a patient's blood vessels, an equal amount of blood came from branching vessels to replace it, and he persuaded himself of the truth of this purposeful activity of blood and other fluids by building a mechanical model of the circulatory system.[46]

A competitor of Quesnay's, a fellow surgeon named Claude-Nicolas Le Cat, also designed moving anatomies. In 1739, he published a description (now lost) of an "automaton man in which one sees executed the principal functions of the animal economy," circulation, respiration, and "the secretions."[47] His idea, like Vaucanson's and Quesnay's, was that one could experiment on this automaton to test the effects of therapies. It is not clear what became of this early project, but Le Cat returned to the idea in 1744 when, according to the proceedings of the Academy of Rouen, he read a memoir there making the same proposal, to build "an artificial man or automaton, in which he hopes to show all the operations of a living man, the circulation of blood, the movement of the heart, the play of the lungs, the swallowing of food, its digestion, the evacuations, the filling of the blood vessels and their depletion by bleeding, even"—and here Le Cat exhibited that peculiarity of contemporary materialist-mechanist philosophy, the treatment of language as a bodily function—"speech and the articulation of words."[48]

A great crowd was assembled to hear the memoir, and one witness described the scene as follows: "Monsieur Le Cat told us of a plan for an artificial man. . . . His automaton will have respiration, circulation, quasi-digestion, secretion and chyle, heart, lungs, liver and bladder, and God forgive us, all that follows from it. Let him have a fever, we will bleed him, we will purge him and he will but too much resemble a man."[49] Now, to say that one could build a machine man capable not only of respiration and digestion but of speaking, of having a fever, of being treated and cured of illness held implications not only for what human beings were like, but also for what machinery was like. What sort of machinery did Le Cat have in mind? Like Quesnay, Le Cat gave the primary role in animal machinery to its liquid components, also dividing the liquids into two categories, the "liqueurs"—which were the tangible liquids such as blood, chyle, lymph, and bile—and the "fluids"—which were rarefied, intangible media that flowed through the nerves: the motor fluid; the sensitive fluid; and above all the animal or vital fluid. These motive fluids were the primary force in the "animal machine." They acted upon the solids, which acted, by means of their property of "organic spring," upon the liqueurs, which reacted in their turn to maintain a continual oscillation.[50] Central to Le Cat's model of animal machinery, as to Quesnay's, was his assumption of the active nature of organic matter and vital fluids.

Eighteenth-century wetware, then, made manifest, not a reduction of animals to machinery, but a convergence in people's understanding of animals and of machines. Not only did they begin to understand animals as machine-like, but they also, at the same time, began to understand machines as animal-like: soft, malleable, sometimes warm, with fluid parts that acted not only by constraint but by inner purpose.

These projects in artificial life represented one moment in an ongoing dialectical engagement between our understandings of life and of machinery, in which living creatures and machines have continually redefined each other, both by being identified with each other and by being opposed. Eighteenth-century wetware, like its present-day analogue, arose from an initial assumption of an unbreachable rift dividing cold, hard, dry, machinery, its inanimate parts moving only by constraint, from warm, soft, wet, living creatures, their organic parts driven by vital purpose. It was the articulation of certain differences between natural and artificial life that triggered the invention of machines that undermined those differences. But these machines in turn led people to rethink what constituted life, and to redefine natural life by contrast with artificial life, as when early-nineteenth-century philosophers and engineers turned away from speech simulation. And so people's assumptions about what is essential to life and what is within the purview of machinery have continually transformed each other.

Present-day builders of automata, when they encounter the work of their eighteenth-century predecessors, invariably ask why no one in that earlier period tried to simulate the action of the five senses. In their view, sensation is the single most obvious function to give an artificial creature. Their question is all the more intriguing when one considers that eighteenth-century materialist-mechanists such as La Mettrie subscribed to the sensationist doctrine that ideas were not innately implanted in the mind, but were created by the action of the senses and the nervous system and, therefore, could not be abstracted from body. The eighteenth-century conviction that life, consciousness, and thought were essentially embodied in animal and human machinery has striking parallels in current Artificial Intelligence (AI). A prominent school of AI, called Artificial Life, is founded in the principle that intelligence must be "physically grounded" and "embodied."[51] Rodney Brooks, director of the AI Lab at MIT, has left behind the purely software model of AI, and instead builds robots with sensors and feedback loops, giving them vision, hearing, and touch. The eighteenth-century materialist-mechanist insistence that the functions of mind were all carried out by the brain, as distinct from the soul, and Brooks's claim that the software of the mind cannot be abstracted from its hardware, come down to strikingly similar conceptions of the nature of thought. We have returned to a rigorously literal view of the sameness of living and artificial machinery. Brooks's writings about his robots, in their insistence that intelligence cannot be disembodied, have a distinctly eighteenth-century sound, and indeed, a recent book on Artificial Life identifies Vaucanson's Duck as the progenitor of the field.[52]

Why, then, did Brooks's eighteenth-century equivalents not try to simulate sensation? Perhaps the answer is that what we find blindingly obvious, endowing an automaton with the ability to sense, is not at all obvious but the product of the centuries-long interaction that I have been sketching, between our understandings of life and of machinery. This essay has examined a single phase of the engagement. In the subsequent phase, during the early nineteenth century, critics of eighteenth-century "wetware" drew new lines between living creatures and machines. They observed, for example, that no automaton had been truly self-moving and reaffirmed the Aristotelian principle that animal life was defined by the ability of living creatures to produce their own source of motion. Animals were self-moving and machines were not. Next, around the middle of the nineteenth century, Hermann von Helmholtz and others undermined the notion that living creatures produced their own power by establishing the concepts of energy and its conservation. Animals, like machines, simply converted energy into work. Life and machinery had been similar in their ability to move autonomously, then antithetical because of the reliance of machinery on external sources of motion, and were now similar again, because animals too consumed energy.

Nineteenth-century critics of eighteenth-century projects in artificial life also decided that animal life was defined by its ability to maintain a stable internal environment in response to the external conditions in which it found itself. It was chiefly Claude Bernard, the same who insisted that a "larynx is a larynx," who redefined living creatures in these terms.[53] Animals were responsive to their environments and machines were not. Or were they? The mid-twentieth-century mechanical tortoises designed by a Cambridge University neurologist and engineer named Grey

Walter had two sensors, one for light and the other for touch. They were designed to explore and respond to a simple environment consisting of lightbulbs and obstacles.[54] Moreover, when Walter and Norbert Weiner and others became interested in the possibility of designing artificial creatures that would be responsive to their environments, they traced responsive machinery—machines that employed what they now called feedback—back to the eighteenth century, in particular to James Watt's steam engine governor.[55] That is, they retrospectively designated as responsive machines whose designers had by no means understood them as such. It was only after machines were compared and then contrasted and then compared again with living beings that they came to seem capable of responding to their environments. By the same token, it was by being contrasted and then compared and then contrasted again with inanimate machinery that animal machinery came to seem defined by its responsiveness to the world around it.

In the long history of this dialectical engagement between our understandings of animals and of machines, I have suggested that the second half of the eighteenth century and the second half of the twentieth century represent similar moments in which people were preoccupied by the possibility of simulating life, whereas, during the intervening period they mostly renounced this project. After the first decades of the nineteenth century, and until about the middle of the twentieth, people became largely disenchanted with the close simulation of life.[56] Even when they drew analogies between animals and machines, such as the analogy between labor and mechanical work—and despite the growing presence of automation all around them—nineteenth-century scientists and engineers mostly rejected the possibility of mechanically simulating life processes. Helmholtz, for example, accused eighteenth-century mechanicians of hubris, alleging that they had considered "no problem beyond . . . [their] power."[57]

Such moral indictments of artificial life—depictions of the quest to synthesize a living creature as hubristic, and of the results as monstrous—were absent from eighteenth-century commentaries. These indictments were rather a development of the early nineteenth century, coeval with Mary Shelley's *Frankenstein* (1818). People began around the same time to debunk the frauds of eighteenth-century artificial life. In 1821, Robert Willis, the same who disparaged the practice of creating artificial speech by simulating the vocal organs, published a pamphlet denouncing the more famous, but fraudulent, automaton that Kempelen had designed, in addition to his talking head, the Chess-playing Turk.[58] Similarly, in 1858, the French magician and automaton-maker Jean-Eugène Robert-Houdin exposed the charlatanism at the heart—or really the stomach—of Vaucanson's Duck. He also commented sarcastically on a notice in the *Journal des savants* from a century and a half earlier that had described an automaton in which "with the exception of the operation of the soul, everything that takes place in the body may be witnessed." Robert-Houdin wrote, "What a pity the mechanician stopped so soon! For it would have cost him so little, while making so exquisite a resemblance to the fairest work of the Creator, to add to his automaton a soul moving by clockwork."[59] Robert-Houdin's own automata were not true automata, in that they all involved hidden levers or pedals attended by human operators (often his son). Not until Walter's mid-twentieth-century mechanical tortoises did the next period of intensive interest in physiological simulation begin.

Why did people mostly turn away from the close simulation of living processes in the early part of the nineteenth century? This turning away does seem, it is true, to be in keeping with certain contemporaneous developments, in particular a Romantic distaste for rational and mechanical systems and the development of vitalism in biology. On the other hand, this essay has shown, I hope, that the simulations of the later eighteenth century transformed the meaning of mechanist philosophy to accommodate such previously nonmechanical phenomena as emotions, desires, and vital fluids. Moreover, physiologists of the nineteenth century—like those of the seventeenth century—as well as physicists establishing the concepts of energy and its conservation drew frequent analogies between animals and machines, making their disenchantment with simulation seem all the more curious.

To understand this curious disenchantment we might return to the distinction I have been suggesting between drawing such analogies and using machinery to simulate animal life. These are two quite different endeavors, since an analogy rests upon an assumed difference between its two terms, while a simulation is an attempt to eradicate the difference. Thus we can make sense of the fact that, in the very same text in which he described his mechanical simulation of the circulatory system, Quesnay urged, "let us stop representing the human body as a hydraulic machine." The objectionable analogy belied the "active" nature of the animal machine, and the "organic action" of its "flexible" parts.[60] Seventeenth- and nineteenth-century physiologists drew analogies, but did not simulate; Quesnay simulated, but disapproved of mechanistic analogies.

Why were the seventeenth and nineteenth centuries periods of analogy, and the late eighteenth and late twentieth centuries periods of simulation? I have returned repeatedly to the double-edged nature of simulations: they represent transformations, not only of people's understanding of animals, but of their understanding of machines as well. Analogies, in contrast, tend to hold one side of the equation fixed and use it to say something about the other side: we know what machines are, and animals turn out to be a lot like them. Thus, when he objected to the analogy between the body and a hydraulic machine, Quesnay had in mind an older, more static notion of a machine as something rigid that moved purely by constraint. But simulations transform both sides: we are not entirely sure what animals are, or what machines can be, and we can find out about both by trying to build an animal-machine. With his moving anatomy, Quesnay did not merely mechanize the circulatory system. He also transformed machinery into something active, flexible, and organic.

It makes sense, in light of this tendency of simulations to transform both sides of the equation, that the second half of the eighteenth century and the second half of the twentieth century have both been periods of simulation. The beginnings of the Industrial Revolution and the beginnings of the Information Revolution were both periods of extreme fluidity in people's understandings of what machines were—and indeed in the nature of machines. Once the industrial period was fully under way, manmade machinery and its relations to living creatures stabilized, replacing the fluidity required by a simulation with two terms that were, for the moment, fixed: "life" and "mechanism." Only when the Information Revolution introduced a new kind of machinery did this fixity give way to a new fluidity, and the possibility of using machinery to simulate life again seemed intriguing.

In other words, the modern makers of automata that see, hear, and feel in fact have a great deal in common with the eighteenth-century makers of automata that breathed, spoke, and defecated. They too use machines to simulate life precisely because their conception of machines is no better established than their understanding of life.

Notes

This essay and another, "The Defecating Duck, Or, The Ambiguous Origins of Artificial Life," *Critical Inquiry* 29, no. 4 (Summer 2003): 599–633, are two pieces of a larger project on the history of artificial life and intelligence circa 1730–1950, hence the frequent references in each essay to the other.

1. Julien Offray de La Mettrie, *Man a Machine and Man a Plant*, trans. Richard A. Watson and Maya Rybalka (Indianapolis, 1994), 71–72 (first published as *L'Homme-machine* in 1747).
2. Rudy Rucker, *Wetware* (New York, 1988), 66.
3. "Biomimetic" means in imitation of biological systems, and "chemomechanical" means that chemical energy is converted directly into mechanical work, as is the case in living creatures. The terms, along with "wetware" and "soft machines," are to be found in Yoshihito Osada and Simon B. Ross-Murphy, "Intelligent Gels," *Scientific American*, May 1993, 82–87.
4. Riskin, "Defecating Duck."
5. I am grateful to Evelyn Fox Keller for pointing out the difference between eighteenth- and twentieth-century meanings of "simulation" and for pressing me to clarify my use of the term. For arguments that eighteenth-century machines were simulative in the modern sense, see André Doyon and Lucien Liaigre, "Méthodologie comparée du biomécanisme et de la mécanique comparée," *Dialectica* 10 (1956): 292–335; Georges Canguilhem, "The Role of Analogies and Models in Biological Discovery," in A. C. Crombie, ed., *Scientific Change: Historical Studies in the Intellectual, Social, and Technical Conditions for Scientific Discovery and Technical Invention, from Antiquity to the Present* (New York, 1961), 507–20, esp. 510–12; Derek de Solla Price, "Automata and the Origins of Mechanism and Mechanistic Philosophy," in *Technology and Culture* 5, no. 1 (Winter 1964): 9–23; David M. Fryer and John C. Marshall, "The Motives of Jacques Vaucanson," in *Technology and Culture* 20, no. 1 (January 1979): 257–69.

6. Gaby Wood, *Living Dolls: A Magical History of the Quest for Mechanical Life* (London, 2002), xvi, 59, xiv (the American edition was issued under the title *Edison's Eve*). Similarly, Tom Standage, in his recent account of the Turk, emphasizes how "little has changed" since its performances; Tom Standage; *The Turk: The Life and Times of the Famous Eighteenth-Century Chess-Playing Machine* (New York, 2002), 246.
7. La Mettrie, *Man a Machine*, 63–64.
8. "Diverses machines inventées par M. Maillard. Cygne artificiel," in M. Gallon, ed., *Machines et inventions approuvées par l'Académie royale des sciences depuis son établissement jusqu'à present; avec leur Déscription*, 7 vols. (Paris, 1735–77), 1:133–35. On Maillard's Swan and the contrast between seventeenth- and eighteenth-century automata, see also Riskin, "Defecating Duck."
9. Georges Canguilhem has observed that the "Cartesian animal-machine remained as a manifesto, a philosophical war-machine, so to speak" in contrast with eighteenth-century physiologists' and mechanicians' "elaboration of detailed plans with a view to the construction of simulators"; Georges Canguilhem, "Analogies and Models in Biological Discovery," in Crombie, *Scientific Change*, 510–11. On the importance of automata as "models of intelligibility" in Descartes's philosophy, see Peter Dear, "A Mechanical Microcosm: Bodily Passions, Good Manners, and Cartesian Mechanism," in Christopher Lawrence and Stephen Shapin, eds., *Science Incarnate: Historical Embodiments of Natural Knowledge* (Chicago, 1998), 51–82 (here 59). I have found one possible exception to the general rule that seventeenth-century automata were not simulative, a "statue" designed by a Württemburg physician named Reyselius. According to reports, this artificial man demonstrated circulation, digestion, and respiration with great "resemblance to man in all the internal parts"; *Journal des savants* (1677): 352. Unless otherwise noted, all translations are my own. On the artificial man of Reyselius, see also Thomas L. Hankins and Robert J. Silverman, *Instruments and the Imagination* (Princeton, 1995), 182; and André Doyon and Lucien Liaigre, *Vaucanson, mécanicien de genie* (Paris, 1966), 117–18, 162–63. Going back still earlier, one might well take Leonardo da Vinci's uses of cords and wires to model the muscles as simulations; see Paolo Galluzzi, "Leonardo da Vinci: From the 'Elementi Macchinali' to the Man-Machine," in *History and Technology* 4 (1987): 235–65. I am grateful to Michael John Gorman for pressing me to consider the simulative aspects of sixteenth- and seventeenth-century automata and models, and for pointing me to Dear's and Galluzzi's articles. There does seem to me to be an important difference between a model or illustration, which is meant to depict its natural subject, and a simulation, which is meant to reproduce it. Whereas a model assumes a gap between itself and its subject, a simulation tries to collapse the gap.
10. Christian Bailly, Sharon Bailly, and Eric Desmarest, *Automates* (Paris, 1993), 20, 26; Henri Nicolle, *Les jouets—ce qu'il y a dedans* (Paris, 1868).
11. Anson Rabinbach has studied the cultural importance of such analogies in his book *The Human Motor: Energy, Fatigue, and the Origins of Modernity* (Berkeley, 1990).
12. Pierre Jaquet-Droz built clocks, watches, and automata together with his son Henri-Louis and his adopted son, Jean-Frédéric Leschot. On the Jaquet-Droz family, see Charles Perregaux and F.-Louis Perrot, *Les Jaquet-Droz et Leschot* (Neuchâtel, 1916); Alfred Chapuis and Edmond Droz, *The Jaquet-Droz Mechanical Puppets* (Neuchâtel, 1956); and F. M. Ricci, *Androïdes, les automates des Jaquet-Droz* (Lausanne, 1979).
13. Perregaux and Perrot, *Les Jaquet-Droz et Leschot*, 31–34.
14. See Richard Altick, *The Shows of London* (Cambridge, 1978); Simon Schaffer, "Enlightened Automata," in William Clark, Jan Golinski, and Simon Schaffer, eds., *The Sciences in Enlightened Europe* (Chicago, 1999), 126–65, here 138; and Alfred Chapuis and Edmond Droz, *Automata: A Historical and Technological Study* (Neuchâtel, 1958), 280–82.

15. Jacques Vaucanson, *Le mécanisme du fluteur automate* (Paris, 1738).
16. "Lettre de M. Vaucanson, à M. l'abbé D.F.," in Vaucanson, *Le Mécanisme du fluteur automate*, 19–22. On the close simulation of bodily and intelligent processes in the Jaquet-Droz Lady-musician and in Vaucanson's automata, see Riskin, "Defecating Duck."
17. Jean-Eugène Robert-Houdin exposed Vaucanson's fraud (see my discussion later in the text); Jean-Eugène Robert-Houdin, *Memoirs of Robert-Houdin*, trans. Lascelles Wraxall (New York, 1964), 103–7 (first published in French as *Confidences d'un prestidigitateur* [Blois, 1858]). See also Doyon and Liaigre, *Vaucanson*, 124–27.
18. Jonathan Swift, "The Lady's Dressing Room" (1730), in Robert A. Greenberg and William B. Piper, eds., *The Writings of Jonathan Swift* (New York, 1973), 537–38.
19. John Wilkins, *Mathematicall Magick. Or, The Wonders that may be performed by Mechanicall Geometry* (London, 1648), 177–78. See Hankins and Silverman, *Instruments and the Imagination*, 181.
20. Denys Dodart, "Sur les causes de la voix de l'homme et de ses différents tons," 13 November 1700, in *Histoire de l'Académie royale des sciences*, Année 1700, *Mémoires*, 244–93; Dodart, "Supplément au Mémoire sur la voix et sur les tons," 14 April 1706, and "Suite de la première partie du Supplément," in *Histoire de l'Académie royale des sciences*, Année 1706, *Mémoires*, 136–48, 388–410; and Dodart, "Supplément au Mémoire sur la voix et les tons," 16 March 1707, in *Histoire de l'Académie royale des sciences*, Année 1707, *Mémoires*, 66–81. For Fontenelle's commentary on Dodart's memoirs, see Bernard le Bouyer de Fontenelle, "Sur la formation de la voix," in *Histoire de l'Académie royale des sciences*, Année 1700, 17–24; Année 1706, 136–48; Année 1707, 18–20. See also Jean-Pierre Séris, *Langages et machines à l'age classique* (Paris, 1995), 231–35.
21. Fontenelle, "Sur la formation de la voix," 20.
22. Abbé Desfontaines, "Lettre CLXXX sur le Flûteur et l'Aristippe Moderne," in *Observations sur les écrits modernes* XII (1738), 341; reproduced in Doyon and Liaigre, *Vaucanson*, 162.
23. Antoine Court de Gébelin, *Le Monde primitif, analysé et comparé avec le Monde moderne* (Paris, 1775), 2:83–84. See Séris, *Langages et machines*, 239.
24. Erasmus Darwin, *The Temple of Nature; or, The Origin of Society* (London, 1803), 119–20. See Hankins and Silverman, *Instruments and the Imagination*, 199.
25. *Têtes parlantes inventées et exécutées par M. l'abbé Mical. (Extrait d'un ouvrage qui a pour titre: Système de prononciation figurée, applicable à toutes les langues et exécuté sur les langues française et anglaise)*, VZ-1853, Bibliothèque nationale, Paris; *Procès verbaux*, 3 Septembre 1783, Archives de l'Académie des Sciences, Paris; Antoine Rivarol, "Lettre à M. le president de ***, sur le globe aerostatique, sur les têtes parlantes et sur l'état present de l'opinion publique à Paris," in *Oeuvres completes de Rivarol* (Paris, 1808), 2:207. See Séris, *Langages et machines*, 245; André Chapuis and Edouard Gélis, *Le Monde des automates* (Paris, 1928), 2:204–6.
26. Wolfgang von Kempelen, *Le Mécanisme de la parole, suivi de la déscription d'une machine parlante* (Vienna, 1791), 413–14. I discuss Kempelen's speaking machine at greater length in Riskin, "Defecating Duck." See also Hankins and Silverman, *Instruments and the Imagination*, 190–97; and Séris, *Langages et machines*, 245–46. In 1779, probably at the instigation of Leonhard Euler, the St. Petersburg Academy of Sciences sponsored a prize competition to determine the nature of the vowels and to construct an instrument like *vox humana* organ pipes to express them. C. G. Kratzenstein, a member of the Academy, won the prize. He used an artificial glottis (a reed) and organ pipes shaped according to the situation of the tongue, lips, and mouth in the pronunciation of the vowels; Hankins and Silverman, *Instruments and the Imagination*, 188–89; Séris, *Langages et machines*, 247. Hankins and Silverman write that "Wilkins, Mical, Kempelen, Dar-

win, and several of Vaucanson's contemporaries shared a consistent approach to the imitation of the voice. All of them defined vowels and other speech sounds in terms of the configurations of the human organs of speech"; Hankins and Silverman, *Instruments and the Imagination*, 198. This seems to me to be true of Mical, Kempelen, and Darwin but not of Wilkins; see discussion earlier in the text.

27. On Wheatstone's and Bell's reproductions, see J. L. Flanagan, "Voices of Men and Machines," in *Journal of the Acoustical Society of America* 51 (1972): 1375–87; James L. Flanagan, *Speech Analysis, Synthesis, and Perception* (Berlin, 1965), 166–71; M. R. Schroeder, "A Brief History of Synthetic Speech," in *Speech Communication* 13 (1993): 231–37; and Hankins and Silverman, *Instruments and the Imagination*, 218–19. Hankins and Silverman write that many "artificial glottises, similar in design to those that seem to have activated Mical's heads, were made in the nineteenth century," but the physiologists who made these (Johannes Müller, Édouard Fournié) "did *not* aim to copy articulate speech, but simply to disclose the operation of the larynx"; Hankins and Silverman, *Instruments and the Imagination*, 199. "Nineteenth-century physicists who studied the voice were generally much less interested in reproducing articulate speech than their eighteenth-century counterparts had been" (209). The following are some exceptions: Richard Potter, in the 1870s, "imitated vowels with an apparatus that would have seemed familiar to the eighteenth-century investigators mentioned above: a free reed connected to a hollow india rubber sphere that could be deformed to copy the shape of the mouth and produce a variety of vowels." R. J. Lloyd, a Liverpool phonetician, wrote in 1890 that the best apparatus for studying speech would have some resemblance to the vocal organs, but not too close a resemblance, and used glass bottles. "One of Lloyd's methodological descendants, Sir Richard Paget, contrived plasticine models of the vocal tract in his study of imitation vowel sounds during the 1920s" (210). "Copying the manifest appearance of the organs of speech was the ultimate end of the French physiologist Georges René Marie Marage, who worked in the late nineteenth and early twentieth centuries. . . . Marage's resonant cavities exactly copied the shape of the oral cavity. In fact, they were cast from molds of the mouth, complete with lips and teeth" (210–11). "In 1905, E. W. Scripture discussed another attempt based on the model of the vocal anatomy—one that did not even bother to make a copy of the human form. His 'vowel organ' involved fitting a human skull with artificial cheeks and lips to re-create a resonance chamber. Rubber glottises imitated the larynx" (211–12). "The first patent for a talking doll was awarded to J. M. Maelzel, the inventor of the metronome, in 1824. It consisted of a bellows, reed and cup-shaped resonator" (213).

28. Hermann von Helmholtz, for example, built a machine using tuning forks and resonance chambers to produce the vowel sounds, described in Helmholtz, *On the Sensations of Tone as a Physiological Basis for the Theory of Music*, trans. A. J. Ellis (New York, 1954), 399. On Helmholtz's speech synthesizer, see Flanagan, *Speech Analysis, Synthesis, and Perception*, 172–74; Timothy Lenoir, "Helmholtz and the Materialities of Communication," in *Osiris*, 2d ser., 9 (1993), 185–207; Schroeder, "A Brief History of Synthetic Speech," 232–33; and Hankins and Silverman, *Instruments and the Imagination*, 203–5.

29. Robert Willis, "On the Vowel Sounds, and on Reed Organ-Pipes," read 24 November 1828 and 16 March 1829, published in the *Transactions of the Cambridge Philosophical Society* 3 (1830): 231–68. See Hankins and Silverman, *Instruments and the Imagination*, 201.

30. Claude Bernard, *Cahiers des notes*, M. D. Grmek, ed. (Paris, 1965), 171. See Séris, *Langages et machines*, 248.

31. David Lindsay, "Talking Head," *Invention and Technology* (Summer 1997): 56–63; Hankins and Silverman, *Instruments and the Imagination*, 214–16.
32. Cf. Hankins and Silverman, *Instruments and the Imagination*, 216, where the authors identify a partial return to "more humanoid apparatus" in "the last years of the nineteenth century." Investigators such as Lloyd, Marage, Scripture, and Paget "approached the problem from a physiological and phonetic point of view. If Faber had demonstrated his machine either fifty years earlier (in Kempelen's time) or fifty years later than its introduction in the 1840's, the Euphonia might have been greeted by an enthusiastic audience" (216). It seems to me, however, that despite Lloyd, Marage, Scripture, and Paget, the simulative approach to artificial speech never regained the dominance it had had during the late eighteenth century.
33. On the early history of electrical speech synthesis, see Flanagan, *Speech Analysis, Synthesis, and Perception*, 171–72; Flanagan, "Voices of Men and Machines," 1381–83; Dennis H. Klatt, "Review of Text-to-Speech Conversion for English," *Journal of the Acoustical Society of America* 82, no. 3 (Summer 1987): 741–42; Schroeder, "A Brief History of Synthetic Speech."
34. Ambroise Paré, "Of the Meanes and Manner to Repaire or Supply the Naturall or accidentall defects or wants in mans body," in *The Collected Works of Ambroise Paré*, trans. Thomas Johnson (New York, 1968). Paré also presents designs for prostheses to replace missing eyes, ears, noses, teeth, tongues, and penises. These, like his prosthetic limbs, are as remarkable for their unlikeness as for their likeness to the parts they replace. They fulfill either an aesthetic purpose (in the case of the eyes, ears, and noses) or a functional one (the tongues and penises) but not both (except perhaps in the case of the teeth).
35. Fontenelle, "Éloge du père Sébastien Truchet Carme," in *Éloge des académiciens* (La Haye, 1740), 2:366–67.
36. Gallon, *Machines et inventions approuvées par l'Académie des sciences*, 6:71–73.
37. Jacques Delille, *Épitre à M. Laurent, . . . à l'occasion d'un bras artificiel qu'il a fait pour un soldat invalide*, 2d ed. (London, 1761). See Reed Benhamou, "From *Curiosité* to *Utilité*: The Automaton in Eighteenth-Century France," *Studies in Eighteenth-Century Culture* 17 (1987): 91–105, here 100.
38. In 1786, a cousin and perhaps collaborator of the Jaquet-Droz family, the Director of the French Mint in Paris, a man named Jean-Pierre Droz, designed an artificial hand to improve the safety of workers at the mint, who, because they had to slide metal strips under the balance arm of the machine that stamped them, frequently had bad accidents. Droz's artificial hand was intended to take on this dangerous task. See Perregaux and Perrot, *Les Jaquet-Droz et Leschot*, 31–36, 89–91, 100–111, 140; Linda Marlene Strauss, "Automata: A Study in the Interface of Science, Technology, and Popular Culture, 1730–1855" (Ph.D diss., University of California, San Diego, 1987), 109.
39. Nina Rattner Gelbart, *The King's Midwife: A History and Mystery of Madame du Coudray* (Berkeley, 1998).
40. Ibid., 60, 116, 207.
41. The eerily accurate wax models that anatomists began to use during the late seventeenth and early eighteenth centuries—such as those of the Italian naturalist and physiologist Felice Fontana—provide an interesting comparison. They are uncanny in their visual resemblance to their natural subjects, but make no attempt to simulate texture or substance, and therefore seem to me to belong more in the older tradition of illustration than the newer one of simulation. Nevertheless, they evoke actual flesh to such a degree that their relation to projects in mechanical simulation seems well worth investi-

gating. On eighteenth-century wax anatomical models, see F. Gonzalez-Crussi and Rosamond Wolff Purcell, *Suspended Animation* (San Diego, 1995); and Thomas Schnalke, *Diseases in Wax: The History of the Medical Moulage* (Berlin, 1995). I am grateful to Paula Findlen for pointing out the relevance of wax anatomical models to the emergence of artificial life in the eighteenth century.

42. The machine is described as an "anatomie mouvante" in Commision extraordinaires du Conseil, Plumitif no. 10, *Archives nationales* V7 582, cited in Doyon and Liaigre, *Vaucanson*, 110; see also 18, 34. The second description is from Acte de société Colvée-Vaucanson du 26-1-1734, *Archives nationales*, Minutier Central, Notaire CXVIII, cited in Doyon and Liaigre, *Vaucanson*, 18.
43. *Registre contenant le Journal des Conférences de l'Académie de Lyon*, quoted in Doyon and Liaigre, *Vaucanson*, 148; and in translation in Jean-Claude Beaune, "The Classical Age of Automata," in *Fragments for a History of the Human Body*, ed. Michel Feher, Ramona Naddaff, and Nadia Tazi (New York, 1989), 1:430–80, here 457. See also Doyon and Liaigre, "Méthodologie comparée," 298.
44. On the plans for a model of the circulatory system, see Marie Jean Antoine Nicolas de Caritat, marquis de Condorcet, "Eloge de Vaucanson" (1782), in A. Condorcet O'Connor and M. F. Arago, eds., *Oeuvres de Condorcet* (Paris, 1847), 2:655; Éliane Maingot, *Les Automates* (Paris, 1959), 18; Doyon and Liaigre, *Vaucanson*, 152–61; Strauss, *Automata*, 71–72.
45. François Quesnay, *Essai phisique sur l'oeconomie animale* (Paris, 1736), 219–23.
46. François Quesnay, *Observations sur les effets de la saignée* (Paris, 1730), iv–vi. See also François Quesnay, *L'Art de guerir par la saignée* (Paris, 1736), and François Quesnay, *Traité des effets et de l'Usage de la saignée* (Paris, 1750). The *Traité* is a later version of the *Observations* and of *L'Art de guérir* (1736). See Doyon and Liaigre, "Méthodologie comparée," 297.
47. This description appeared in conjunction with Le Cat's *Traité de la saignée* (1739) as its "experimental part." The machine was invented "to confirm by experience [Le Cat's] theory of Bleeding"; "Précis sur la Vie de Mr. Le Cat" (1768), cited in Doyon and Liaigre, "Méthodologie comparée," 298–99. See also Denis Ballière de Laisement, *Eloge de Monsieur Le Cat* (Rouen, 1769), 53. See Doyon and Liaigre, "Méthodologie comparée," 299.
48. *Registre-Journal des Assemblées et Délibérations de l'Académie des sciences* . . . établie en 1744: 3 (manuscrit *non classé* de la Bibliothèque publique de Rouen), cited in Doyon and Liaigre, "Méthodologie comparée," 300.
49. Le Cornier de Cideville to Fontenelle, 15 December 1744, in Abbé Tougard, *Documents concernant l'histoire littéraire du XVIIIe siècle* (Rouen, 1912), 1:52–54, here 53. See Doyon and Liaigre, "Méthodologie comparée," 300.
50. Claude Nicolas Le Cat, *Traité des sensations et des passions en general, et des sens en particulier* (Paris, 1767), 1:xi, xix–xxv, xxix–xxxi, 40–50, 60–61.
51. Rodney A. Brooks, "Elephants Don't Play Chess," *Robotics and Autonomous Systems* 6 (1990): 3–15; "Intelligence Without Reason," MIT AI Lab Memo 1293, April 1991; "Intelligence Without Representation," *Artificial Intelligence Journal* 47 (1991): 139–59; and Rodney A. Brooks et al., "Alternate Essences of Intelligence," in *Proceedings of the Fifteenth National Conference in Artificial Intelligence*, American Association for Artificial Intelligence, Madison, Wisconsin, 1998, 961–76. For another example of the importance of embodiment to current AI researchers' conception of fundamental human capabilities such as conversation, see Justine Cassell, "Embodied Conversational Agents: Representation and Intelligence in User Interface," *AI Magazine* 22, no. 3 (Winter 2001): 67–83; and J. Cassell et al., "More Than Just a Pretty Face: Conversational

Protocols and the Affordances of Embodiment," *Knowledge-Based Systems* 14 (2001): 55–64.

52. Steven Levy, *Artificial Life* (New York, 1992), 19–20.
53. Claude Bernard, *Leçons sur les phénomènes de la vie*, 2d ed. (Paris, 1885), 1:112–24. T. H. Huxley wrote, similarly, that "the living body is not only sustained and reproduced: it adjusts itself to external and internal changes"; T. H. Huxley, "On the Hypothesis That Animals Are Automata, and Its History" (1874), in *Collected Essays* (New York, 1894–98), 2:200.
54. W. Grey Walter, "An Imitation of Life," *Scientific American*, May 1950, 42–63; William Grey Walter, *The Living Brain* (New York, 1953), chaps. 5 and 7. See also Owen Holland, "Grey Walter: The Pioneer of Real Artificial Life," in Christopher G. Langton and Katsunori Shimohara, eds., *Artificial Life V* (Cambridge, Mass., 1997), 34–41.
55. Norbert Weiner, *Cybernetics, or Control and Communication in the Animal and the Machine* (Cambridge, Mass., 1948), 11–12; Otto Mayr, *The Origins of Feedback Control* (Cambridge, Mass., 1970).
56. An exception is the French physiologist Etienne-Jules Marey, who is best known for his photographic study of animal motion during the 1880s and '90s. A couple of decades earlier, Marey built artificial insects and birds to study the "mechanical conditions" of flight; Etienne-Jules Marey, "Mécanisme du vol chez les insectes," *Revue des cours scientifiques de la France et de l'étranger* no. 16 (20 March 1869): 253–56; Victor Tatin, "Expériences sur le vol mécanique," in Etienne-Jules Marey, *Physiologie expérimentale. Travaux du laboratoire de M. Marey* (Paris, 1876–80), 2:86–108. Marey also describes using artificial bird and insect wings in his *Animal Mechanism* (New York, 1873). On Marey's artificial insect, see also Michel Frizot, ed., *E.J. Marey. 1830/1904 La Photographie du Mouvement* (Paris, 1977), 96–98. Further, Marey built an artificial heart to study the circulation of the blood, described in Etienne-Jules Marey, *La Circulation du sang à l'état physiologique et dans les maladies* (Paris, 1881). On Marey's completion of Vaucanson's project, see Hankins and Silverman, *Instruments and the Imagination*, 185–86. Finally, on Marey's study of the mechanics of the body in general, see Rabinbach, *The Human Motor*, chap. 4. Marey's move from mechanical simulation to photography during the 1880s suggests that his central interest was in using machinery to analyze natural life rather than to produce artificial life.
57. Hermann von Helmholtz, "On the Interaction of Natural Forces" (1854), in *Popular Lectures on Scientific Subjects*, trans. E. Atkinson (New York, 1873), 155.
58. Robert Willis, *An Attempt to Analyse the Automaton Chess Player, of Mr. de Kempelen* (London, 1821).
59. Robert-Houdin, *Memoirs*, 103–7. Robert-Houdin referred to the artificial man of Reyselius. See note 9.
60. Quesnay, *Traité des effets de la saignée*, 17–18.