investigates three related aspects of the information age: the story of how information lost its body, the development of the cultural icon of the cyborg, and the emergence of posthuman identities. In *Writing Machines* (2002), whose page layouts sometimes resemble computer screens and abstract information patterns, Hayles playfully and creatively illustrates her notion of "flickering signifiers." Focusing on the complex ways in which various forms of media interpenetrate, she insists on the materiality of different kinds of literary artifacts such as hyperfiction, the artist's book, and the traditional novel. *My Mother Was a Computer: Digital Subjects and Literary Texts* (2005) offers new ways of understanding the relationships between language and code. It investigates processes of intermediation through which traditional cultural practices interact with digital media. More recently, Hayles's *Electronic Literature: New Horizons for the Literary* (2008) provides a systematic survey of the field of electronic literature, isolating major genres and central theoretical issues pertaining to networked and programmable media. It is accompanied by a CD featuring volume 1 of the *Electronic Literature Collection*, co-edited by Hayles with Nick Montfort, Scott Rettberg, and Stephanie Strickland; the collection of sixty works is intended for courses on contemporary electronic literature. In addition to her own books, Hayles has edited the essay collection *Chaos and Order: Complex Dynamics in Literature and Science* (1991); guest edited *Technocriticism and Hypernarrative* (1997), a special issue of *Modern Fiction Studies* (43.3); and edited *Nanoculture: Implications of the New Technoscience* (2004). She has also published numerous articles in books and journals on literature, computer culture, cyborg theory, and the history of technology.

Notable assessments of Hayles's work have come from literary critics concentrating on science fiction and on feminist theory. Istvan Csicsery-Ronay Jr.'s "Till We Have Interfaces," *Science Fiction Studies*, no. 78 (1999), offers a pointed review of *How We Became Posthuman*. While praising Hayles as a sharp diagnostician of the social and cultural implications of information technologies, Csicsery-Ronay observes that her theory of the posthuman ends in anxiety and uncertainty, failing to indicate what comes after the demise of the liberal humanist subject. In "Theory of a Different Order: A Conversation with Katherine Hayles and Niklas Luhmann," in *Observing Complexity: Systems Theory and Postmodernity* (ed. William Rasch and Cary Wolfe, 2000), Cary Wolfe, William Rasch, and Eva Knodt specify potential shortcomings of Hayles's work. Though commending her theory for usefully avoiding the impasse of relativism, they note that it occasionally resorts to a representationalist understanding of "objective" reality that threatens to undercut the very project of cybernetics. In her review of *How We Became Posthuman* in *Signs* 27 (2002), Amelia Jones acknowledges the literary and cultural significance of Hayles's theory even as she points out its limitations from a feminist perspective. According to Jones, Hayles's insistence on material embodiment potentially undermines the constitutive role of discourse in building feminist identities.

From How We Became Posthuman: Virtual Bodies in Cybernetics, Literature, and Informatics

Chapter 2. Virtual Bodies and Flickering Signifiers

We might regard patterning or predictability as the very essence and raison d'être *of communication . . . communication is the creation of redundancy or patterning.*

Gregory Bateson,[1] *Steps to an Ecology of Mind*

The development of information theory in the wake of World War II left as its legacy a conundrum: even though information provides the basis for much of contemporary U.S. society, it has been constructed never to be present in itself. In information theoretic terms, as we saw in chapter 1,[2] information is conceptually distinct from the markers that embody it, for example newsprint or electromagnetic waves. It is a pattern rather than a presence, defined by the probability distribution of the coding elements composing the message. If information is pattern, then noninformation should be the absence of pattern, that is, randomness. This commonsense expectation ran into unexpected complications when certain developments within information theory implied that information could be equated with randomness as well as with pattern.[3] Identifying information with *both* pattern and randomness proved to be a powerful paradox, leading to the realization that in some instances, an infusion of noise into a system can cause it to reorganize at a higher level of complexity.[4] Within such a system, pattern and randomness are bound together in a complex dialectic that makes them not so much opposites as complements or supplements to one another. Each helps to define the other; each contributes to the flow of information through the system.

Were this dialectical relation only an aspect of the formal theory, its impact might well be limited to the problems of maximizing channel utility and minimizing noise that concern electrical engineers. Through the development of information technologies, however, the interplay between pattern and randomness became a feature of everyday life. As Friedrich Kittler has demonstrated in *Discourse Networks 1800/1900*, media come into existence when technologies of inscription intervene between the hand gripping the pen or the mouth framing the sounds and the production of the texts. In a literal sense, technologies of inscription are media when they are perceived as mediating, inserting themselves into the chain of textual production. Kittler identifies the innovative characteristics of the typewriter, originally designed for the blind, not with speed but rather with "spatially designated and discrete signs," along with a corresponding shift from the word as flowing *image* to the word "as a geometrical figure created by the spatial arrangements of the letter keys" (here Kittler quotes Richard

1. English-born American ethnologist and biologist (1904–1980), who was involved in the early development of cybernetics theory; *Steps to an Ecology of Mind* was published in 1972.
2. Titled "Toward Embodied Virtuality."
3. The paradox is discussed in N. Katherine Hayles, *Chaos Bound: Orderly Disorder in Contemporary Literature and Science* (Ithaca: Cornell University Press, 1990), pp. 31–60 [Hayles's note].
4. Self-organizing systems are discussed in Grégoire Nicolis and Ilya Prigogine, *Exploring Complexity: An Introduction* (New York: Freeman and Company, 1989); Roger Lewin, *Complexity: Life at the Edge of Chaos* (New York: Macmillan, 1992); and M. Mitchell Waldrop, *Complexity: The Emerging Science at the Edge of Order and Chaos* (New York: Simon and Schuster, 1992) [Hayles's note].

Herbertz).[5] The emphasis on spatially fixed and geometrically arranged letters is significant, for it points to the physicality of the processes involved. Typewriter keys are directly proportionate to the script they produce. One keystroke yields one letter, and striking the key harder produces a darker letter. The system lends itself to a signification model that links signifier to signified[6] in direct correspondence, for there is a one-to-one relation between the key and the letter it produces. Moreover, the signifier itself is spatially discrete, durably inscribed, and flat.

How does this experience change with electronic media? The relation between striking a key and producing text with a computer is very different from the relation achieved with a typewriter. Display brightness is unrelated to keystroke pressure, and striking a single key can effect massive changes in the entire text. The computer restores and heightens the sense of word as image—an image drawn in a medium as fluid and changeable as water.[7] Interacting with electronic images rather than with a materially resistant text, I absorb through my fingers as well as my mind a model of signification in which no simple one-to-one correspondence exists between signifier and signified. I know kinesthetically as well as conceptually that the text can be manipulated in ways that would be impossible if it existed as a material object rather than a visual display. As I work with the text-as-flickering-image, I instantiate within my body the habitual patterns of movement that make pattern and randomness more real, more relevant, and more powerful than presence and absence.

The technologies of virtual reality, with their potential for full-body mediation, further illustrate the kind of phenomena that foreground pattern and randomness and make presence and absence seem irrelevant. Already an industry worth hundreds of millions of dollars, virtual reality puts the user's sensory system into a direct feedback loop with a computer.[8] In one version, the user wears a stereovision helmet and a body glove with sensors at joint positions. The user's movements are reproduced by a simulacrum, called an avatar, on the computer screen. When the user turns his or her head, the computer display changes in a corresponding fashion. At the same time, audiophones create a three-dimensional sound field. Kinesthetic sensations, such as G-loads[9] for flight simulators, can be supplied through more extensive and elaborate body coverings. The result is a multisensory interaction that creates the illusion that the user is *inside* the computer. From my experience with the virtual reality simulations at the Human Interface Technology Laboratory[1] and elsewhere, I can attest to the disorienting, exhilarating effect of the feeling that subjectivity is dispersed throughout the cybernetic circuit. In these systems, the user learns, kinesthetically and proprioceptively, that the relevant boundaries for interaction are defined less by the skin than by the feedback loops connecting body and simulation in a technobio-integrated circuit.

Questions about presence and absence do not yield much leverage in this situation, for the avatar both is and is not present, just as the user both is and is not inside the screen. Instead, the focus shifts to questions about pattern and randomness. What transformations govern the connections between user and avatar? What parameters control the construction of the screen world? What patterns can the user discover through interaction with the system? Where do these patterns fade into randomness? What stimuli cannot be encoded within the system and therefore exist only as extraneous noise? When and how does this noise coalesce into pattern? Working from a different theoretical framework, Allucquère Roseanne Stone has proposed that one need not enter virtual reality to encounter these questions, although VR brings them vividly into the foreground. Merely communicating by email or participating in a text-based MUD (multi-user dungeon) already problematizes thinking of the body as a self-evident physicality.[2] In the face of such technologies, Stone proposes that we think of subjectivity as a multiple warranted by the body rather than contained within it. Sherry Turkle, in her fascinating work on people who spend serious time in MUDs, convincingly shows that virtual technologies, in a riptide of reverse influence, affect how real life is seen. "Reality is not my best window," one of her respondents remarks.[3]

In societies enmeshed within information networks, as the U.S. and other first world societies[4] are, these examples can be multiplied a thousandfold. Money is increasingly experienced as informational patterns stored in computer banks rather than as the presence of cash; surrogacy and in vitro fertilization court cases offer examples of informational genetic patterns competing with physical presence for the right to determine the "legitimate" parent; automated factories are controlled by programs that constitute the physical realities of work assignments and production schedules as flows of information through the system;[5] criminals are tied to crime scenes through DNA patterns rather than through eyewitness accounts verifying their presence; access to computer networks rather than physical possession of data determines nine-tenths of computer law;[6] sexual relationships are pursued through the virtual spaces of computer networks rather than through meetings at

5. Friedrich A. Kittler, *Discourse Networks, 1800/1900*, translated by Michael Metteer (Stanford: Stanford University Press, 1990), p. 193 [Hayles's note]. Kittler (b. 1943), German literary critic and media theorist. Herbertz (1878–1959), professor of philosophy at the University of Bern.
6. The sign was divided into *signified* (the meaning conveyed) and *signifier* (the symbol or sound that conveys that meaning) by the Swiss linguist Ferdinand de Saussure (1857–1913), who argued that in language, the relation between the two is arbitrary.
7. The fluidity of writing on the computer is eloquently explored by Michael Joyce in *Of Two Minds: Hypertext Pedagogy and Poetics* (Ann Arbor: University of Michigan Press, 1995) [Hayles's
8. Howard Rheingold surveys the new virtual technologies in *Virtual Reality* (New York: Summit Books, 1991). Also useful is Ken Pimentel and Kevin Teixeira, *Virtual Reality: Through the New Looking Glass* (New York: McGraw-Hill, 1994). Benjamin Woolley takes a skeptical approach toward claims for the new technology in *Virtual Worlds: A Journey in Hyped Hyperreality* (Oxford: Blackwell, 1992) [Hayles's note]. Rheingold (b. 1947), American writer of fiction and nonfiction.
9. Forces of acceleration; one G is equivalent to the force exerted by Earth's gravity on a body at rest.
1. A multidisciplinary research and development lab focusing on human-machine interfaces, established in 1989 at the University of Washington

2. Allucquère Roseanne Stone, *The War of Desire and Technology at the Close of the Mechanical Age* (Cambridge: MIT Press, 1995) [Hayles's note]. Stone (b. late 1940s?), American theorist, performer of New Media Art, and founder and director of the Advanced Communication Technologies Laboratory in the Department of Radio-Television-Film at the University of Texas at Austin. MUD: a multiplayer online computer game that is text based, combining role-playing and social interaction.
3. Sherry Turkle, *Life on the Screen: Identity in the Age of the Internet* (New York: Simon and Schuster, 1995) [Hayles's note]. Turkle (b. 1948), Abby Rockefeller Mauzé Professor of the Social Studies
Institute of Technology and a clinical psychologist; she also is founder and director of the MIT Initiative on Technology and Self.
4. The highly industrialized (largely Western) nations in a global economy, which dominate the "underdeveloped" countries of the "third world," many of which are former colonies.
5. In *The Age of the Smart Machine: The Future of Work and Power* (New York: Basic Books, 1988), Shoshana Zuboff explores, through three case studies, the changes in U.S. workplaces as industries become informatted [Hayles's note].
6. Computer law is discussed in Katie Hafner and John Markoff, *Cyberpunk: Outlaws and Hackers on the Computer Frontier* (New York: Simon and

which the participants are physically present.[7] The effect of these transformations is to create a highly heterogeneous and fissured space in which discursive formations based on pattern and randomness jostle and compete with formations based on presence and absence. Given the long tradition of dominance that presence and absence have enjoyed in the Western tradition, the surprise is not that formations based on them continue to exist but that these formations are being displaced so rapidly across a wide range of cultural sites.

These examples, taken from studies of information technologies, illustrate concerns that are also appropriate for literary texts. If the effects that the shift toward pattern/randomness has on literature are not widely recognized, perhaps it is because they are at once pervasive and elusive. A book produced by typesetting may look very similar to one generated by a computerized program, but the technological processes involved in this transformation are not neutral. Different technologies of text production suggest different models of signification; changes in signification are linked with shifts in consumption; shifting patterns of consumption initiate new experiences of embodiment; and embodied experience interacts with codes of representation to generate new kinds of textual worlds.[8] In fact, each category—production, signification, consumption, bodily experience, and representation—is in constant feedback and feedforward loops with the others.

As the emphasis shifts to pattern and randomness, characteristics of print texts that used to be transparent (because they were so pervasive) are becoming visible again through their differences from digital textuality. We lose the opportunity to understand the implications of these shifts if we mistake the dominance of pattern/randomness for the disappearance of the material world. In fact, it is precisely because material interfaces have changed that pattern and randomness can be perceived as dominant over presence and absence. The pattern/randomness dialectic does not erase the material world; information in fact derives its efficacy from the material infrastructures it appears to obscure. This illusion of erasure should be the *subject* of inquiry, not a presupposition that inquiry takes for granted.

To explore the importance of the medium's materiality, let us consider the book. Like the human body, the book is a form of information transmission and storage, and like the human body, the book incorporates its encodings in a durable material substrate. Once encoding in the material base has taken place, it cannot easily be changed. Print and proteins in this sense have more in common with each other than with magnetic encodings, which can be erased and rewritten simply by changing the polarities. (In chapter 8[9] we shall have an opportunity to see how a book's self-representations change

The Hacker Crackdown: Law and Disorder on the Electronic Frontier (New York: Bantam, 1992) [Hayles's note]. Hayles plays on the old adage "Possession is nine-tenths of the law" (i.e., physical possession usually establishes ownership).

7. Sherry Turkle documents computer network romances in *Life on the Screen*. Nicholson Baker's *Vox: A Novel* (New York: Random House, 1992) imaginatively explores the erotic potential for better living through telecommunications; and Rheingold looks at the future of erotic encounters in cyberspace in "Teledildonics and Beyond," *Virtual Reality*, pp. 345–77 [Hayles's note].

8. Among the studies that explore these connections are Jay Bolter, *Writing Space: The Computer, Hypertext, and the History of Writing* (Hillsdale, N.J.: Lawrence Erlbaum Associates, 1991); Michael Heim, *Electric Language: A Philosophical Study of Word Processing* (New Haven: Yale University Press, 1987); and Mark Poster, *The Mode of Information: Poststructuralism and Social Context* (Chicago: University of Chicago Press, 1990) [Hayles's note].

9. Titled "The Materiality of Informatics."

when the book is linked with magnetic encodings.) The printing metaphors pervasive in the discourse of genetics are constituted through and by this similarity of corporeal encoding in books and bodies.

The entanglement of signal and materiality in bodies and books confers on them a parallel doubleness. As we have seen, the human body is understood in molecular biology simultaneously as an expression of genetic information and as a physical structure. Similarly, the literary corpus is at once a physical object and a space of representation, a body and a message. Because they have bodies, books and humans have something to lose if they are regarded solely as informational patterns, namely the resistant materiality that has traditionally marked the durable inscription of books no less than it has marked our experiences of living as embodied creatures. From this affinity emerge complex feedback loops between contemporary literature, the technologies that produce it, and the embodied readers who produce and are produced by books and technologies. Changes in bodies as they are represented within literary texts have deep connections with changes in textual bodies as they are encoded within information media, and both types of changes stand in complex relation to changes in the construction of human bodies as they interface with information technologies. The term I use to designate this network of relations is *informatics*. Following Donna Haraway, I take *informatics* to mean the technologies of information as well as the biological, social, linguistic, and cultural changes that initiate, accompany, and complicate their development.[1]

I am now in a position to state the thesis of this chapter explicitly. The contemporary pressure toward dematerialization, understood as an epistemic shift toward pattern/randomness and away from presence/absence, affects human and textual bodies on two levels at once, as a change in the body (the material substrate) and as a change in the message (the codes of representation). The connectivity between these changes is, as they say in the computer industry, massively parallel and highly interdigitated. My narrative will therefore weave back and forth between the represented worlds of contemporary fictions, models of signification implicit in word processing, embodied experience as it is constructed by interactions with information technologies, and the technologies themselves.

The compounding of signal with materiality suggests that new technologies will instantiate new models of signification. Information technologies do more than change modes of text production, storage, and dissemination. They fundamentally alter the relation of signified to signifier. Carrying the instabilities implicit in Lacanian[2] floating signifiers one step further, information technologies create what I will call *flickering signifiers*, characterized by their tendency toward unexpected metamorphoses, attenuations, and dispersions. Flickering signifiers signal an important shift in the plate tectonics of language. Much of contemporary fiction is directly influenced by information technologies; cyberpunk, for example, takes informatics as

1. Donna Haraway, "Manifesto for Cyborgs: Science, Technology, and Socialist Feminism in the 1980s," *Socialist Review* 80 (1985): 65–108; see also Donna Haraway, "The High Cost of Information in Post World War II Evolutionary Biology: Ergonomics, Semiotics, and the Sociobiology of Communications Systems," *Philosophical Forum* 13, nos. 2–3 (1981–82): 244–75 [Hayles's note]. On the American theorist HARAWAY (b. 1944), and for her "Manifesto for Cyborgs," see below.

2. Of the French psychoanalyst JACQUES LACAN (1901–1981); Hayles explains his "floating signifiers" in the following section.

its central theme. Even narratives without this focus can hardly avoid the rippling effects of informatics, however, for the changing modes of signification affect the *codes* as well as the subjects of representation.

SIGNIFYING THE PROCESSES OF PRODUCTION

"Language is not a code," Lacan asserted, because he wanted to deny one-to-one correspondence between the signifier and the signified.[3] In word processing, however, language *is* a code. The relation between machine and compiler languages is specified by a coding arrangement, as is the relation of the compiler language to the programming commands that the user manipulates. Through these multiple transformations, some quantity is conserved, but it is not the mechanical energy implicit in a system of levers or the molecular energy of a thermodynamical system. Rather it is the informational structure that emerges from the interplay between pattern and randomness. When a text presents itself as a constantly refreshed image rather than as a durable inscription, transformations can occur that would be unthinkable if matter or energy, rather than informational patterns, formed the primary basis for the systemic exchange. This textual fluidity, which users learn in their bodies as they interact with the system, implies that signifiers flicker rather than float.

To explain what I mean by flickering signifiers, I will briefly review Lacan's notion of floating signifiers. Lacan, operating within a view of language that was primarily print-based rather than electronically mediated, not surprisingly focused on presence and absence as the dialectic of interest.[4] When he formulated the concept of floating signifiers, he drew on Saussure's idea that signifiers are defined by networks of relational differences between themselves rather than by their relation to signifieds. He complicated this picture by maintaining that signifieds do not exist in themselves, except insofar as they are produced by signifiers. He imagined them as an ungraspable flow floating beneath a network of signifiers, a network that itself is constituted through continual slippages and displacements. Thus, for him, a doubly reinforced absence is at the core of signification—the absence of signifieds as things-in-themselves as well as the absence of stable correspondences between signifiers. The catastrophe in psycholinguistic development corresponding to this absence in signification is castration, the moment when the (male) subject symbolically confronts the realization that subjectivity, like language, is founded on absence.

How does this scenario change when floating signifiers give way to flickering signifiers? Foregrounding pattern and randomness, information technologies operate within a realm in which the signifier is opened to a rich internal play of difference. In informatics, the signifier can no longer be understood as a single marker, for example an ink mark on a page. Rather it exists as a flexible chain of markers bound together by the arbitrary relations

3. Jacques Lacan, "Radiophonies," *Scilicet* 213 (1970): 55, 68. For floating signifiers, see *Le Séminaire XX: Encore* (Paris: Seuil, 1975), pp. 22, 35 [Hayles's note].

4. Although presence and absence loom much larger in Lacanian psycholinguistics than do pattern and randomness, Lacan was not uninterested in information theory. In the 1954–55 *Seminar*, he played with incorporating ideas from information theory and cybernetics into psychoanalysis. See especially "The Circuit," pp. 77–90, and "Psychoanalysis and Cybernetics, or on the Nature of Language," pp. 294–308, in *The Seminar of Jacques Lacan: Book II*, edited by Jacques-Alain Miller (New York: W. W. Norton and Company, 1991) [Hayles's note].

specified by the relevant codes. As I write these words on my computer, I see the lights on the video screen, but for the computer, the relevant signifiers are electronic polarities on disks. Intervening between what I see and what the computer reads are the machine code that correlates alphanumeric symbols with binary digits, the compiler language that correlates these symbols with higher-level instructions determining how the symbols are to be manipulated, the processing program that mediates between these instructions and the commands I give the computer, and so forth. A signifier on one level becomes a signified on the next-higher level. Precisely because the relation between signifier and signified at each of these levels is arbitrary, it can be changed with a single global command. If I am producing ink marks by manipulating movable type, changing the font requires changing each line of type. By contrast, if I am producing flickering signifiers on a video screen, changing the font is as easy as giving the system a single command. The longer the chain of codes, the more radical the transformations that can be effected. Acting as linguistic transducers, the coding chains impart astonishing power to even very small changes. Such amplification is possible because the constant reproduced through multiple coding layers is a pattern rather than a presence.

Where does randomness enter this picture? Within information theory, information is identified with choices that reduce uncertainty, for example when I choose which book, out of eight on a reading list, my seminar will read for the first week of class. To get this information to the students, I need some way to transmit it. Information theory treats the communication situation as a system in which a sender encodes a message and sends it as a signal through a channel. At the other end is a receiver, who decodes the signal and reconstitutes the message. Suppose I write my students an email. The computer encodes the message in binary digits and sends a signal corresponding to these digits to the server, which then reconstitutes the message in a form the students can read. At many points along this route, noise can intervene. The message may be garbled by the computer system, so that it arrives looking like "*#e%^&s**." Or I may have gotten distracted thinking about DeLillo halfway through the message, so that although I meant to assign Calvino for the first week, the message comes out, "If on a winter's night a white noise."[5] These examples indicate that for real-life communication situations, pattern exists in dynamic tension with the random intrusions of noise.

Uncertainty enters in another sense as well. Although information is often defined as *reducing* uncertainty, it also *depends* on uncertainty. Suppose, for example, *Gravity's Rainbow*[6] is the only text on the reading list. The probability that I would choose it is 1. If I send an email telling my students that the text for this week is *Gravity's Rainbow*, they will learn nothing they did not already know, and no information is communicated. The most surprising information I could send them would be a string of random letters. (Remember that information in the technical sense has nothing to do with meaning; the fact that such a message would be meaningless is thus paradoxically

5. A conflation of the titles of 2 novels: *If on a Winter's Night a Traveler* (1979), by the Italian writer Italo Calvino (1923–1985), and *White Noise* (1985), by the American writer Don DeLillo (b. 1936).

6. A 1973 postmodern novel by the American writer Thomas Pynchon.

irrelevant to calculating the amount of information it contains.) These intuitions are confirmed by the mathematical theory of information.[7] For an individual message, the information increases as the probability that the event will occur diminishes; the more unlikely the event, the more information it conveys. Appropriately, this quantity is usually called the "surprisal." Let's say that nine of my reading assignments were on *Gravity's Rainbow*, and one was on *Vineland*.[8] The students would gain more information from a message telling them that the assignment was *Vineland* than from a message stating that the assignment was *Gravity's Rainbow*—the more probable event and hence the more expected. Most of the time, however, electrical engineers are not interested in individual messages but in all the messages that can be produced from a given source. Thus they do not so much want to know the surprisal as the *average* amount of information coming from a source. This average reaches a maximum when it is equally likely that any symbol can appear in any position—which is to say, when there is no pattern or when the message is at the extreme of randomness. Thus Warren Weaver, in his interpretation of Shannon's theory of information, suggested that information should be understood as depending on both predictability and unpredictability, pattern and randomness.[9]

What happens in the case of mutation? Consider the example of the genetic code. Mutation normally occurs when some random event (for example, a burst of radiation or a coding error) disrupts an existing pattern and something else is put in its place instead. Although mutation disrupts pattern, it also presupposes a morphological standard against which it can be measured and understood as a mutation. If there were only randomness, as with the random movements of gas molecules, it would make no sense to speak of mutation. We have seen that in electronic textuality, the possibilities for mutation within the text are enhanced and heightened by long coding chains. We can now understand mutation in more fundamental terms. Mutation is crucial because it names the bifurcation point at which the interplay between pattern and randomness causes the system to evolve in a new direction. It reveals the productive potential of randomness that is also recognized within information theory when uncertainty is seen as both antagonistic and intrinsic to information.

We are now in a position to understand mutation as a decisive event in the psycholinguistics of information. Mutation is the catastrophe in the pattern/randomness dialectic analogous to castration in the presence/absence dialectic. It marks a rupture of pattern so extreme that the expectation of continuous replication can no longer be sustained. But as with castration, this only appears to be a disruption located at a specific moment. The randomness to which mutation testifies is implicit in the very idea of

7. For an individual event s_i, the information $I(s_i) = -\log p(s_i)$, where p is the probability, expressed as a decimal between 1 and 0, that s_i will occur. To give a sense of how this function varies, consider that –log base 2 of .9 (an event that occurs nine times out of ten) is .15, whereas –log base 2 of .1 (an event that occurs only one in ten times) is 3.33. Hence, as the probability p decreases (becomes less likely), –log p increases. In the case of elements whose probabilities do not conditionally depend on one another, the *average* information of a source s is $I(s) = \Sigma - p(s_i) \log p(s_i)$, where p is again the probability that s_i will occur [Hayles's note].

8. A 1990 novel by Pynchon.

9. Claude E. Shannon and Warren Weaver, *The Mathematical Theory of Communication* (Urbana: University of Illinois Press, 1949). For a further discussion of this aspect of information theory, see Hayles, *Chaos Bound*, pp. 31–60 [Hayles's note]. Weaver (1894–1978), American scientist and mathematician. Shannon (1916–2001), American engineer and mathematician known as the father of information theory.

pattern, for only against the background of nonpattern can pattern emerge. Randomness is the contrasting term that allows pattern to be understood as such. The crisis named by mutation is as wide-ranging and pervasive in its import within the pattern/randomness dialectic as castration is within the tradition of presence/absence, for it is the visible mark that testifies to the continuing interplay of the dialectic between pattern and randomness, replication and variation, expectation and surprise.

Shifting the emphasis from presence/absence to pattern/randomness suggests different choices for tutor texts. Rather than studying Freud's discussion of "fort/da"[1] (a short passage whose replication in hundreds of commentaries would no doubt astonish its creator), theorists interested in pattern and randomness might point to David Cronenberg's film *The Fly*.[2] At a certain point, the protagonist's penis does fall off (quaintly, he puts it in his medicine chest as a memento of times past), but the loss scarcely registers in the larger mutation he is undergoing. The operative transition is not from male to female-as-castrated-male but from human to something radically other than human. Flickering signification brings together language with a psychodynamics based on the symbolic moment when the human confronts the posthuman.

As I indicated in chapter 1, I understand human and posthuman to be historically specific constructions that emerge from different configurations of embodiment, technology, and culture. My reference point for the human is the tradition of liberal humanism; the posthuman appears when computation rather than possessive individualism[3] is taken as the ground of being, a move that allows the posthuman to be seamlessly articulated with intelligent machines. To see how technology interacts with these constructions, consider the picture that nineteenth-century U.S. and British anthropologists have drawn of "man" as a tool-user.[4] Using tools may shape the body (some anthropologists made this argument), but the tool nevertheless is envisioned as an object that is apart from the body, an object that can be picked up and put down at will. When the claim that man's unique nature was defined by tool use could not be sustained (because other animals were shown also to use tools), the focus shifted during the early twentieth century to man the tool-maker. Typical is Kenneth P. Oakley's 1949 *Man the Tool-Maker*, a magisterial work with the authority of the British Museum behind it. Oakley, in charge of the Anthropological Section of the museum's Natural History Division, wrote in his introduction, "Employment of tools appears to be [man's] chief biological characteristic, for considered functionally they are detachable extensions of the forelimb."[5] The kind of tool he envisioned was mechanical rather than informational; it goes *with* the hand, not *on* the head. Significantly, he imagined the tool to be at once "detachable" and an

1. Gone/there (German); in *Beyond the Pleasure Principle* (1920), Sigmund Freud (1856–1939), the Austrian founder of psychoanalysis, describes his grandson's game of throwing a wooden reel away from himself and pulling it back with a string (thereby establishing control over presence and absence).

2. A 1986 film, directed by the Canadian filmmaker Cronenberg (b. 1943); its protagonist, a scientist, is gradually transformed into a fly.

3. Individualism is "possessive" insofar as the individual is conceived of as owning him- or herself.

4. The gender encoding implicit in "man" (rather than human) is also reflected in the emphasis on tool usage as a defining characteristic rather than, say, altruism or nurturing, traits traditionally encoded female [Hayles's note].

5. Kenneth P. Oakley, *Man the Tool-Maker* (London: Trustees of the British Museum, 1949), p. 1 [Hayles's note]. Oakley (1911–1981), English physical anthropologist and geologist.

"extension," separate from yet partaking of the hand. If the placement and the kind of tool mark Oakley's affinity with the epoch of the human, the construction of the tool as a prosthesis points forward to the posthuman.

By the 1960s, Marshall McLuhan was speculating about the transformation that media, understood as technological prostheses, were effecting on human beings.[6] He argued that humans react to stress in their environments by withdrawing the locus of selfhood inward, in a numbing withdrawal from the world he called (following Hans Selye and Adolphe Jonas[7]) "autoamputation." This withdrawal in turn facilitates and requires compensating technological extensions that project the body-as-prosthesis back out into the world. Whereas Oakley remains grounded in the human and looks only distantly toward the posthuman, McLuhan clearly sees that electronic media are capable of bringing about a reconfiguration so extensive as to change the nature of "man."

As we saw in chapter 1, similar shifts in orientation informed the Macy Conference[8] discussions taking place during the same period (1946–53). Participants wavered between a vision of man as a homeostatic self-regulating mechanism whose boundaries were clearly delineated from the environment[9] and a more threatening, reflexive vision of a man spliced into an informational circuit that could change him in unpredictable ways. By the 1960s, the consensus within cybernetics had shifted dramatically toward reflexivity. By the 1980s, the inertial pull of homeostasis as a constitutive concept had largely given way to self-organization theories implying that radical changes were possible within certain kinds of complex systems.[1] In the contemporary period, the posthuman future of humanity is increasingly evoked, ranging from Hans Moravec's argument for a "postbiological" future in which intelligent machines become the dominant life form on the planet, to the more sedate and in part already realized prospect of a symbiotic union between human and intelligent machine, a union that Howard Rheingold calls "intelligence augmentation."[2] Although these visions differ in the degree and kind of interfaces they imagine, they concur that the posthuman implies not only a coupling with intelligent machines but a coupling so intense and multifaceted that it is no longer possible to distinguish meaningfully between the biological organism and the informational circuits in which the organism is enmeshed. Accompanying this change is a corresponding shift in how signification is understood and corporeally experienced. In contrast to Lacanian

6. Marshall McLuhan, *Understanding Media: The Extensions of Man* (New York: McGraw Hill, 1964), pp. 41–47 [Hayles's note]. McLuhan (1911–1980), Canadian communications theorist and philosopher.
7. Yugoslavian-born British psychiatrist (b. 1913). Selye (1907–1982), Austrian-born Canadian endocrinologist.
8. A series of 10 conferences (1946–53) that led to the foundation of cybernetics.
9. The term *homeostasis*, or self-regulating stability through cybernetic corrective feedback, was introduced by physiologist Walter B. Cannon in "Organization for Physiological Homeostasis," *Physiological Reviews* 9 (1929): 399–431. Cannon's work influenced Norbert Wiener, and homeostasis became an important concept in the initial phase of cybernetics from 1946 to 1953; see chapters 3 and 4 [in *How We Became Posthuman*] for details [Hayles's note]. Wiener (1894–1964), American theoretical and applied mathematician, pioneer of cybernetics.
1. Key figures in moving from homeostasis to self-organization were Heinz von Foerster, especially in *Observing Systems* (Salinas, Calif.: Intersystems Publications, 1981), and Humberto R. Maturana and Francisco J. Varela, *Autopoiesis and Cognition: The Realization of the Living* (Dordrecht: Reidel, 1980), discussed in detail in chapter 6 [of *How We Became Posthuman*] [Hayles's note].
2. Howard Rheingold, *Virtual Reality*, pp. 13–49; Hans Moravec, *Mind Children: The Future of Robot and Human Intelligence* (Cambridge: Harvard University Press, 1988), pp. 1–5, 116–22 [Hayles's note]. Moravec (b. 1948), Austrian-born researcher at the Robotics Institute of Carnegie Mellon University, known for his work on artificial intelligence.

psycholinguistics, derived from the generative coupling of linguistics and sexuality, flickering signification is the progeny of the fascinating and troubling coupling of language and machine.

Information Narratives and Bodies of Information

The shift from presence and absence to pattern and randomness is encoded into every aspect of contemporary literature, from the physical object that constitutes the text to such staples of literary interpretation as character, plot, author, and reader. The development is by no means even; some texts testify dramatically and explicitly to the shift, whereas others manifest this shift only indirectly. I will call those texts in which the displacement is most apparent *information narratives*. Information narratives show, in exaggerated form, changes that are more subtly present in other texts as well. Whether in information narratives or contemporary fiction generally, the dynamic of displacement is crucial. One could focus on pattern in any era, but the peculiarity of pattern in these texts is its interpenetration with randomness and its implicit challenge to physicality. *Pattern tends to overwhelm presence*, leading to a construction of immateriality that depends not on spirituality or even consciousness but only on information.

Consider William Gibson's[3] *Neuromancer* (1984), the novel that—along with the companion volumes *Count Zero* (1986) and *Mona Lisa Overdrive* (1988)—sparked the cyberpunk movement. The *Neuromancer* trilogy gave a local habitation and a name to the disparate spaces of computer simulations, networks, and hypertext windows that, before Gibson's intervention, had been discussed as separate phenomena. Gibson's novels acted like seed crystals thrown into a supersaturated solution; the time was ripe for the technology known as cyberspace to precipitate into public consciousness. In *Neuromancer* the narrator defines cyberspace as a "consensual illusion" accessed when a user "jacks into" a computer. Here the writer's imagination outstrips existing technologies, for Gibson imagines a direct neural link between the brain and the computer through electrodes. Another version of this link is a socket, implanted behind the ear, that accepts computer chips, allowing direct neural access to computer memory. Network users collaborate in creating the richly textured landscape of cyberspace, a "graphic representation of data abstracted from the banks of every computer in the human system. Unthinkable complexity. Lines of light ranged in the nonspace of the mind, clusters and constellations of data. Like city lights, receding."[4] Existing in the nonmaterial space of computer simulation, cyberspace defines a regime of representation within which pattern is the essential reality, presence an optical illusion.

Like the landscapes they negotiate, the subjectivities who operate within cyberspace also become patterns rather than physical entities. Case, the computer cowboy who is the protagonist of *Neuromancer*, still has a physical presence, although he regards his body as so much "meat" that exists primarily to sustain his consciousness until the next time he can enter cyberspace. Others have completed the transition that Case's values imply. Dixie Flatline, a cowboy who encountered something in cyberspace that flattened

3. American-born Canadian novelist (b. 1948).
4. William Gibson, *Neuromancer* (New York: Ace Books, 1984), p. 51 [Hayles's note].

er's responses. Working with a VR simulation, the user learns to move his or her hand in stylized gestures that the computer can accommodate. In the process, the neural configuration of the user's brain experiences changes, some of which can be long-lasting. The computer molds the human even as the human builds the computer.

When narrative functionalities change, a new kind of reader is produced by the text. The material effects of flickering signification ripple outward because readers are trained to read through different functionalities, which can affect how they interpret any text, including texts written before computers were invented. The impatience that some readers now feel with print texts, for example, no doubt has a physiological as well as a psychological basis. They miss pushing the keys and seeing the cursor blinking at them. Conversely, other readers (or perhaps the same readers in different moods) go back to print with a renewed appreciation for its durability, its sturdiness, and its ease of use. I began to appreciate certain qualities of print only after I had experience with computers. When I open a book, it almost always works, and it can maintain backward compatibility for hundreds of years. I also appreciate that on some occasions—when I am revising a piece of writing, for example—there isn't a cursor blinking at me, as if demanding a response. With print I can take as long as I want, and the pages never disappear or shut themselves down. As these examples illustrate, changes in narrative functionalities are deeper than the structural or thematic characteristics of a specific genre, for they shift the embodied responses and expectations that different kinds of textualities evoke. Arguing from a different historical context, Friedrich Kittler made a similar point when he wrote about medial ecology.[5] When new media are introduced, the changes transform the environment as a whole. This transformation affects the niches that older media have carved for themselves, so they change also, even if they are not directly involved with the new media. Books will not remain unaffected by the emergence of new media.

If my assessment—that the emphasis on information technologies foregrounds pattern/randomness and pushes presence/absence into the background—is correct, the implications extend beyond narrative into many cultural arenas. As I indicated in chapter 1, one of the most serious of these implications is a *systematic devaluation of materiality and embodiment*. I find this trend ironic, for changes in material conditions and embodied experience are precisely what give the shift its deep roots in everyday experience. Implicit in nearly everything I have written here is the assumption that presence and pattern are opposites existing in antagonistic relation. The more emphasis that falls on one, the less the other is noticed and valued. Entirely different readings emerge when one entertains the possibility that pattern and presence are mutually enhancing and supportive. Paul Virilio has observed that one cannot ask whether information technologies should continue to be developed.[6] Given market forces already at work, it is virtually (if I may use the word) certain that we will increasingly live, work, and play

5. Kittler, *Discourse Networks*. Joseph Tabbi and Michael Wurtz further explore the implications of medial ecology in *Reading Matters: Narrative in the New Media Ecology* (Ithaca: Cornell University Press, 1996) [Hayles's note].

6. Paul Virilio and Sylvérè Lotringer, *Pure War*, translated by Mark Polizzotti (New York: Semiotext(e), 1983) [Hayles's note]. Virilio (b. 1932), French theorist of culture, architecture, and technology.

in environments that construct us as embodied virtualities.[7] I believe that our best hope to intervene constructively in this development is to put an interpretive spin on it—one that opens up the possibilities of seeing pattern and presence as complementary rather than antagonistic. Information, like humanity, cannot exist apart from the embodiment that brings it into being as a material entity in the world; and embodiment is always instantiated, local, and specific. Embodiment can be destroyed, but it cannot be replicated. Once the specific form constituting it is gone, no amount of massaging data will bring it back. This observation is as true of the planet as it is of an individual life-form. As we rush to explore the new vistas that cyberspace has made available for colonization, let us remember the fragility of a material world that cannot be replaced.

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7. "Embodied virtuality" is Mark Weiser's phrase in "The Computer for the 21st Century," *Scientific American* 265 (September 1991): 94–104. Weiser distinguishes between technologies that put the user into a simulation with the computer (virtual reality) and those that embed computers within already existing environments (embodied virtuality or ubiquitous computing). In virtual reality, the user's sensorium is redirected into functionalities compatible with the simulation; in embodied virtuality, the sensorium continues to function as it normally would but with an expanded range made possible through the environmentally embedded computers [Hayles's note].

DONNA HARAWAY
b. 1944

In the introduction to her book *Simians, Cyborgs, and Women: The Reinvention of Nature* (1991), Donna Haraway describes her transformation from a "proper, U.S. socialist feminist, white, female, hominid biologist" into a "multiply marked cyborg feminist" whose writings range freely from primatology to epistemology and on subjects from AIDS to feminist science fiction. Haraway's challenging and innovative theoretical work is part of the cultural studies of science and technology, a thriving subdiscipline interested in the history, sociology, and politics of technoscience. Her best-known text, "A Manifesto for Cyborgs" (1985), has been hailed as the central text of cyberfeminism—a new and often iconoclastic wave of feminist theory and practice that is seeking to reclaim technoscience. As she attempts to understand the place of technology within a postmodern, socialist feminism, Haraway argues that far from being antithetical to the human organism, technology is a material and symbolic apparatus that is already deeply involved in what it means to be human. The old political strategies—Marxist, liberal, and conservative—have become obsolete in the face of a global technoscience that is outpacing the ethical and political mechanisms we have devised for containing it. Her landmark essay is a call for "reconstructing socialist-feminist politics . . . through theory and practice addressed to the social relations of science and technology." In this manifesto, she introduces the mysterious boundary creature and new myth: the cyborg, a "hybrid of machine and organism" that, for Haraway, becomes a metaphor for the "disassembled and reassembled, post-modern collective and personal self" of contemporary cultural theory suited to the West's late capitalist social order.