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Inventing the Medium

Janet H. Murray

This is a landmark volume, marking the first comprehensive effort at establishing the genealogy of the computer as an expressive medium.

Although the name of the book is *The New Media Reader,* its subject is the emergence of a single medium, and one which we can define more particularly than by merely by pointing to its novelty. The *digital medium* which we see emerging in these well-selected and contextualized essays may seem plural to us now, because it is so myriad in its forms—virtual reality CAVEs, the Internet, "enhanced" television, videogames. Indeed, like the medium of film 100 years earlier, the computer medium is drawing on many antecedents and spawning a variety of formats. But the term "new media" is a sign of our current confusion about where these efforts are leading and our breathlessness at the pace of change, particularly in the last two decades of the 20th century. How long will it take before we see the gift for what it is—a single new medium of representation, the digital medium, formed by the braided interplay of technical invention and cultural expression at the end of the 20th century? This reader, reflecting the burgeoning of "New Media Studies" throughout academic life and new media practice throughout the world, should help to hasten that change in our thinking.

Here for the first time within a single volume we can trace the cultural helix, the echoing and opposing strands that form the DNA for cyberspace itself. The first two essays establish the pattern, a call and response of fantasist and engineer, philosopher and inventor. Borges (◊01), the storyteller-librarian, and Bush (◊02), the soldier-scientist, speak to us out of the same midcentury frame of mind, exhausted by war, exhilarated by a dawning sense of globalism. They are both almost viscerally aware of the increased complexity of human consciousness and the failure of linear media to capture the structures of our thought. Borges, one of the first fiction writers to place himself in the expanded context of a global culture, is fascinated by the arbitrariness of language itself, by the flutter of meaning across cultural boundaries. His fiction evokes a sense of flickering focus, of an individual consciousness constantly reforming itself, of an utterance constantly in the process of translation. Borges confronts us with the "pullulating" moment, when we become aware of all the possible choices we might make, all the ways in which we might intersect one another for good or evil. His imagined Garden of Forking Paths is both a book and landscape, a book that has the shape of a labyrinth that folds back upon itself in infinite regression. It is a dizzying vision, one which will be described again by humanist writers for the rest of the century.

For Vannevar Bush, the scientist, the world is not an imprisoning labyrinth, but a challenging maze, waiting to be solved by an appropriately organized and clever team effort. Like Borges, Bush imagines alternate libraries. But where Borges's visions are playful and subversive of rationalist exploration, Bush dreams of the hyperrational. He is alarmed to discover that the library shelf is no longer an adequate map of knowledge. Book-based organizational structures have been outpaced by the tempo of investigation, and no longer reflect the constantly reformulating disciplinary boundaries of contemporary scholarship. Knowledge is expanding, but human life remains too short. Where Borges is frozen at the crossroads, enraptured by the proliferating paths, Bush is impatiently searching for the shortcuts, the paths forged by the experts who have scouted the territory before us. He wants to follow in their footsteps and to lay down new trails, trails that do not fade. His engineer's commitment to the redemptive machine runs throughout this volume as well.

Bush, of course, is not thinking about the "computer"—and neither is Borges. Instead they are inventing fantasy information structures—a book-garden-maze, a desk-library-machine—that reflect not a new technology but a change in how our minds are working. The change they imagine is made more urgent by the experience of two world wars, wars that made apparent the huge gulf between our technological prowess and our social development, between our complex thinking and our atavistic behavior. In Borges's fable, the protagonist kills a man as a form of information processing, the murdered man being significant only because his name in the newspaper will act as an appropriate coded message.

Bush's example of a representative research subject is the history of bow and arrow technology. He has learned the power of information organization in the context of wartime weapons development, where more knowledge means more power against the enemy.

Central to Borges's story is our discomfort over the narrator's amoral choice, the impersonal, political murder of a man who in alternate "forks" becomes his friend. There is no right side in his warscape; the murderer does not believe in his cause or care which side wins. In the world of the forking path garden, time does not move forward at all, but outward in proliferating possibilities of creation and destruction that make up the totality of human potential. To live in Borges's world is to feel complicity and exhaustion, but also wonder. Bush's view, on the other hand, is moralistic, energetic, and engaged. Implicit in Bush's narrative is the Enlightenment faith in human progress driven by expanded knowledge, the American metaphor of the rich frontier waiting to be conquered by the able trailblazer, the absolute necessity of self-defense. Bush's maze challenges us, but we are smart enough to find our way out. The solution lies in building something, in making something new that will better serve human need. This dichotomy runs through the rest of the century and is echoed throughout this anthology.

All creativity can be understood as taking in the world as a problem. The problem that preoccupies all of the authors in this volume is the pullulating consciousness that is the direct result of 500 years of print culture. One can think of the humanist strand as dramatizing the problem, amplifying our discomfort by denaturalizing the rituals by which we deny it. The disciplinary humanists in this volume, whether artists, theorists, or scholars, are all engaged in foregrounding our cultural confusions, tuning up our sense of existential befuddlement before the scientifically revealed world of the twentieth century. The engineers, on the other hand, put their faith in the invention of the proper instruments, that, like the microscope and telescope before them, will let us focus on the things that baffle and unhinge us so that we can think about them in a systematic way. The right instruments organize not just the outer world but consciousness itself, a phenomenon that is feared by the humanists and embraced by the engineers. The engineers see the central task of our time—finding the key to survival in the atomic age—as a challenge to our intellects. The world has become more difficult to understand, so we need better ways of thinking about it, more powerful methods of mastering complexity. The library shelf and the chaptered book create both overview and close-up and allow us to move between them without losing our place. What the computer offers us is a more capacious shelf, a finer grained division. The engineers articulate a vision of a new meta-book, a navigable collection of books that will carry us gracefully to the next level of information control and systematic thought, just as the invention of print did 500 years ago. The humanist voices in this survey start off at a greater distance from the material basis of the new medium, and they are often much less hopeful. They find the punch cards of the early information age of little use. They are surveying the wreck of ideologies, coming to terms with the failed promises of print, the horrifying trajectory of the rationalist arrow. They insist that we experience the flickering focus, the slipping away of meaning between the signifier and the signified, that is the intellectual predicament of the second half of the twentieth century.

The authors in this volume line up on both sides of this divide, but they are also facing one another along the braided path. The difference is not so much in what they describe as in their orientation to it. The humanists see the contradictions and limitations of the great systems of thought and it causes them to question the very project of systemized thinking. Such questioning is of their moment but it also is part of a longer tradition of literary and philosophical discourse that articulates the unknowability of life, its tragic dimension, and the absurd and maddening persistence of longing, suffering, need.

The engineers are grounded in a tradition that emphasizes solution and defines the needs it cannot satisfy—and the suffering its solutions can inflict—as outside the domain of the problem. At its worst, the engineering mentality creates efficient killing machines, faster and more deadly arrows. It exults in the ability to "Put-That-There" (◊29), to move weapons around a map with the flick of a magically gloved finger. At its best, it fosters the comic view of the world in which we are resilient enough to problem-solve our way out of our troubles up to the very barrier of mortality itself. At its best, it also celebrates the human capacity to learn and to conceive things that had not been thought of before, things that might make us not just smarter but more creative.

The strands cross one another throughout the period that this anthology delineates, and a single individual often seems to straddle the gap between them. The engineers draw upon cultural metaphors and analogies to express the magnitude of the change, the shape of the as yet unseen medium. The storytellers and theorists build imaginary landscapes of information, writing stories and essays that later become blueprints for actual systems. The engineers pace themselves against an accelerating threat of annihilation by the new war technologies; the humanists imagine the machine as a redemptive environment, welcoming the prospect of cyborg architectures that reconfigure our bodies, our cultures, our selves in hopeful ways. The two traditions come together most energetically in collaborations focused on new structures of learning in which exploration of the computer is motivated by a desire to foster the exploratory processes of the mind itself. Gradually, the braided collaboration gives rise to an emergent form, a new medium of human expression.

By bringing these two strands together in this chronologically arranged collection, the editors invite us to look more closely at the rich interplay of cultural practice and technical innovation. We see the scientific culture articulating a medium that "augments" our humanity, that makes us smarter by pooling our thinking and organizing it at a higher level, and even by facilitating new ways of thinking that are more synthetic and have more power to master complex operations and ideas. Meanwhile the arts are engaged in dicing the language and recombining it randomly, calling attention to the arbitrary nature of the written and spoken signifiers, dramatizing the sense of cultural unraveling after two world wars. Seeing all of these players gathered within the boundaries of this one volume we can almost imagine them in a single room, participating in a kind of quilting bee. In one corner, Borges (◊01), Burroughs (◊07), and the Oulipo (◊12) are busy shredding the outgrown garments of print, while across the room Bush (◊02), Engelbart (◊08, ◊16), and the Xerox PARC collaborators (◊26) are eagerly sewing the fragments together into an intricately patterned, vast, and welcoming quilt. The process begins in mid-century, with the earliest understanding by Turing (◊03), Wiener (◊04), and others of the potential of the computer for symbolic representation and for the capturing of complex interactive systems.

Computer languages were developed that allowed for more powerful manipulation of quantitative and text-based data, supporting large databases, scientific and economic simulations, and research in artificial intelligence. The 1960s were a time of dizzying progress for computer scientists, the period in which the field itself was defined, separated from electrical engineering and mathematics with its own advanced degree programs. It was the time when Licklider (◊05) and others were proposing the Internet, when Weizenbaum (◊24) inadvertently invented the first believable computer-based character, when Nelson (◊11, ◊21, ◊30) coined the word "hypertext" and began his lifelong quest to embody it.

And it was the time when Douglas Englebart, looking about him and seeing that the human race was "in trouble," committed his career to the "augmenting of human intellect." Had Englebart been given the resources to realize more of his "Framework," he might have been the prolific Michaelangelo of the computer renaissance, demonstrating how to do many difficult things with maximum expressivity. As it was, he has been a kind of Leonardo, accomplishing much, indirectly influencing much, but leaving behind the unrealized plans for even more. Englebart did not think of the computer as merely improving human thinking, but as transforming the processes of our institutions in a more profound way. The "augmented institution" as he saw it would change not into a "bigger and faster snail" but would become a new species, like a cat, with new sensory abilities and entirely new powers. The evolutionary metaphor is an expression of awe at the magnitude of the shift, a way of sharing the shiver of terror at the unfamiliar rush of mind-power that makes us wonder if we might be capable of outthinking our very humanity.

By the end of the 1960s the engineers had a good understanding of the potential of the computer. They were supporting large databases, experimenting with on-screen images and game-like interaction, establishing networked systems that could be accessed by remote terminals with multiple users sharing the same mainframe, and building large-scale simulation systems. Although the machines themselves were slow and of little capacity by current standards, and were primarily used for number crunching,

they had been developed well enough to make concrete Turing's vision of a universal machine. A decade before the development of "multimedia" and at the point when "hypertext" was just a concept, the sheer representational power of the computer was apparent to those who were leading its development. They realized that the whole of the medium was much more than the sum of the various enabling technologies.

As I have argued elsewhere, the awe-inspiring representational power of the computer derives from its four defining qualities: its procedural, participatory, encyclopedic, and spatial properties. The most obvious property of the new medium, the one most clearly needed by the post-war world, was its encyclopedic capacity. The digital computer is simply the largest medium human beings have ever invented, the one capable of holding the most information. In the 1960s much of that memory was on tape or punch cards, and dependent on linear reading. In the succeeding decades it reached dizzying thresholds of random access availability, with exponential increases becoming the norm. But the deeper encyclopedic potential of binary representation itself was clear from Turing's time. If the computer is a universal machine, capable of representing anything, then can it represent all of human knowledge? Like other capacious technologies (print, moving images) which the computer contains, it calls forth our desire to get everything in one place, to get, as William Faulkner once described the aspiration of the novelist, the whole world in one sentence.

Furthermore, the computer can present itself to us as a place, one which we enter and do not wish to leave. This enveloping quality derives from the spatial property of the medium, its capability for embodying dimensionality. That is, we can place things within it in assigned locations, both actual (as registers within the machines) and, more importantly, symbolic (as on a Web "site," or in a dungeon under a trap door within a fantasy environment). These locations are more than merely labels because we can navigate by them, and they will be consistent relative to one another. This spatial quality made the early text-based dungeon games like *Adventure* ⊗ and *Zork* enormously successful. This spatializing quality is based upon the other two properties of the digital medium, the two most basic and defining attributes: its processing power, which allows us to specify procedures which will be not merely recorded but executed; and its participatory quality, which allows it to receive input, to allow manipulation of its processes and data by the user. The creation of the illusion of space within the machine, which can be achieved with only a text-based display, is the result of its capacity for accepting navigational commands from us and then responding according to its programming in a consistent manner that reinforces our notion of space. That is, we can program the responses of the computer to simulate any space we can imagine, displaying "north" and "south" or "left" and "right" appropriately so that the participating user will form a reliable mental map of the symbolically represented territory. But even though this "spatial" property is derivative of the procedural and participatory properties, it is so fundamental to the way we experience the world, and so desirable a means of representing the world, that we have to think about it as a property in itself. It is not accidental that we refer to information in digital networks as existing in "cyberspace," or that the first computer game to be massively distributed by network was a text-based exploration of a virtual cave.

Together the two properties of encyclopedic capacity and spatial navigability create the experience of enclosure in explorable, extensive spaces. These can be fictional landscapes, like Borges's labyrinthine garden, or they can be information spaces, like Bush's memex machine. The sense of following a trail is the same in both cases, and it is a sense that creates the pleasurable experience of immersion, of moving within a capacious, consistent, enveloping digital environment rather than just looking at it.

But the more fundamental properties, the procedural and participatory foundation of the computer, are the ones that provide the basis for what we think of as the defining experience of the digital medium, its "interactivity." Although this word is often used loosely it can be thought of as encompassing these two properties, and also the pleasure of agency, the sense of participating in a world that responds coherently to our participation. We do something with the computer—whether it is shooting at a fantasy enemy or manipulating words or images or moving from one Web site to another—and it processes our input and responds in a way that makes sense to us. Because of the interactive nature of the medium, the computer environment is not just

immersive, it is animated. This effect was clear from the introduction of the computer workstation in the 1960s, when the new conversational structure of programmer and processor, keyboard and display, connected in real time provoked playful applications like the therapist Eliza ⊗ or the dungeon and dragon of *Adventure* ⊗. Both of these inventions took advantage of the streamlined interactivity of the new environments. They elicited engagement from an interactor, and they responded to that engagement in a way that made clear the animating rules of the computer's world.

The invention of Eliza is particularly instructive. Unlike early hypertext systems that were developed in answer to the vision of the memex, Eliza far exceeded expectations. Eliza's persuasiveness, her existence not as a program but as a perceived human being, as a character capable of inspiring theatrical belief, came as a shock to Joseph Weizenbaum. Turing had called for a similar system as a test of the powers of the computer to simulate a human being in free conversation, but Weizenbaum was offended by such confusions and dismayed to have inadvertently created a program that was mistakenly believed to have passed the Turing test. The widespread confusion over Eliza's potential as a real rather than a simulated and comic therapist, and Weizenbaum's attempts to straighten people out, were symptoms of the gap between our new ability to make digital artifacts and our inability to understand what we were making. Weizenbaum came to terms with his creation only after he was able to describe it in literary terms. His secretary who thought Eliza was a real therapist and his computer scientist friends who were charmed by her despite their understanding of the code were not deluded; they were merely engaging in the willing suspension of disbelief, as Coleridge had pointed out that theater goers do. But he missed the importance of this event: the discovery of a new literary medium, like the play or the novel or the sonnet—a medium that consisted of the writing of procedural rules and the engagement of an improvising interactor with the rule-governed system.

With the invention of Eliza, the computer had reached an important milestone: it had achieved the illusion of life through the rules of behavior. But it was not until the 1980s that practice became self-conscious enough to allow for a serious discourse about digital artifacts. For while computer scientists were laying down the technical foundation for such immersive and interactive environments, humanists were expanding our theoretical grasp of technologies of representation. Cultural critics and communications researchers, responding to the growth of television in the 1950s and its expansion in the 1960s, focused our attention on the media experience itself as a subject of analysis and encouraged a new interest in analyzing the varieties of media experiences. Newer media such as photography, radio, film, and television could now be seen in the longer history that stretched back beyond the printing press to oral composition and the invention of writing. Marshall McLuhan (◊13) in particular brought interest in media to the forefront with his playful and insightful aphoristic writings. Like the computer scientists who were inventing the foundational technologies of the coming Internet, McLuhan saw media as "extensions of man," a means to augment our powers of perception and communication. He celebrated this change, but he did so in the tone of an old testament prophet, acknowledging the threatening as well as the thrilling aspects of this new communicative power. Other critics were more distrustful, seeing the mass media as the means by which the existing power structures maintain the status quo. The basis of the much of the popular and academic discourse on the media of later decades begins in the 1960s with this fascination with, and distrust of, television. As a result digital enthusiasts often described their efforts as remediating the dangers of television (for example, in allowing two-way instead of only one-way communication), and digital skeptics condemned the new medium as amplifying the destructive powers of television (for example, in exercising even greater holding power over consumers, further alienating them from the "real" world).

The technophobic response to computers, which was strong throughout the period covered here, was also an important part of the story, and it should continue to be so. The augmenting of human intellect remains an uncertain and even a perilous activity. Hitler's genocidal efficiency was made possible by sophisticated information processing. The census tools he relied on are mere crayon scratches compared with those a tyrant could now command to automate the knowledge of everything from our reading habits to our DNA. Surveillance can now be extended not just inside the walls of our houses but inside our brain where we can witness the retrieval of a memory almost neuron by neuron.

New media in any age are always distrusted media. Prometheus is a hero to some and a transgressor to others, and both are right. Fire warms and fire burns. It remains to be seen which of the anti-technological voices from the second half of the twentieth century will be of lasting importance. The technophobic response is most clearly useful when it spurs us to question the uses to which we put technology and to guard against the dangers of abuse. It is perhaps less persuasive when arguing the abandonment of a medium—whether it is print, photography, television, or computers—or when it argues for the cultural or moral superiority of one means of expression over another, regardless of the content. But the anxieties aroused by a new medium are real, and worthy of attending to. The critics of technology are an important part of the development of a new medium because they challenge us to identify more clearly what we find so compelling about it, why we are so drawn to shape this new clay into objects that have not existed before.

Throughout the 1970s the humanities expanded its critical vocabulary and sophistication in understanding the process of representation, applying the same focused analysis to mass communication and cultural rituals (such as advertising posters and sports events) as had formerly been directed toward great works of literature. And as the postwar babies came into maturity, eager to understand and transcend the destructive history of the 20th century, ideology itself became an important subject of study, especially its embodiment in cultural artifacts within both high and low culture. The political insights of the 1960s combined with the methodologies of semiotics and its successors were applied to every aspect of human society, including the discourses of humanism itself—with devastating results. The great pillars of knowledge and social coherence were exposed as tyrannical at worst, delusional at best. All was ideology, and at the bottom of these vast nested pyramids of ideological representation was language itself, which was left to point at nothing real beyond our own consciousness, nothing external beyond our shared hallucinations. The signifiers of cultural discourse by which we defined our lives—faith, love, gender, family, nation, morality—pointed at one another in a dizzyingly infinite regression. In short, for humanists of the late 20th century the tools of analysis were increasing, but the content of the analysis was disorienting. We understood how human beings constructed meaning better than we had ever done before; but we no longer could believe in anything that we asserted. This condition, which came to be thought of as postmodernism, was one that called for new forms of artistic expression that simultaneously utilized and distanced themselves from the great traditions of cultural expression. It was the age of the put-on, an ironic age in which even the most exuberant expressions had a bitter aftertaste, and much of the most ambitious work possessed a cold derisive quality, a sense that everything had been said before and that it was all lies. Academic discourse was infected with word-play that substituted allusion for assertion as its prevalent rhetorical style.

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For the computer scientists, on the other hand, the 1970s were a time of great earnestness and exhilarating possibilities as the computer was coming into its own as a new medium of representation. But while educational innovators like Alan Kay (◊26) and Seymour Papert (◊28) were celebrating the computer as a new and powerful tool for the active construction of meaning, artists and humanists were celebrating deconstruction, finding evidence in high and low culture throughout the world of the inevitable unraveling of meaning. All throughout the 1970s while university-based researchers were enjoying the new Internet technologies, and the computer was growing as a vehicle for connection and imaginative engagement—the discourse of humanism was growing increasingly fragmented and distrustful of the constructive imagination.

Of course the humanists were not inventing the postmodern condition—they were merely chronicling it, registering and giving form to the cultural anxiety caused by the loss of faith in the great human meta-narratives of sacred and secular salvation. At the heart of the most ironic deconstruction of outworn conventions was a celebration of expressivity itself, a delight in throwing off the monolithic straightjacket in favor of an antic, mutable series of costumes, of foregoing the longing for the end of the story in order to revel in the possibilities of the middle. What was missing was a form that could contain so many middles and such a sustained refusal of an ending.

The 1980s marked the beginning of the shift. For many humanists a key component of this change was provided by Deleuze and Guattari (◊27) who, without thinking of

computers at all, offered a metaphor for intellectual discourse that served as a bridge for many humanists to the otherwise alien world of the machine. The two philosophers suggested a new model of textual organization to replace the ideologically suspect hierarchies of the old print-based world. The new ideal of form was the rhizome—an erudite word for a very down to earth thing: a potato root system. It was as if Deleuze and Guattari had dug beneath the forking path garden of Borges (which after all was still a hierarchy of sorts) and come up with an even more profound labyrinth, but one that offers the hope of knowability and a metaphor of healthy growth. The potato root system has no beginning, no end, and grows outward and inward at the same time. It forms a pattern familiar to computer scientists: a network with discrete interconnected nodes. Here was a way out of the pullulating paralysis, one that went beyond the subversion of all existing hierarchies. Here was a way of constructing something new. The humanist project of shredding culture had found a radical new pattern of meaning, a root system that offered a metaphor of growth and connection rather than rot and disassembly.

The gift of this metaphor at the beginning of the 1980s coincided with the introduction of the first personal computers and the introduction of word processing software, bringing a new accessibility of computational power to those outside the computer lab. At the more privileged educational institutions, the 1980s brought gifts of equipment and grant money that allowed for hitherto unprecedented collaborations between engineers and humanists. George Landow at Brown University, Gregory Crane at Harvard, Larry Friedlander at Stanford, and others gained access to sophisticated computational systems and began applying them to the representation of networked knowledge systems, working in fields such as Victorian culture, Ancient Greece, and Shakespeare. In North Carolina, J. David Bolter (◊47), Michael Joyce (◊42), and John Smith invented Storyspace, a hypertext system specifically designed for storytelling, which greatly expanded the use of computers in the humanities. With the arrival of HyperCard and similar notecard-based systems the personal computer came into usefulness throughout the educational system as a location for the creation of educational resources by teachers and students, rivaling the development of textbooks. These authoring environments and applications programs of the 1980s marked a new era in the expressiveness of the medium, by opening up the encyclopedic and spatial properties of the computer to wider communities of practices, communities composed not of programmers but of artists, writers, and educators.

While the academically-rooted experiments with hypertext took their course and found their enthusiastic but relatively small audiences, the video game was growing into a entertainment form to rival movies and television. Video games were successful because, as Brenda Laurel (◊38) pointed out, they exploited the computer's capacity to "represent action in which humans could participate." The videogame also won over the young to the new medium and developed an expanding vocabulary of engagement, including ever more detailed and intricate elaboration on the theme of the violent contest as well as increasing interest in creating detailed, immersive, expressive story worlds.

The expansion of practice was accompanied by another mark of a maturing medium, the moment at which computer practice became widespread enough to become an object of study in itself. Sherry Turkle (◊34) offered the foundational view of the psychosocial dynamics of the digital medium, calling it a "second self" upon which we projected consciousness, and an "evocative object" which had tremendous "holding power" over the interactor. The first online communities were forming and began to display the complex social relationships so well captured in the account by Morningstar and Farmer (◊46) of Lucasfilm's Habitat. The conflict between player killing and community building in that world was mirrored by the conflict between those, like Richard Stallman (◊36), who wanted a distributed, cooperative open programming community and the commercial influences, now personified by Microsoft, who wanted to standardize development on closed, centrally controlled systems. The computer began to emerge as a noticeable entity in the social world, with its utopian and dystopian promises now the subject of explicit policy debates.

The 1980s also marked the beginning of our understanding of interactive design as a new field of study, the beginning of the self-conscious creation of digital artifacts not by small teams of researchers but by a newly defined profession. Apple established guidelines for its graphical user interface, allowing multiple developers to use

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the same conventions for the same functions. The original focus of design, building on the industrial design insights of Donald Norman and others, placed emphasis on the "interface." Shneiderman (◊33), Laurel (◊38), and Winograd (◊37) moved the emphasis to the human actor and the shaping of the interaction. This change was marked by the movement of the field from Computer Human Interface to Human Computer Interaction, from CHI (which is still the designation of the special interest group of the ACM which holds the central meeting in the field) to HCI (which is what universities now teach and give degrees in).

The humanities and arts became more visible to the engineers as computers became more available to the humanists. The spatial property of the medium brought forth a new interest in architecture; the participatory property provoked interest in improvisational theater. The teams who produced new application software, new educational environments, and new "multimedia" games became intentionally interdisciplinary. As they struggled to understand one another's conflicting design criteria, new academic programs arose to educate professionals for a rapidly morphing field.

By the end of the 1980s the computer had emerged as an everyday tool for business, education, and entertainment. But it was primarily a desktop tool, networked to a few co-workers perhaps. Those who were using the Internet on a regular basis were mostly using it for email or for the uploading and downloading of files between home and office machines or perhaps among a small circle of close collaborators. This was to change dramatically with the invention of the World Wide Web, which is the subject of the final essay in this anthology.

It is fitting that this chronicle of joint invention ends with Tim Berners-Lee (◊54), who is both inventor and culture hero. Berners-Lee set out to solve a technical problem of information flow, to simplify the communication of the worldwide community of physics. He changed the model of communication from passing around containers of information (streaming bits identified by filename) to passing around viewable documents (Web pages). By displaying the documents on the screen and at a distance, he opened up the possibility of a true global library, an ultimate Alexandria. He also, somewhat inadvertently, opened up a new marketplace. The World Wide Web stands at the crossroads of many of the strands within this volume, combining Stallman's passion for open standards with Negroponte's (◊23) enchantment with "bits" (replacing "atoms") as a global commodity. It is the best embodiment so far of the encyclopedic, labyrinthine fantasies of the memex and the potato garden. It allows for previously unimaginable levels of surveillance—webcams operating 24/7 in the service of science, tourism, exhibitionism, policing, stalking, and even pure whimsy, monitoring, for instance, the state of a coffee pot in a lab halfway around the world. The Web also provides participatory experiences with such ease of availability that gaming is often described in the press as a threat to productivity in the office and to learning from kindergarten through college. And over the horizon is a faster connection, a bigger data pipe, a more elegantly designed indexing, retrieval, and display system, a more tactile interface, a more complete convergence of entertainment media into interactive TV and of museums, libraries, universities into a single digital information source. The title of one active current field of design could stand as summary for the whole effort at the turn of the 21st century: we are moving toward a world of *ubiquitous computing*. And a key enabling technology behind this change is the coherent transmission of information across multiple platforms with standardized protocols like those that now underlie the Web.

But as important as Tim Berners-Lee's technical work is his role as culture hero of the information age. Instead of commercializing his invention, Berners-Lee established an open Web standard, administered in the interest of uniting all the worlds' information sources into ever larger and more coherent units. Berners-Lee's grand gesture of renunciation (as it is often described) is a counter-fable to the one with which this anthology begins. The spy in the forking garden is a tool of the meaning machine, bound to transmit messages at any cost (messages that carry no meaning to him) in obedience to the prevailing social order, the order of competition to the death. The Berners-Lee fable, on the other hand, celebrates a refusal to commodify the message, an affirmation of meaning over money, of world cooperation over global competition. It offers a way out of the pullulating, paralyzed consciousness of meaningless. It offers a fulfillment in part of Bush's vision. In the world of structured Web pages, we agree on metadata that will link one bit of

information with its counterpart across the globe, annotated by another hand. We make multiple patterns and change them kaleidoscopically to express many views of the same data, the same object, the same event. The promise of the Web, not as it is, but as it could be, is like that of the book before it: it will allow us to say more complicated things to more people with greater understanding. The promise is that we will not be crushed by our own knowledge, as the writers at the beginning of this period anticipated, because we will organize it together in a vast distributed and synchronized effort. We will not be mere prisoners of the labyrinth, nor even trail-blazers: we will be the makers of the labyrinth, the gods of our own machines.

Perhaps the most amazing thing in all these essays is the record of perseverance. What would make us engage with machines for fifty years despite their core stupidity, their 0s and 1s and their propensity to crash, their maddening literalness and oblivious torpor? Why do we struggle to make them coherent and expressive despite all that can be said of their inhuman rigidity and still primitive state? Why do human beings choose at this time in our cultural history to communicate with one another by making complex artifacts out of electrical impulses? For the same reason that we couldn't put down the stylus or the whittling knife. We are drawn to a new medium of representation because we are pattern makers who are thinking beyond our old tools. We cannot rewind our collective cognitive effort, since the digital medium is as much a pattern of thinking and perceiving as it is a pattern of making things. We are drawn to this medium because we need it to understand the world and our place in it.

To return to Bush's speculations: now that we have shaped this a new medium of expression, *how may we think?* We may, if we are lucky and mindful enough, learn to think together by building shared structures of meaning. How will we escape the labyrinth of deconstructed ideologies and self-reflective signs? We will, if we are lucky enough and mindful enough, invent communities of communication at the widest possible bandwidth and smallest possible granularity.

We need not imagine ourselves stranded somewhere over the evolutionary horizon, separated from our species by the power of our own thinking. The machine like the book and the painting and the symphony and the photograph is made in our own image, and reflects it back again. The task is the same now as it ever has been, familiar, thrilling, unavoidable: we work with all our myriad talents to expand our media of expression to the full measure of our humanity.