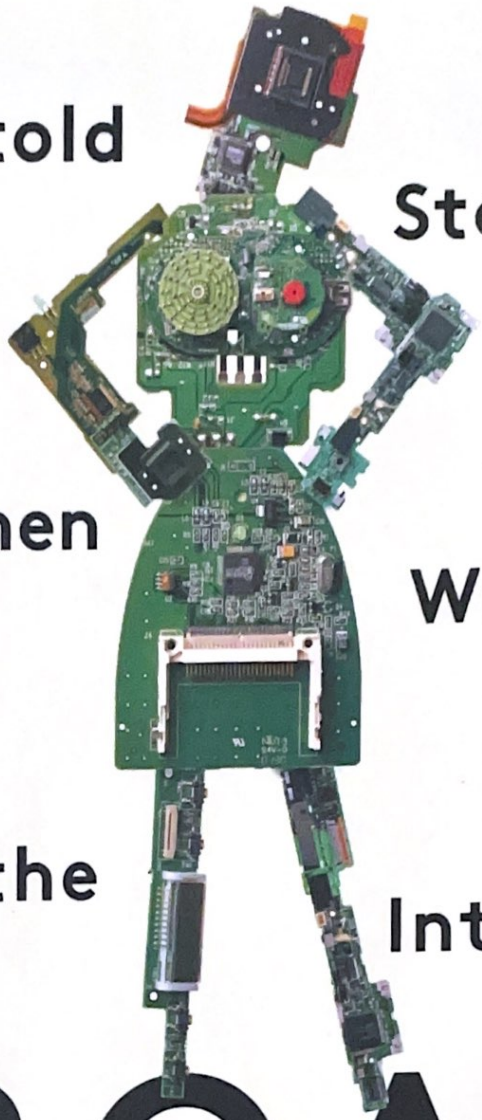
The Untold Story of the Women Who Made the Internet



BROAD BAND

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Chapter Ten

HYPERTEXT

When we say the words "Internet" and "Web" today, we often mean the same thing: the force, larger than nature, that emanates from our screens. But "Internet" and "Web" are not interchangeable; as we've learned from Echo, people were connecting online for decades before graphical Web pages appeared on the scene. They dialed directly into each other's machines and into host computers to exchange files and post messages, as on Echo or The WELL, or they participated in commercial online services like AOL, CompuServe, and Prodigy. Before the Web, when people talked about the "Net," or "going online," this is usually what they meant. Many of these ad hoc networks interacted with, and eventually coalesced with, the infrastructure of the Internet, which finally hit critical mass when the ARPANET's successor, the National Science Foundation's NSFNET, gave way to the network we use today, with the appearance of commercial Internet service providers, in 1994.

It was a great complication. Early maps of ARPANET were easy to read: a few nodes placed in America's academic and military capitals radiating in straight lines of wire and fiber. As the amount of nodes increased, the maps grew busier and the straight lines multiplied, softening into wide curves to accommodate their multitudes. Finally, the

geographical background disappeared from Internet maps, and the network itself went sovereign. Today, a map of the Internet is a tensile, crazy, fractal thing; it resembles a beating heart, a web of synapses, a supernova.

On top of all this sits the World Wide Web, a network of interconnected visual pages built in a shared language called HTML, or Hypertext Markup Language. "Hypertext" is not a word we use frequently today, but much of the Web is built from these hypertext documents: structured pages of text, images, and video dotted with clickable links connecting individual points to one another. Those connections don't just influence how we *navigate* the Web—Google built its empire on a search engine that brought up Web pages with the highest number and quality of hypertext links—but how we communicate with one another, and ultimately how we understand the world.

In a way, it's fundamental. The Talmud is a hypertext, with layers of annotations arranged in concentric rectangles around a theological heart. Any text referencing another is considered a form of hypertext: sequels, which begin where the last page of the previous book left off; footnotes; endnotes; marginalia; and parenthetical asides. Sprawling, self-referential novels like *Ulysses* or *Finnegan's Wake* are like flattened hypertexts, and scholars love to cite "The Garden of Forking Paths," a short story by the Argentine writer Jorge Luis Borges, as the height of precomputer hypertext. "This web of time," Borges wrote, "the strands of which approach one another, bifurcate, intersect or ignore each other through the centuries—embraces every possibility." He may have loved the World Wide Web.

The Web as we know it isn't modeled on Borges, Joyce, or the Talmud. The most famous hypertext pioneers are men—Doug Engelbart, Jake Feinler's mentor at Stanford, incorporated hypertext into his oNLine System, and Ted Nelson, a Bay Area counterculture hero, coined the word and has championed utopian hypertext ideas for decades—but the Web appeared on the scene only *after* hypertext principles and conventions had been explored for nearly a decade by brilliant female researchers and computer scientists. They were the architects of the hypertext

systems that time forgot, systems with names like Intermedia, Microcosm, Aquanet, NoteCards, and VIKI, the earliest ontological frameworks of the information age. Hypertext is, in many ways, the practice of transforming pure data into knowledge. And like programming a generation before, it was where the women were.

MICROCOSM

To understand hypertext, I've turned to one of the brightest computer scientists in the world. Dame Wendy Hall is a garrulous, strawberry blonde Brit with a disarmingly warm manner and a busy calendar. We're talking over Skype, nine hours apart. Wendy, who was appointed Dame Commander of the Order of the British Empire—the female equivalent of being knighted—in 2009 for her contributions to computer science, is in a hotel room in London, dressed for dinner. I'm in my pajamas, drinking coffee, surrounded by index cards, in my office in Los Angeles. For reasons I don't yet understand, she has chosen this moment to catch me up on medieval European history.

The Battle of Hastings, to be precise. "It's something we learn about in history," Wendy tells me, unsure if news of William the Conqueror's eleventh-century triumph ever made it stateside. William the Conqueror earned his nickname by invading England from its southern coast and defeating the last Anglo-Saxon king, Wendy explains, as I indulge this diversion. A few years later, he decided to take stock of his spoils, the entire Saxon kingdom. He ordered an audit of everything he owned. "Every cow, every sheep, every person, every house, every village, everything," she says. "They went 'round, by hand, counting everything up."

The result was an unusual book, now invaluable to historians, detailing the minutiae of the Saxon world, the only survey of its kind. Because the judgments made by the Norman assessors who compiled it were supposed to be definitive, native English people called it the *Domesday Book,* Middle English for "Doomsday Book." As the British cleric Richard FitzNeal wrote nearly a century later, decisions made in the

Domesday Book, "like those of the Last Judgement, are unalterable." The *Domesday Book* is what led Wendy Hall, in a circuitous way, to her career creating hypertext systems long before the dawn of the Web.

In 1986, as Wendy was beginning her teaching career, the BBC—"that's the British Broadcasting Corporation," she reminds me, gently—celebrated the nine hundredth anniversary of the *Domesday Book* by updating it for the modern world, issuing a new British census on a pair of multimedia video LaserDiscs, then the height of technological sophistication. They called them, of course, the *Domesday Discs*. More than a million people contributed to the project, which became a massive volunteer time capsule encoded in bits and light. "Every school in the country was asked to send in three photos of their area," Wendy explains. Schoolchildren wrote accounts of their day-to-day life; Britons sent in photos of office parks, pubs, and windmills. One child, from the village of Spennymoor, contributed this spot-on prediction of the future:

> Robot limbs will be used when natural limbs are lost.
>
> Computers will take over much of the diagnosis now made by doctors.
>
> Food will be made tastier by artificial means.
>
> Children will learn chiefly by computers.

This crowdsourced survey made up the first of the two *Domesday Discs;* the second was filled with interactive material about British heritage, government, and royalty, including census data and some early virtual reality–like tours of notable sites. When Wendy saw the *Discs* for the first time, they blew her away. It wasn't the information that impressed her as much as the *way* it was displayed. "The ideas were stunning," she tells me. The *Domesday Discs* were interactive, using interconnected links that could be navigated with a pointer, much as we're accustomed to doing on the Web today. For Wendy, moving with ease from first-person reflections on British life to census data and 3-D photo tours was

a rich, rewarding, and immersive experience. She'd never seen a computer do anything like it before.

Of course, she'd never been much interested in computers. Although her alma mater, the University of Southampton, was one of the first schools in the United Kingdom to teach computer science, Wendy was a student of pure mathematics. According to her doctoral adviser, Wendy was in those years a "shy and retiring student," working in an area of topology "so obscure that to this day I can't understand the title of the thesis." She learned some programming in a first-year course but found it tedious and impersonal. "I was happy in my world of mathematics, and really didn't see, then, that computers would ever really offer me anything," she told a radio interviewer in 2013. But once she saw the *Domesday Discs,* she overlooked her distaste. Suddenly, she understood what kinds of experiences computers could make possible, and as personal computers began to appear in the United Kingdom, "I began to see the future," she says.

Not everyone saw it as clearly. When Wendy returned to the University of Southampton after a stint teaching mathematics to trainee teachers, she accepted a lecturing position in computer science, but her enthusiasm for multimedia was out of step with the established views of the department. "One professor told me in public once that if I carried on doing this multimedia work, there was no future for me at Southampton or in computer science," she remembers, "because I wasn't writing compilers, or new programming languages, or doing operating systems." Many of her colleagues didn't consider interactive multimedia to be real computer science—it was seen as something fluffy, less serious, far closer to the humanities than to classical programming.

But Wendy couldn't shake the glimpse of the future she had seen: a future where images, texts, and ideas were connected through intuitive screen-based links, and computer screens were approachable to all. In 1989, she left Southampton and took a job at the University of Michigan, where she immersed herself in American tech culture, went to conferences, and finally learned that clickable multimedia on computers was indeed a serious discipline, and that it had a name: the Americans called

it "hypertext," or "hypermedia." Although her interests seemed out there to most of her British colleagues, she was right at the cutting edge in the United States. She returned to Southampton with a blinding vision for a new hypertext system. In order to explain it, she takes me back in time—again.

This time, we jump decades instead of centuries. Wendy tells me about the Earl of Mountbatten, a second cousin of Elizabeth II. Mountbatten is something of an avatar for twentieth-century Britain. As last Viceroy of India, he oversaw the country's transition into a modern republic. He captained a naval destroyer during the Second World War, and was appointed by Churchill to Supreme Allied Commander of the Southeast Asian theater, where he oversaw a bloody Burmese campaign under monsoon rains. He met Stalin. He met Emperor Hirohito. However, his prominence in British colonial history made him a target. In the summer of 1979, long after his retirement, as Mountbatten was lobster potting from a wooden boat off the coast of County Sligo, he was assassinated along with his family by the Irish Republican Army. They bombed the boat to pieces, blowing his legs almost clear off.

The Mountbattens lived in Romsey, a market village so old the medieval *Domesday Book* made note of its three water mills. According to the schoolchildren who surveyed the village for the *Domesday Disc* project, among the most salient features of life in Romsey in 1986 were a preponderance of punks ("Their spare time, of which they have a lot, is spent hanging around with friends, sometimes playing space-invader machines, with money from dole"), a beloved fish shop, a Waitrose supermarket, and Broadlands, the Palladian estate where the Earl of Mountbatten entertained royal visitors. Broadlands sits on the River Test, which only ten miles south flows past Southampton to join the briny waters of the English Channel. As it happens, the University of Southampton is known for its archives—which is why, after his violent assassination, the records of the Earl of Mountbatten's considerable life ended up in its library.

At Southampton, the Mountbatten archive joined millions of manu-

scripts, but it was distinctly modern in comparison to most of the library's holdings. Because Mountbatten's public life transected all the touchstones of twentieth-century media, the library inherited some fifty thousand photographs, speeches recorded on 78 rpm records, and a large collection of film and video. There was no linear sequence to the material, save chronological order, and no hope of fitting it neatly into a database. Ten years after the library's acquisition of the Mountbatten archive, Wendy Hall returned from her hypertext sabbatical in America.

Not long after she'd settled back in, she heard a knock at her office door. Word of her interests had drifted from the computer science department to the library. "The archivist came to see me," Wendy remembers, "and he said, 'Couldn't we do something wonderful? I've got this multimedia archive, it's got pictures, it's got film and it's got sound. Couldn't we put it on a computer and link it all together?' And that was the beginning."

The Mountbatten archive was the perfect test case for a hypertext project: a vast, interrelated collection of documents spanning many different media, subject to as many interpretations as there could be perspectives on the last century of British history. Wendy put together a team, and by Christmas 1989, they had a running demo for a system called Microcosm. It was a remarkable design: just as the World Wide Web would a few years later, Microcosm demonstrated a new, intuitive way of navigating the massive amounts of multimedia information computer memory made accessible. Using multimedia navigation and intelligent links, it made information dynamic, alive, and adapted to the user. In fact, it wasn't like the Web at all. It was better.

Microcosm's core innovation was the way it treated links. Where the Web focuses on connecting documents across a network, Wendy was more interested in the *nature* of those connections, how discrete ideas linked together, and why—what we would today call "metadata." Rather than embedding links in documents, as the Web embeds links in its pages, Microcosm kept links separated, in a database meant to be regularly updated and maintained. This "linkbase" communicated with

Wendy Hall demonstrating Microcosm in her research lab in the Department of Computer Science at the University of Southampton.

documents without leaving a mark on any underlying document, making a link in Microcosm a kind of flexible information overlay, rather than a structural change to the material.

To use one of Wendy's examples, say I'm browsing the Mountbatten archive using her system, Microcosm, circa 1989. I'm interested in Mountbatten's career in India, a two-year period during which he oversaw the country's transition from colonial rule to independent statehood. This history has its recurring characters: his field marshal, the leader of the Indian National Congress, Jawaharlal Nehru, and of course, Mahatma Gandhi, whose name is everywhere in the source material. Say also that within the Microcosm linkbase, an instance of the name "Mahatma Gandhi" has been linked to some multimedia information—a video, perhaps, of a Gandhi speech. Because of the nature of Microcosm links, that connection isn't isolated to a single, underlined, hyperlink-blue instance of those words. Rather, it's connected to the *idea* of Gandhi, following the man wherever his name may turn up, across every document in the system. Further, if I were to bring a new document into

Microcosm, the system would automatically identify any words corresponding to links in the linkbase and update it accordingly. Imagine the analog on the Web we know today: for every name, for every idea, *for every linkable thing,* a single repository of supplementary material, updated by everyone in the world, filtered based on parameters determined by the user.

Links in Microcosm could be tailored to the user's knowledge level and could point to several places in the linkbase at once. Microcosm was even able to dig up new links on the fly by running simple text searches on all the material in the system—a prescient design that anticipated the importance of search in navigating information. This "generic" linking, in concert with linkbases, created a system that could adapt to its users while presenting them with more opportunities to learn. "Links in themselves are a valuable store of knowledge," Wendy explained. "If this knowledge is bound too tightly to the documents, then it cannot be applied to new data." Which is to say: where one instance of a connection might be interesting, multiple instances, expressed laterally, look more like truth. By making space for this generic knowledge, Wendy's system placed value on the association *between* documents, rather than on the documents themselves. To hypertext's small but active community of scholars, this is what the field was all about.

In the years between 1984 and 1991, a flurry of hypertext systems like Microcosm emerged from universities and from research labs at technology companies like Apple, IBM, Xerox, Symbolics, and Sun Microsystems. Each suggested different linking conventions, spatial associations, and levels of micro- and meta-precision over contained corpora of information. If this sounds dry, remember that managing, navigating, and optimizing information is a central pursuit of modern life—we do it fifty times a day before breakfast—and that each one of these systems had the potential to become as important to us as the Web is today.

The young discipline of hypertext was heavily populated with women. Nearly every major team building hypertext systems had women in senior positions, if not at the helm. At Brown University,

several women, including Nicole Yankelovich and Karen Catlin, worked on the development of Intermedia, a visionary hypertext system that connected five distinct applications into one "scholar's workstation," and invented, in the process, the "anchor link." Intermedia inspired Apple, which had partially funded the project, to integrate hypermedia concepts into its operating systems. Amy Pearl, from Sun Microsystems, developed Sun's Link Service, an open hypertext system; Janet Walker at Symbolics single-handedly created the Symbolics Document Examiner, the first system to incorporate bookmarks, an idea that eventually made its way into modern Web browsers.

For women interested in the nature and future of computers, hypertext was far more collegial than other areas of computer science, which was at that time seeing a rapid decline in female participation at both the academic and professional level. The reasons for this aren't cut-and-dried, but they reflect some of the same tendencies at play over previous generations. While "the whole foundation of hypertext is collaborative," suggests Intermedia's Nicole Yankelovich, and "collaborative work appeals to women," hypertext was also, like programming before it, an entirely new field, a clean slate upon which women could mark their place. Further, hypertext was open to scholars from outside computer science departments, who emerged from such wide-ranging disciplines as interface design and sociology. What these people shared was a humanistic, user-driven approach. To them, the final product wasn't always software: it was the *effect* software had on people.

But I don't really get that until I start talking to Cathy Marshall.

NOTECARDS

Cathy is a hypertext researcher who spent most of her professional career at Xerox PARC, a Palo Alto think tank founded by the printer company in 1970 to help invent the paperless office of the future. "I have to ask you a little about your process," she says, in our first interview.

Interviewing hypertext researchers entails its share of going under the microscope: many of them have never shaken their professional in-

terest in how people organize their thoughts. The second time Cathy and I talk, I find myself describing to her my office pin board of index cards and serial killer–like yarn threads. She shares her own approach. "If I write something and if it doesn't work, I'll throw out the whole thing and start again," she tells me. "I don't think you lose what you've written. It's still in your head. Over time, what you're doing is changing what's in your mind—what's on paper is just incidental." She makes this comment offhand, but the insight knocks me out. That's what software is, I realize: a *system for changing your mind.*

Cathy grew up in Los Angeles and was one of the first women to attend CalTech, after it went coed in 1970. She was only sixteen, small—under five feet on a good day—and mildly averse to math and science; the summer she matriculated, she was more interested in *The Rocky Horror Picture Show,* J.D. Salinger, and macramé than differential equations. When she asked for help, she remembers one professor who told her she'd be better off as a housewife—"my housewifing skills are even worse than my math skills," she thought at the time—and another who waited until the day she missed class to tell a dirty joke. A fellow student filled her in on the punch line, which she still remembers, something about a whorehouse keeping down the "fucking overhead." It wasn't the joke that bothered her—it's that the professor waited to tell it. "I felt so conspicuous and weird," she says.

When she graduated from CalTech with an English degree, she started working as a systems analyst for a company that did radars and signal processing in Santa Monica. Her office had a view of the ocean, but she wrote utility code for a Prime microcomputer, about as dry a technical job as you could get in those days. She went to work at Xerox PARC in the mid-1980s. Even outside computing circles, PARC was known for its freewheeling, hothouse approach: engineers worked alongside anthropologists on a terraced campus built into a wooded hillside overlooking Silicon Valley, and important meetings were held in a room full of corduroy beanbag chairs, low and cozy enough that nobody would be tempted to jump up and attack anyone else's ideas.

After so many years of feeling like an outsider, Cathy worked hard

to become part of Xerox PARC's unorthodox workplace culture. "The thing I loved most about PARC is that it was really multidisciplinary," she remembers. "I think it would be hard to find a place that was like that now. They weren't afraid to hire people that had different kinds of backgrounds." The mix was fun: she'd sometimes get silly with the computer scientists, putting Ivory soap in the office microwave until it made huge piles of snaking froth, and she participated in PARC's Artist-in-Residence Program, which paired artists with technologists to create ambitious new media works. Her partner, Judy Malloy, a poet, would often cut a sideways path across the PARC campus, through a field with horses and under a barbed-wire fence, just to pass by Cathy's office window and wave hello.

NoteCards, the first system Cathy worked on at Xerox PARC, was modeled after the kinds of old-school writing techniques about which we'd soon find ourselves debating the relative merits. The software emulated "the way you wrote papers when you were in junior high: with notecards and file boxes." Using hypertext links, users could chain their cards into complex collections, sequences, and mental maps, modeling their thought processes and making it easier for others to understand their conclusions. NoteCards wasn't a writing tool, and it wasn't an information browser like Microcosm, either. When pressed, Cathy calls it an "idea processor."

Hypertext is to text as the technical grammar of cinema is to celluloid: words on-screen become a dynamic medium through buttons and links, just as jump cuts and editing tricks turn moving images into movies. This grammar can be applied to any kind of text, making hypertext highly useful for everything from browsing the Web, as we do today, to idea processing and writing choose-your-own-adventure fiction. NoteCards was designed for intelligence analysis. Before recommending policy, Cathy figured, intelligence brass might want to examine the underlying argument. "Back then I was naïve," she says, and laughs.

The intelligence community never picked up on hypertext, but NoteCards fit perfectly into the multidisciplinary atmosphere of Xerox PARC, a place where anthropologists, linguists, physicists, and computer

scientists worked alongside one another. Installed on all the campus workstations, NoteCards became a vital tool for sharing ideas across disciplines, and its influence flowed beyond PARC's borders. In 1987, Apple released a NoteCards–like application, HyperCard, which came bundled with Apple Macintosh and Apple IIGS computers and became the most popular hypermedia system ever developed before the advent of the World Wide Web. People used it to build databases, write branching novels, and create PowerPoint–like presentation slides. Popular games, like the bestselling CD-ROM *Myst*, were prototyped in HyperCard. Within Apple, it was often used to test out interface design ideas, and some publishers even issued magazines as HyperCard "stacks."

Nineteen eighty-seven was a banner year for hypertext, as it happens. Beyond the release of HyperCard, it marked the first academic hypertext conference, Hypertext '87, in Chapel Hill, North Carolina. Academic conferences of this type can forge intellectual communities out of atomized researchers, and this is what happened in North Carolina. Twice as many delegates as expected showed up, leading one attendee to observe a "rueful sense that this was the last time any hypertext gathering will be of manageable size." It was a heady mix, unusual for a technical conference, due largely to hypertext's many applications in the humanities: computer scientists rubbed elbows with classicists, professors with entrepreneurs. "The hypertext conferences were lovely, wonderful in those days," Wendy Hall tells me. "We had what I call the literati there, the poets and the writers. I think that's why it attracted more women."

"Computer science has always marginalized people that are interested in users," explains Cathy, but they found common ground in hypertext research, which was really the study of how people use computers to organize thoughts and data. Those who attended Hypertext '87 came home emboldened by the realization that hypertext wasn't an esoteric interest pursued only by a few fanatics but rather a true movement—one to which tech giants like Apple had clearly been paying attention. "There were little islands of ideas, when we started," Cathy remembers, but as the community coalesced, scholars like Cathy and

Wendy began to think of their vastly different systems as part of a whole. The hypertext systems to come would influence one another in manifold ways, progressively refining the ideas that undergird our century's most transformative information technology.

Part of being interested in users is paying attention to *how* they use software once it's in their hands. Surveying a group of Xerox PARC scholars working in NoteCards, Cathy's colleagues found that although each person "inhabited" the system differently, most used it to plot the big picture: organizing and structuring, sketching outlines, and maintaining references. Building connections and viewing them globally helped writers work through their arguments and ideas, and since NoteCards allowed multiple arrangements to exist in parallel, writers could explore various interpretations before settling. Cathy called this kind of work "knowledge-structuring," and it would dominate her subsequent research. The children of NoteCards—Aquanet, a system named after a hairspray because it held knowledge in place, and VIKI, the first spatial hypertext system—allowed users to organize ideas spatially from the outset, creating graphical schemas for how things fit together. Studying philosophy and logic, and consulting with the anthropologists and social scientists at Xerox PARC, Cathy learned how interpreting material and developing a position is often a process of abstract associations "difficult to articulate within the bounds of language, no matter how informal." Her hypertext systems were meant to empower kinesthetic thinking, the process of moving things around and trying them out akin to "wiggling molecular models in space or moving a jigsaw puzzle piece into different orientations."

All of this might sound bogglingly abstract and strange. Why spend so much time arranging boxes on a screen? But even in the physical world, the piles and clusters we make reflect our thinking: I'm reminded of Jake Feinler's desk at the NIC, covered in precious piles of paper, and of my own desk at home, with its mountains of dog-eared books, notepads, and printouts. Their proximity to one another, and their distance from arms' reach, suggest thematic connections and conceptual closeness to my thought process. In an influential paper of the hypertext era, Alison

Kidd, a researcher at Hewlett-Packard, called such piles "spatial holding patterns," suggesting that they play an important role in "creating, exploring and changing structures which can inform us in novel ways."

Cathy's hypertext systems shifted all these mental patterns on-screen and integrated them into larger writing and argument-building environments, presaging the ways in which we'd all soon find ourselves working on computers, with ever-expanding tabs, documents, and apps organized to suit our particular thought processes. They also demonstrate just how complex and nuanced hypertext can be, when the technology is explored to its fullest potential: it supports not just links but entire mental maps, systems that model—and more important, change—our minds.

This is the kind of thinking that prompts Cathy, thirty-odd years later, to tell me that what's on paper is incidental. That the only important thing is what stays in your head. If my documents, strewn on my desk or clustered as icons on a screen, appear inscrutable to an outside observer, that's no flaw in my system. They *should* be meaningless, because they're only the remnants of a transformation process, like a sheaf of molted skin. The real technology is the user.

That means me. And you.

HYPERTEXT '91

It all came to a head at Hypertext '91.

The conference was held that year in San Antonio, Texas. North Carolina had indeed been the first and last time the hypertext community would be a manageable size—in the four years since Hypertext '87, it had exploded, and academics, writers, engineers, and developers from around the world converged in Texas for the occasion. Wendy Hall came from England to demonstrate the latest build of Microcosm. The conference floor, a hotel reception area lined with rows of tables, was clustered with representatives from dozens of hypertext projects with names like AnswerBook and LinkWorks. Several tables down from Wendy Hall sat another British computer scientist, Tim Berners-Lee.

He'd had his conference paper rejected, but he'd come to San Antonio anyway, to show off a new system to the hypertext crowd.

He'd brought Robert Caillau, a colleague from CERN, the European Organization for Nuclear Research. The pair was demonstrating a distributed hypertext system Berners-Lee had built to make sharing data on networked computers across their massive Swiss campus a little easier. To anyone who saw it in 1991, it would have looked something like NoteCards or Apple's HyperCard: small graphical "pages" connected by links. The major difference was that these pages didn't all live on the same computer; Berners-Lee and Caillau, in the hopes of making data accessible to physicists outside of CERN, had built their hypertext system on the backbone of the academic Internet. They called it the World Wide Web.

To demonstrate the World Wide Web, Berners-Lee and Caillau brought their own computer with them on the plane from Geneva: a ten-thousand-dollar jet-black NeXT cube, at the time the only machine capable of running Berners-Lee's graphical World Wide Web browser. Still, the hypertext community wasn't impressed. "He said you needed an Internet connection," remembers Cathy Marshall, "and I thought, 'Well, that's expensive.'" Wendy Hall took a break from her own demo to try the Web on the conference floor. "I was looking at it," she remembers, laughing ruefully, "and I'm thinking, 'These links, they're embedded in the documents, and they're only going one way—this is really too simplistic.'"

They were right. It was expensive. Although Stanford had established the first stateside Web server only three days before, the hotel in San Antonio wasn't fronting for an Internet connection, so Berners-Lee and Caillau were forced to demo a dummy version of the Web saved on optical disk. And it *was* too simplistic. Compared with the other systems on display, the Web's version of hypertext was years behind. Links on the World Wide Web went in only one direction, to a single destination, and they were contextual—tethered to their point of origin—rather than generic, like Wendy's Microcosm links. Instead of employing a linkbase that could update documents automatically when links were moved or

of hypertext principles. The Web is hypertext's killer app, just as e-mail was the Internet's killer app—but its success hit the hypertext community hard. "I'm not sure exactly how to describe it," Cathy Marshall tells me. "All of a sudden you were the outsider, when you'd been the insider." At the first World Wide Web conference in 1994, Wendy Hall noticed that many delegates thought the Web was the first hypertext system, and she was stunned to read a paper reinventing her generic link ideas from scratch. By 1997, the two fields were so divergent that the Hypertext and World Wide Web conferences were scheduled for the exact same week.

To this day, the World Wide Web suffers from problems that systems like Microcosm solved decades ago. Because Web links are entirely dependent on their context, they're almost impossible to maintain. If a Web site is moved, deleted, or hidden behind a paywall, every link that pointed to it becomes meaningless, dangling like an anchor line cut loose from a ship. This should be familiar to anyone who has spent five minutes browsing the Web: according to a 2013 study, the median life span of a Web page is 9.3 years, a rate of obsolescence that sows rotten links throughout the network over time. We all regularly experience these dead ends, which are called 404 Errors. The document you're looking for, they tell us, simply cannot be found.

The hypertext researchers who demoed the World Wide Web back in San Antonio assumed this issue would be the system's undoing. After all, what good is a hypertext system if the links don't even work? Further, the Web isn't constructive. In all of the major pre-Web hypertext systems—Microcosm, NoteCards, Aquanet, VIKI, and Intermedia—creating links was just as important as clicking them. The point was for users to build their own paths through the material, a creative process of forging associative trails that could be shared with others. The Web, however, is a passive medium, a highway we wander without leaving much of a trace.

The World Wide Web may not have been powerful enough for academics, but a lightweight, user-friendly tool is often more likely to take off than a vastly more powerful one. And while linkbases and construc-

tive hypertext were easily maintained in relatively contained research and classroom environments, or on small networks of computers all running the same operating system, they would have quickly become unmanageable on a global scale. Today, we accept 404 Errors as the cost of doing business, and the Web runs the world.

MULTICOSM

The second time I talk to Wendy Hall, she's finishing up a long day with the department she now chairs at Southampton, the Web Science Institute. As I reach her on Skype, she's just saying good-bye to the last students trailing out of the conference room where they've been meeting. "Claire's writing a book about me," she says, laughing, to someone I can't see, gesturing at my head on the screen. "Or people like me, anyway."

Wendy will be the first to tell you that she's a very social person. She loves to make connections with people, and between them. When she talks, she does so in long, unselfconscious streams, jumping from one big, seemingly unrelated idea to another on her own invisible tracks—the mark of a true hypertext researcher. She loves science fiction and asks me repeatedly if I've read Douglas Adams's *Hitchhiker's Guide to the Galaxy* or Isaac Asimov's Foundation series. These novels contain her go-to analogies: the World Wide Web, she says, is an experiment on the whole world, just like the white mice in *Hitchhiker's Guide,* who run through mazes to test the scientists, and trying to understand the Web is like studying Isaac Asimov's "psychohistory," a mathematics of social complexity that can predict the rise and fall of galaxies.

Back in 1991, after drinking her fill of courtyard margaritas in San Antonio, Wendy went back to Southampton to continue developing her multimedia hypertext system, Microcosm. To survive, it needed to adapt to changing times. This it did admirably: for every new form of media, Wendy and her team developed new Microcosm "viewers," windows through which its users could draw material into their growing personal linkbases. There were Microcosm digital video viewers for video LaserDiscs, viewers for animation, sound, and 3-D models, and

viewers for competing hypertext systems. After San Antonio, however, Wendy was careful to add one more: a viewer for the World Wide Web.

The Microcosm Web viewer served as a hypertext replacement for the standard Web browser. Where browsers like Mosaic—and later Netscape and Internet Explorer—were read-only, Microcosm users could, using their Web viewer, select text from anywhere on the Web to use as the starting point or destination of their own hypertext threads, linking to other Web pages, multimedia documents, and their personal Microcosm linkbases. This all seemed to Wendy to be the most natural thing in the world. Many in the hypertext community balked at the Web's brutal simplicity, but Wendy corrected for it, layering her robust—and proprietary—system on top of the more skeletal world of interlinked Web pages. "I saw the Web through a Microcosm viewer," she explains. "Of course, Tim saw it completely the other way around."

Like many hypertext researchers, Wendy had every reason to assume that her system could happily coexist with the Web. After all, Microcosm worked better. It didn't suffer from dead links, and where the Web connected Web pages only to one another, Microcosm connected word-processor documents, spreadsheets, videos, images, and CAD files, like a micro-Internet interlinking *everything* on the desktop. "You could follow links to many different destinations," she says. "You could have one-to-one, one-to-many, many-to-many links. And you could reverse it all." Because Microcosm links were stored in a database rather than embedded into documents, the system could generate new connections on the fly, tailoring itself to individual users' browsing habits. "I was still thinking of the Web as *one* of the systems we would use," Wendy says.

What she didn't anticipate is the network effect. Because the Web was built on top of the Internet, and because it was free, early adopters quickly gave way to more mainstream users, and the more people got on the Web, the more interesting it became to their friends and family, and so on, very quickly making it dominant. Meanwhile, the Microcosm team released new stopgaps. They streamlined the system's key concepts—its generic links and linkbases—into a Web browser add-on

called the Distributed Link Service, which made any browser into a kind of Microcosm Lite, applying generic linking principles to the interchange between client and server. Effectively, this allowed Web users to interrogate material on the Web regardless of whether an explicit link was there. "By enhancing the Web with Microcosm's link services, WWW readers would be freed from the tyranny of the button," Wendy's team wrote in a 1994 paper.

The tyranny of the button, however, prevailed. People navigating the Web for the first time, few of whom had any experience with the kind of hypertext people like Wendy and Cathy created, were perfectly happy to click buttons, roaming with no clear destination along the Web's labyrinthine paths. Such curiosity-driven *dérives* were, in fact, part of the Web's early appeal. When people hit a dead end, they went back and tried a different link. The maze was a mess, but it was worth running.

Had Wendy's team at Southampton concentrated its energies differently, it's very possible that Microcosm could have been the first graphical Web browser to really take off. But that would have entailed making the software as free to use as the Web itself, and Wendy's team had its sights on commercializing their efforts. In 1994, they established Multicosm, Ltd.: if one microcosm is a window on the world, their company would produce many. The timing couldn't have been worse. "People used to say," she remembers, and laughs, "'I think what you're doing is wonderful, but this Web thing is free, so we're gonna try that first.'"

Fortunately, Wendy never abandoned university life. Running an expanding department at Southampton, she remained in contact with the growing Web development community, and after working closely with Tim Berners-Lee to develop the Microcosm Web viewer and the Distributed Link Service, she became a sustained presence on the early Web scene. In 1994, she helped to organize the first Web conference but still wasn't confident that the Web was the end-all solution. In a 1997 lecture at Southampton, she minced no words. "The Web has shown us that global hypertext is possible, but it has also shown us that it is easier to put rubbish on the Net than anything of real and lasting value," she said. How right she was.

There is a coda to this story, however. Microcosm's ideas may not have been implemented on a global scale in their day, but their prescience is undeniable. The way Wendy's system created links dynamically, based on the context of the information being linked, was a form of what we now call metadata. "We are now, twenty-seven years after the Web, living in a world that is driven by data," Wendy reminds me. *How* and *why* that data are linked is becoming increasingly important, especially as we teach machines to interpret connections for us—in order for artificial intelligence to understand the Web, it will need an additional layer of machine-readable information on top of our documents, a kind of meta-Web that proponents call the Semantic Web. While humans might understand connections intuitively, and are willing to ignore when links rot or lead nowhere, computers require more consistent information about the source, the destination, and the meaning of every link. "That was the core of Microcosm," Wendy says. When she began to participate in building the Semantic Web in the 2000s, it was "so exciting because I could see all my original research ideas coming to life in the Web world. We still couldn't do all the things we could do in Microcosm in the '90s, but we could see how effective our linkbases were."

In the end, however, the system is immaterial to her. It's the connections she's after: the magnificent complexity of human society and thought, all influencing one another in the unfolding of history. "There's lots of different ways that we could have implemented a global hypertext system," Wendy says. "The Web won—for now. But it feels like this is an experiment that has involved the entire world. Have you read *Hitchhiker's Guide to the Galaxy*?"