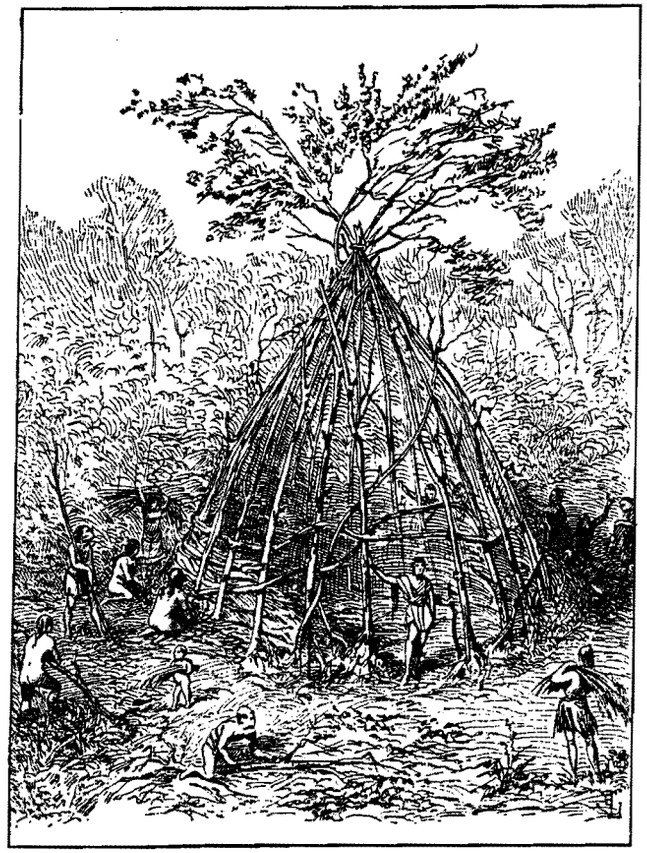


The first building provides a physical space to assemble: Viollet-le-Duc's speculation from 1876.

Telepresence creates a virtual space to assemble: a *Punch* cartoonist's speculation from 1878.

As our bodies morph into cyborgs, the buildings that house them are also transforming. Increasingly, telecommunication systems replace circulation systems, and the solvent of digital information decomposes traditional building types. One by one, the familiar forms vanish. Then the residue of recombinant fragments yields up mutants.

FACADE / INTERFACE

First, some historical perspective. Not so long ago, when the world seemed simpler, buildings corresponded one-to-one with institutions and rendered those institutions visible. Architecture played an

indispensable representational role by providing occupations, organizations, and social groupings with their public faces. Firehouses were for firefighters, schoolhouses were for scholars, and jailhouses were for jailbirds. The monarch's palace at Versailles, like the Forbidden City of Beijing or the Red Fort in Delhi, housed the ruler and his court, and its in-your-face form unambiguously expressed established power; it was where the ruling got done, and it was what you tried to grab if you wanted to usurp. Everyone knew that the General Motors headquarters building in Detroit — with its boardroom on the topmost floor — was where cigar-sucking captains of industry ran the company and decided (so they thought) what was good for the country as well. Buildings were distinguished from one another by their differing uses, and the inventory of those uses represented social division and structure. The Roman

theorist Vitruvius recognized this when he enunciated the principle of architectural decorum — appropriateness of form to purpose and status. And when the French revolutionary architect Ledoux wanted to demonstrate the possibility of a new social order, he designed and drew the hardware of his utopia — *architecture parlante,* the buildings that were to accommodate and vividly illustrate its restructured institutions.

Under this historically familiar condition, the internal organization of a building — its subdivision into parts, the interrelation of those parts by the circulation system, and the evident hierarchies of privacy and control — reflected the structure of the institution and physically diagrammed its pattern of activities. There was a complementarity of life and bricks and mortar, like that of snail and shell. If there was a mismatch, then the building had to be modified or the institution was forced to adapt. In his best Obi wan-Kenobi mode, remarking on the British Houses of Parliament, Winston Churchill cast this point into a much-quoted aphorism: we make our buildings and our buildings make us.[1]

But now, increasingly, software beats hardware. In the early 1990s, for example, Columbia University scrapped plans to build a twenty-million-dollar addition to its law library and instead bought a Connection Machine (a state-of-the-art supercomputer) and embarked on a program of scanning and storing ten thousand deteriorating old books yearly.[2] Library users would no longer go to a card catalogue and then physically retrieve books from the stacks. Nor would they open books, look up topics of interest in the table of contents or the index, and then flip through the pages to get to what they wanted. At computer workstations, they would enter queries (in plain English), retrieve lists of stored documents in response, and search through those documents to find relevant passages.[3] The task of designing and implementing the library extension had been fundamentally redefined. It was no longer one of laying out and constructing a building, with storage and circulation areas, to house the shelf space required by an expanding collection. It became one of designing and programming the computer tools for storing, querying, retrieving, and displaying digitally encoded text. Henceforth, the library would be extensible and reconfigurable in software.

Today, institutions generally are supported not only by buildings and their furnishings, but also by telecommunication systems and computer software. And the digital, electronic, virtual side is increasingly taking over from the physical. In many contexts, storage of bits is displacing storage of physical artifacts such as books, so that the need for built space is reduced. Electronic linkage is substituting for physical accessibility and for convenient connection by the internal circulation systems of buildings, so that access imperatives no longer play such powerful roles in clustering and organizing architectural spaces. And — as when an ATM screen rather than a door in a neoclassical edifice on Main Street provides access to a bank — computer-generated graphic displays are replacing built facades as the public faces of institutions.

It is time to update Churchill's *bon mot.* Now we make our *networks* and our networks make us.

BOOKSTORES / BITSTORES

The most obvious epicenter of this shakeup is the information business. And it is particularly instructive to consider the fate of one of its most familiar architectural manifestations, the book shop. Where will we find twenty-first-century Pickwicks?

The problem with printed books, magazines, and newspapers — Gutenberg's gotcha — is distribution. Paper documents can be mass produced rapidly at centralized locations, but they must then be

warehoused, transported, stocked at retail outlets, and eventually hand carried to wherever they will be opened and read. There are built and specially equipped places for each of these activities: the publisher's office, the printing plant, the warehouse, the bookstore, the newspaper kiosk, lounges and waiting rooms stocked with magazines, and the easy chair beside the fire. These places are distributed at appropriate locations within the urban fabric and play important roles in differentiating that fabric and the activities unfolding within it. Harvard Square would not be the same without Out of Town News and its diverse collection of bookstores.

Records and videos generate analogous places and spatial structures. The record store long ago took its place alongside the bookstore in downtown retail districts and shopping malls. Then, in the 1980s, video stores popped up everywhere — proliferating particularly in strips, shopping centers, and rural market centers, where they could easily be reached by car. Like the gas station and the fast-food outlet, video stores became a characteristic element of the suburban landscape.

When we separate information from its usual paper and plastic substrates, though, stockpiling and transporting physical products become unnecessary. Consider, for example, a venture announced by Blockbuster Entertainment (a large video-rental and record store chain) and IBM in May 1993.[4] The idea was to store recordings, in digital format, on a central server and to distribute them via a computer network to kiosks in record stores. There, customers could select recordings from a menu, download them to the kiosk, and copy them to CDs on the spot. Bookstores could work the same way, by downloading texts and rapidly laser-printing them. Through such point-of-sale production, the producers and wholesalers save on inventory, warehouse, and transportation costs, the retailers save on shelf space, and the customer potentially gets access to a much wider selection.

But inscription on to the substrate need not necessarily occur at this particular point along the information distribution chain. (Though, naturally enough, it is the point that most interests retailers.) Electronic, digital distribution might carry all the way to homes or other points of consumption. An alternative publishing strategy, then, is to download books and magazines from online databases to home laser printers (successors to the crude fax machines of the 1980s and 1990s) and to download recordings to home stereos, videos to home televisions, and newspapers to home computers. (This can be integrated with a recycling strategy; print on recycled paper and toss the printouts back into the recycling bin when their useful life is over.) Yet another strategy for text, music, or video on demand is simply to provide hundreds or thousands of simultaneously available digital channels, with each one repeatedly broadcasting specialized programs.

The Internet's Electronic Newsstand pioneered the new publishing pattern of downloading on demand when it opened in July 1993.[5] It provided online access to magazine articles — thus allowing customers to browse, as they might in a traditional newsstand — and also allowed convenient placement of subscription orders for print versions. An electronic bookstore and sections for business publications and newsletters were soon added. It was established with eight magazines; less than a year later the list had grown to eighty, and the service was being accessed forty thousand times per day from all over the world.

With changes in modes of information distribution come changes in acts of consumption — even in the familiar ritual of reading a newspaper. As I write this, the *New York Times* and the *Boston Globe* — in the form of large lumps of reprocessed cellulose — land with thumps on my Cambridge doorstep each morning and must eventually find their way to the recycling bin. The *Chicago Tribune*, the *San Jose Mercury News*, and many others show up as well, but silently

and immaterially — on my computer. Instead of turning their pages, I use software that picks out the items I want to see; headlines become menu items to click. Or I can do keyword searches through databases of accumulated stories. It's a short step to the completely personalized newspaper produced by an interface agent that knows my interests and preferences, continually scans the incoming news stream to pick out items that match my interest profile, and displays them in whatever format I may happen to prefer. Even the ideas of a "daily paper" and a self-contained "story" are challenged; a newspaper can become an accumulating online database of news stories in which a current story is simply an entry point for tracing a topic back through previous stories.

By the mid-1990s a new pattern of information distribution was clearly emerging on the North American continent. Cable, telephone, and computer companies were scrambling to form alliances that would provide homes and workplaces with inexpensive network connections, processing hardware, and presentation software. In 1993, for example, Time Warner announced an ambitious test project to put inexpensive telecomputers in four thousand homes in Orlando, Florida, and the Videoway network in Montreal was already offering a commercially successful interactive television system.[6] Media biggie Rupert Murdoch began to buy into the Internet.[7] Publishers were starting to evolve into organizations that pumped bits into the Net — the loading docks of the information superhighway system. The growing expectation was that bookstores, record stores, video stores, lending libraries, and newspaper kiosks in urban centers would largely be replaced by millions of inconspicuous, widely distributed electronic boxes at the ends of cables.

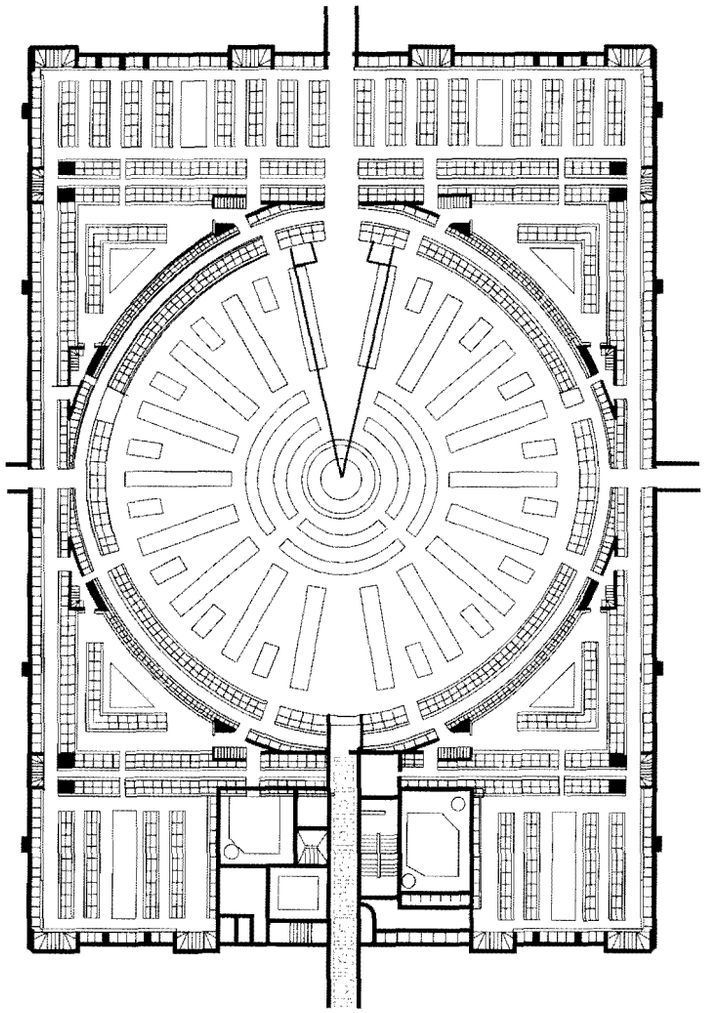
Gutenberg's revolution created places where printed information was concentrated and controlled. But electronic, digital information has a radically different spatial logic. It is immaterial rather than

bonded to paper or plastic sheets, it is almost instantaneously transferable to any place that has a network connection or is within range of a bit radiation source, and it is potentially reprocessable at any reception point — thus shifting much of the editorial and formatting work and responsibility from the producer's centralized plant to the consumer's personal hardware and software. Even more importantly, elimination of the need for access to printing presses and paper supplies has removed traditional barriers to entering the publishing business; anyone with an inexpensive computer and a network connection can now set up a server and pump out bits.

The likely result is a radical change in the sizes and locations of information supply points. When the Chicago Tribune Tower was constructed, it stood as the proudly visible center of a vast collection and distribution system and an emblem of the power of the press. Every day the news flowed in and the printed papers flowed out to the surrounding metropolis. But on the infobahn, where every node is potentially both a publication and consumption point, such centralized concentrations of activity will be supplanted by millions of dispersed fragments.

STACKS / SERVERS

The old British Museum reading room provided an architectural interface to the vast book stacks that lay beyond. From outside, the classical, columnar facade functioned as an icon — signifier of an access point. From within the circular, domed reading room (which looks in plan like a sectored hard disk), books could be summoned up by the action of specifying a call number. Library attendants would then retrieve volumes from the stacks for use at a reading table. (In later years, tourists would come to look for the very table at which Karl Marx sat absorbing vast amounts of printed information and transforming it into a blueprint for revolution.) The cycle would be completed by performing the task of reshelving the books



Iron book stacks designed by Anthony Panizzi surround Sydney Smirke's circular, domed reading room at the British Museum library, London (1854–56).

until they were needed again. Functionally, the whole thing was a very large, very slow version of what computer technicians now know as a database server: you send requests, and you get back items of stored information.

This highly refined functional diagram was the outcome of a long evolutionary process.[8] In early libraries, with small numbers of volumes, books had lined the walls of the reading room. Later, as the ratio of book storage to reading space changed, the book stacks were separated from the reading rooms and increasingly became the dominant spatial element; the new type was clearly emerging in Leopoldo della Santa's 1816 theoretical project for a library.[9] By the time that Karl Friedrich Schinkel produced his Berlin Staatsbibliothek project in 1835–36, it seemed logical to propose a huge, rectangular block of gridded stack space with a grand public stair in the center and access stairs at the four corners. And in 1854–56, when Sydney Smirke designed his rotunda for insertion into the older fabric of the British Museum, the book stacks became a huge, separate iron structure.

Popular graphical user interfaces of personal computers function in much the same way as Smirke's careful architectural arrangements. Icons are arrayed on the screen, like doorways along a street, to make visible the available access points. Clicking on an icon (like knocking on a door) puts the user in a space — in this case a rectangular "window" on the screen — from which files of information can be requested. In response to user requests, software routines retrieve files from the disk, display them on the screen for inspection and manipulation, and perhaps eventually rewrite them back to the disk.

Now extrapolate from this small-scale example and imagine a 10-million-volume, digital, online, humanities research library.[10] (For

comparison, the Library of Congress had nearly 15 million volumes on 550 miles of shelves in the early 1990s, the British Library had about 12 million on a couple of hundred miles, and Harvard's Widener had about 3.5 million.)[11] The catalogue would be available on the network. Volumes or chapters might be downloaded to a scholar's personal workstation in a minute or two, then displayed or laser-printed as required. (It matters little where the digital volumes physically reside — just that they can be accessed efficiently — and they occupy little physical space anyway. The collection's existence would not be celebrated architecturally, as the grandiose mass of Widener celebrates the accumulative power of Harvard.) This library would never close. Those addicted to the look and feel of tree flakes encased in dead cow (and prepared to pay for it) would not have to kick the habit; elegant physical volumes could automatically be generated on demand. Nothing would ever be checked out, in somebody else's carrel, lost, or in the limbo of the reshelving cart. Old volumes could live out their days in safe and dignified retirement in climate-controlled book museums. And the librarians could run backups (look what happened to the Library of Alexandria, where they didn't have a way to do it!).

The task facing the designers of this soft library is a transformation (with some invariants, but many radical changes) of what faced the Smirke brothers and the librarian Panizzi as they evolved the design for the British Museum and Library.[12] The facade is not to be constructed of stone and located on a street in Bloomsbury, but of pixels on thousands of screens scattered throughout the world. Organizing book stacks and providing access to them turns into a task of structuring a database and providing search and retrieval routines. Reading tables become display windows on screens. Resources are made available to the public by allowing anyone to log in and by providing computer workstations in public places, rather than by opening reading room doors. The huge stacks shrink to almost negligible size, the seats and carrels disperse, and there is nothing left to put a grand facade *on*.

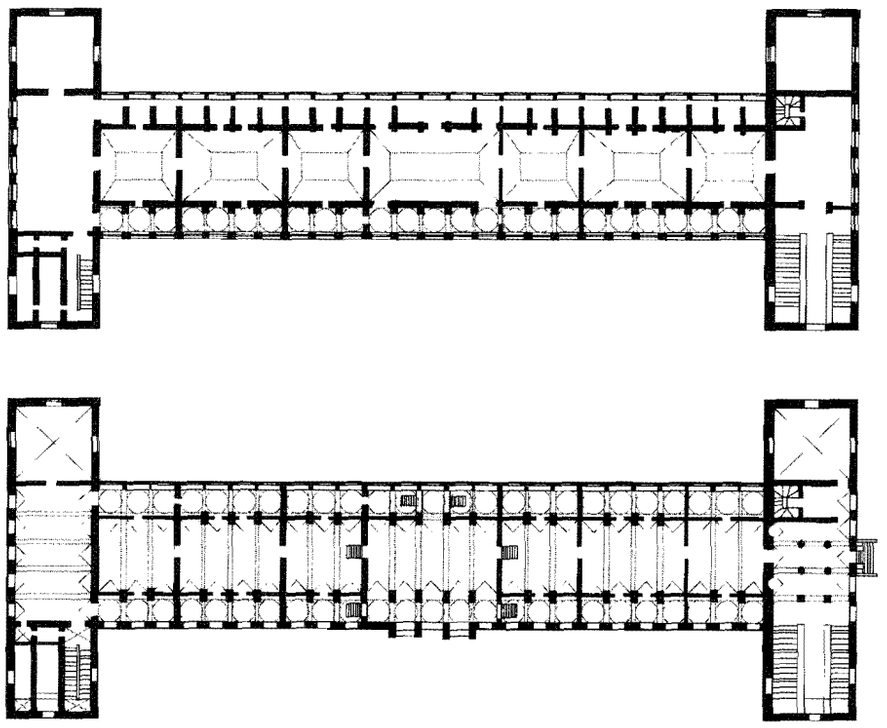
It will not be possible to tell tourists where some Marx of the next millennium sat. All that is solid melts in air.

GALLERIES / VIRTUAL MUSEUMS

Art galleries and museums arrange exhibits in carefully constructed viewing sequences. At blockbuster shows, the long lines of visitors shuffle from one item to the next.

Designing a great museum, then, has traditionally been a task of relating wall or cabinet display space, with appropriate natural lighting, to a circulation system that efficiently conducts visitors through the collection.[13] Nineteenth-century neoclassicists typically solved the problem by symmetrically arranging long, rectangular, skylit gallery spaces around grand, central entrance halls; visitors would enter and orient themselves, circulate around the perimeter, and eventually return to the starting point. The great examples are Leo von Klenze's Glyptothek and Alte Pinakothek in Munich and Schinkel's Altes Museum in Berlin. (At the brilliantly planned Pinakothek, parallel galleries are cross-connected so that visitors can depart from the perimeter circulation ring at will.) But there are other alternatives: at the Guggenheim in New York, Frank Lloyd Wright twisted a single, continuous gallery into a helix wrapped around a skylit atrium. Here, visitors take an elevator to the top and then descend along the ramped floor.

Within such arrangements, the curatorial task is to order exhibits into meaningful sequences. In the Glyptothek works of sculpture have traditionally been set out chronologically — beginning with Egypt, progressing through Greece and Rome, and ending with moderns like Canova. In the painting galleries of the Altes Museum



The Alte Pinakothek, Munich, by Leo von Klenze (1826–36). On the upper floor, interconnected halls were designed to display the works of different schools in chronological sequence.

there was a carefully constructed progression of "quality," leading up to the "perfection" of the High Renaissance. And in the Pinakothek arrangement was by "schools" in roughly chronological order: Flemish, German, French, Spanish, and Italian. Natural history museums, responding to different intellectual agendas, usually arranged exhibits according to scientific principles — by taxonomic grouping, in evolutionary sequence, or by geographic origin. Though older museums and galleries were often designed to present unchanging collections in fixed sequences, this need not be the case; their more modern equivalents usually provide flexible spaces for installing temporary shows.

In a virtual museum digital images of paintings, videos of living organisms, or three-dimensional simulations of sculptures and works of architecture (perhaps destroyed or unbuilt ones) stand in for physical objects, and a temporal sequence on the display plays the role of a spatial sequence along a circulation path. This yields tremendous spatial compression; a huge collection can be viewed, exhibit by exhibit, on a personal computer or in a small video theater. Sprawling gallery spaces become unnecessary.

Crowds become easy to handle. The exhibit material is kept on servers on a network, and viewers can be scattered at remote locations. It is not gallery capacity that matters, but server capability and network bandwidth.

Arrangement and sequencing of material remain crucial issues, of course, but the solutions to the problem are implemented in software instead of being built inflexibly and irrevocably into bricks-and-mortar constructions. Each item in the collection can have hyperlinks to other items that are related in some interesting way, so that the virtual museum visitor can construct a particular path through the collection according to personal interest. A virtual

museum can offer far more choices for exploration than even the Pinakothek.

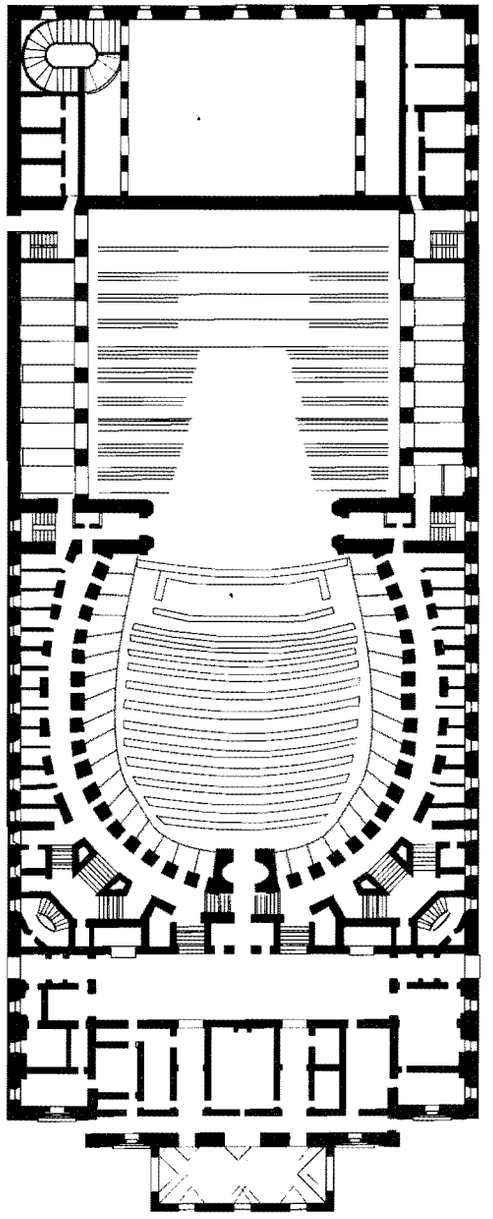
As virtual museums develop, the role of actual museums will shift; they will increasingly be seen as places for going back to the originals. The diagram is clear in the new Sainsbury wing of London's National Gallery. Near the entrance there is a room called the Micro Gallery, containing computer workstations from which visitors can explore the entire collection in hypermedia form.[14] As they do so, visitors note items they will want to see in the original. At the conclusion of the virtual tour, they get a printed plan for a correspondingly personalized tour of the actual museum. An overlay of virtual space thus changes the use of the actual space.

Theaters / Entertainment Infrastructure

Entertainment is information. Actors, directors, singers, and dancers produce it. Audiences consume it. Theaters distribute it. That's the crude analysis, anyway.

Ancient Greek and Roman theaters were compact, elegant distribution diagrams. Since an unaided actor's voice cannot carry very far, spectators were packed in tight circles around the point of production. And, since unobstructed lines of sight were essential, these circles were raked. The audience could see and hear the actors, the actors could see and hear the audience, and the whole system was wrapped up into a neat architectural package.

Andrea Palladio's late-sixteenth-century Teatro Olimpico in Vicenza (among others of around the same time) brought the circles of seats in under a weather-tight roof and got very sophisticated about the sightlines. Two centuries later, in Giuseppe Piermarini's design for La Scala in Milan, the seats were augmented (as



Teatro alla Scala, Milan, by Giuseppe Piermarini (1776–78). The auditorium is configured to keep audience members within earshot of the performers and to provide them with clear views of the stage.

had become customary in Europe) by vertically stacked circles of private boxes — a lot of little drawing rooms with the fourth walls removed, as Proust shrewdly described them.[15]

Broadcast media (radio and television) enlarged the spectator circles to encompass entire communities and shattered the once-unified audience space into thousands of scattered armchairs, couches, car seats, boom-box emplacements, and ear-to-ear spans of headphones. Proust's drawing rooms now spun out of their fixed orbits; recall how the film *American Graffiti* evoked a soft theater centered on the local radio tower — a radiation field emanating from Wolfman Jack, engulfing the ranch-house living rooms and cruising automobiles of a 1950s California town. Transmission towers replaced stage towers, and invisible circles of pulsing electromagnetic waves supplanted static arcs of spectator seating. Since audiences grew huge, broadcast studios became (as Frankfurt School commentators observed, with vivid anxiety about the consequences) favored platforms for big-time manipulators of public opinion — advertisers, demagogues, talk-show hosts, and televangelists.[16]

Electronic enlargement of the spectator circles had an additional important consequence; since performers could no longer hear their far-flung audiences laughing, groaning, muttering, hissing, heckling, cheering, and clapping, the flow of information became almost entirely unidirectional. The traditional asymmetry of theatrical performance was vastly exaggerated. Direct engagement of performers and audiences disappeared, to be replaced partially and unsatisfactorily (if at all) by expedients such as studio audiences, telephone call-ins, and Nielsen boxes.

But switched, broadband, two-way cable networks of the kind that were under development by the early 1990s — sophisticated bit-distribution utilities, much like the water, gas, sewage, and electrical systems which have become so fundamental to modern cities — transform this condition. Most obviously, they can be hooked up to large video servers that allow subscribers interactively to select videos from extensive menus, play them whenever they want, and operate a "virtual VCR" to control viewing conditions. It's "video on demand," as its promoters have dubbed it.

But the traditionally structured video does not have to be the unit that is retrieved and played; finer-grained interactions with hypermedia entertainment productions also become possible. Early versions of these sorts of productions first became popular in the personal computer era, and initially were distributed on floppy disk or CD; in the early 1990s there was an initial flurry of interest in branching hypertext novels with multithreaded narrative structures that could be followed in many different ways, and there were a few experiments with larger-scale hypertext fictions on the Internet. There was also some experimentation with "branching" movies in specially equipped theaters. As switched broadband networks bring sufficient bandwidth into living rooms to allow interactive video, and as home audiences become large enough to justify expensive productions, interactive productions seem destined to become the norm rather than the exception.

Live performances — broadcast, narrowcast, or point-to-point — can also become interactive. You might, for example, have a very literal kind of virtual auditorium in which the display screen functions as a stage and your remote has buttons for sending back applause and other codified responses. If you receive three-dimensional models of a sporting event rather than a stream of two-dimensional video images, you could take control of some directorial functions by selecting viewpoints and operating a virtual camera. It surely will not be very long before there are two-way video equivalents of talk radio. And, no doubt, there will be virtual 47th

Streets and "combat zones" to provide an endless variety of private sexual performances on demand; as 900 numbers, Minitel, and X-rated chat rooms have amply demonstrated, skilled performers can easily overcome bandwidth and interface limitations.

Competitive games will be reinvented for virtual arenas. The usual way to set up a game has been to bring small numbers of competitors together in precisely marked physical places — over chessboards, on tennis courts, basketball courts, or football fields — while spectators watch from the sidelines. In 1993 the hack-and-slash hit *Doom* effectively exploited the idea of putting networked participants together in *virtual* places to battle software monsters and to duel with each other. And by 1994 the videogame pioneer Nolan Bushnell was speculating about the possibility of network-supported, intercity competitive games involving tens of thousands of participants on each team.[17]

Carried to their logical conclusion, these reconfigurations and transformations completely rip apart the traditional architectural relationship between stage and auditorium, performers and audience. The great house of the theater condenses into an electronic box with a screen and a video camera. When you want to be a spectator, the bezel of the screen becomes your proscenium — framer of the action. When you want to become an actor, the camera provides access to an audience and the entire network is potentially your auditorium. And when you want to be a game participant, the network allows you to meet teammates and opponents on virtual turf.

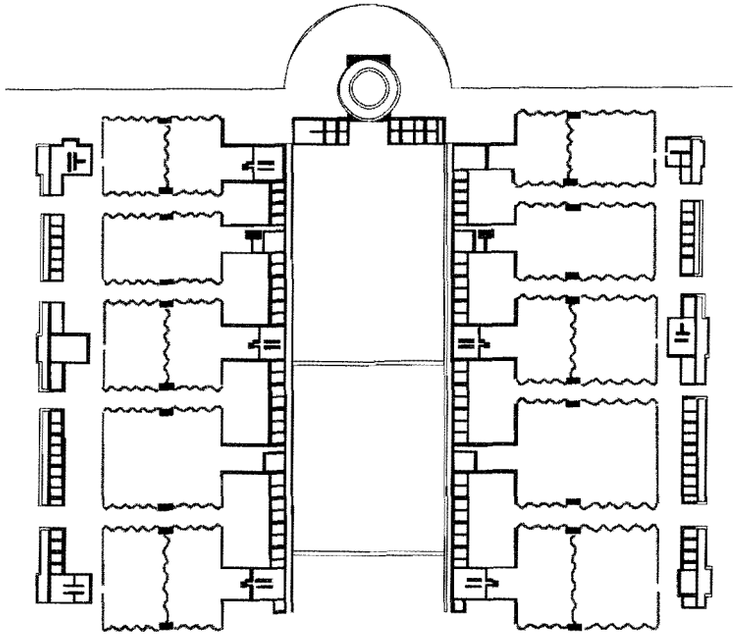
Not only has the old idea of concentrated, physically coherent theatrical or competition space been subverted and eroded, so has that of performance time. Early "live" radio and television shows carefully preserved the theatrical convention of definite performance time, but programmers soon learned tricks of repeating and time-shifting recorded performances and of mixing live and recorded material. With the development of networked interactive video, the show goes on anytime anybody wants it to.

All this reshapes the rules of production and distribution. Under traditional arrangements, the cost of getting to an audience tends to be high; a show has to fill expensive theater seats or attract sufficient advertising to pay for production costs and air time. So the entertainment industry has increasingly become a game for very big players who compete for mass audiences. But as high-bandwidth networks proliferate, and as network navigation software grows in sophistication, the costs of reaching and aggregating audiences should diminish sharply. There will be opportunities to produce and distribute low-budget entertainment for very small audiences and to identify and reach scattered audiences with the most specialized of interests and tastes. The infobahn may become a vast, global Broadway lined with thousands of virtual theaters.

So the social superglue of necessary proximity between performers and audience is losing its old stickiness, and the traditional architectural types and social conventions (going to the theater, cheering for your local team in the ballpark) that we associate with performance are coming unstuck. Speech, music, scenes, and text can now be transmuted into bits and entered into the network almost anywhere. These bits can be decoded to create a performance wherever and whenever a spectator chooses to plug in. Established distinctions between producers and consumers of entertainment (reified by the forms of theater and stadium construction) are breaking down. Soon, all the world will be an electronic stage.

SCHOOLHOUSES / VIRTUAL CAMPUSES

A teacher speaks; students listen and respond. The teacher has access to some corpus of knowledge, beliefs, and practices, and makes this



Thomas Jefferson's layout for an "academical village" — the University of Virginia, Charlottesville (1817–26). Rooms for students and instructors, and meeting places of various kinds, are linked by colonnaded cloisters.

corpus available to the students. Schools, colleges, and universities are spaces that exist primarily to bring students and teachers together so that this sharing of a corpus can take place.

The underlying diagram of a school appears in its simplest and most beautiful form when disciples gather within earshot of a guru in a place made by the shade of a bo tree.[18] The less sedentary Socrates strolled in a grove, with his disciples keeping pace. The little red schoolhouse — appropriate to colder climates — puts the students in a box with the teacher in front. Jeremy Bentham's proposed "Chrestomathic" monitorial school — a variant on the panopticon — had a single master in the middle surrounded by a circle of six monitors to keep order, then circular tiers with seats for nine hundred boys.[19]

Modern schools, colleges, and universities have greater spatial differentiation and far more complex plans. They provide multiple classrooms to allow different sorts of instruction to proceed simultaneously; they add libraries, laboratories, art and design studios, music practice rooms, and other specialized facilities; and they link the pieces together with long cloisters or passageways (MIT's "infinite corridor" is emblematic). Residential institutions — like that planned by Thomas Jefferson at the University of Virginia — integrate rooms for scholars and provide hierarchies of informal and formal meeting places, so that the plan reads as an illustration of the dedicated scholarly life. The demand that colleges and universities typically make is to be "in residence" — to be part of the spatially defined community. And these communities enforce, as well, strict compliance with academic timetables, classroom schedules, and calendars.

Of course there have always been alternatives to making such permanent, rigidly organized places of learning. Preindustrial societies had their itinerant teachers and holy men who spread the word

wherever they could find audiences. By providing printed books and efficient mail service, the Industrial Revolution made correspondence schools possible. Two-way radio allowed a teacher in Alice Springs to instruct children living on remote cattle stations scattered across the great Australian outback. In the era of the Wilson government, broadcast television and videotapes (in conjunction with reasonably good, old-fashioned mail service) created the possibility of Britain's Open University. Today digital telecommunication is producing a powerful resurgence of this alternative tradition; being online may soon become a more important mark of community membership than being in residence. (When the Aga Khan gave MIT's commencement address in 1994, he was not given the traditional honorary degree to make him symbolically part of the community, but rather a modem-equipped laptop computer and an MIT e-mail address.)

As the digital telecommunications era dawned, some universities were very quick to begin exploring the potential role of campus networks. At Dartmouth in the 1960s — way back in the era of time-sharing mainframes — a network of interactive terminals was put in place and heavily used.[20] At MIT in the 1980s, with extensive support from IBM and Digital, the campus-wide Athena system pioneered the educational use of networked workstations with (by the standards of the time) high-bandwidth interconnections.[21] By the 1990s campus networks were commonplace; even the ivy-clad dorms in Harvard Yard had been hooked up.

At the same time (beginning in the 1970s), ARPANET, BITNET, and ultimately the Internet began to shake up the traditional, insular structures of colleges and universities by creating quick, convenient, inexpensive channels for worldwide, campus-to-campus interchange of text and data. These long-distance links were hooked up to local networks, such as MIT's Athena, which disseminated access around the campuses themselves. Scholars quickly found that electronic contact with distant correspondents could sometimes be more rewarding than conversation with colleagues from just down the hall. Online conferences and bulletin boards began to challenge departmental common rooms and local hangouts as the best places to pick up the latest on specialized topics. By the 1990s many academics found that they simultaneously inhabited local scholarly communities, which provided their offices and paid their salaries, and virtual communities, which supplied much of their intellectual nourishment and made increasing demands on their time and loyalties. The tension was beginning to show.

Network connections quickly create new ways of sharing knowledge and enacting practices and so force changes in the characters of teaching spaces. At the very least, a lecture theater now needs a computer workstation integrated with the podium and a computer-connected video projector to supplement the old blackboards and slide projectors; the podium is no longer a place for reading from a book or lecturing from written notes, but a spot for directing and interpreting a stream of bits. And instead of taking notes on paper, students use their laptop computers to capture and annotate these bits.

Seminar rooms change too. They now need to be set up for videoconferencing as well as for face-to-face discussions.[22] But that is just the beginning. Desktop-to-desktop, switched video networks open the more radical possibility of teaching in virtual rather than traditional physical settings. Students might have office conferences with faculty members without leaving their dormitory rooms. Seminars might be conducted without seminar rooms. Symposia might virtually assemble speakers from widely scattered locations. Lecturers might perform from distant places, and without the need to concentrate students in auditoriums.

School and university libraries become less like document warehouses and dispensaries and more like online information-brokering services. Reserve desks are supplanted by online document

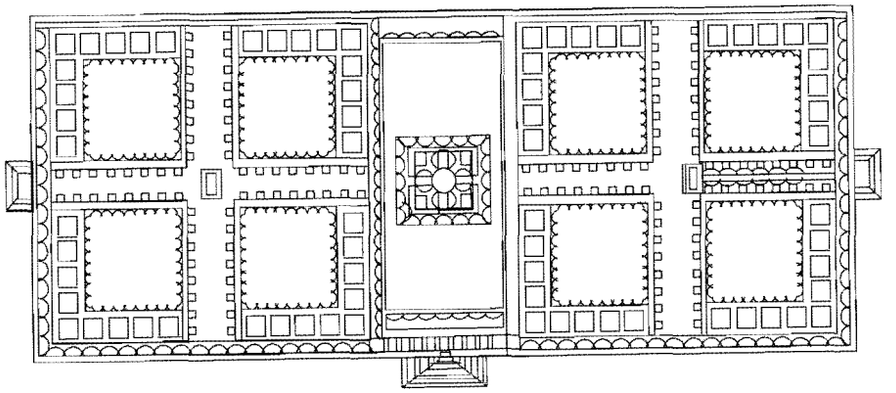
collections, and slide libraries by huge image and video-on-demand servers. Centralized reading rooms fragment into scattered information access points; any place where a student or faculty member may want to sit and work — an auditorium seat, library carrel, desk, dorm room, or office — needs a laptop hookup point.

Even laboratories can sometimes be broken up and scattered — and benefit from it.[23] The Harvard-Smithsonian Center for Astrophysics, for example, has developed an astronomical system called MicroObservatory. The master units of this system are networked computers in school classrooms. These are used to control motorized, digital-imaging telescopes mounted on rooftops and to view the telescope images remotely. Image-processing software is used to subtract out the sky so that observations can be made in the daytime. An extended version of this system might incorporate hundreds of telescopes scattered around the world and allow students to make observations from anywhere there is a network connection.

As the twentieth century draws to a close, the idea of a virtual campus — paralleling or perhaps replacing the physical one — seems increasingly plausible.[24] If a latter-day Jefferson were to lay out an ideal educational community for the third millennium, she might site it in cyberspace.

Hospitals / Telemedicine

The word "hospital" derives from the Latin *hospes,* meaning guest or host; the idea is to confine the sick to one place.[25] In early monastic hospitals the sick were confined so that they could be cared for by the monks and (perhaps more to the point, considering the level of medical treatment that was available) so that they could conveniently be assembled for religious services and speeded on their way to heaven; thus Filarete's famous plan for the Ospedale Maggiore in Milan consisted of immense cruciform wards with



Intended plan for the Ospedale Maggiore, Milan, as shown in Filarete's *Treatise on Architecture* (early 1460s). Cruciform wards, with altars at the crossings, flank a chapel in the central courtyard.

altars at the crossings and a chapel in the central courtyard. (In modern wards the centrally located altars are replaced by nursing stations.) Sometimes, as in hospitals for infectious diseases like Venice's island *lazaretto* and in asylums for the mentally ill like Bedlam and Charenton, the sick have been confined to keep them away from the rest of society. As medical expertise and increasingly sophisticated medical technology have developed in the twentieth century, confinement has been to places where skilled practitioners, medical records, and advanced facilities (such as surgical suites, pathology laboratories, and medical imaging installations) could be concentrated. And in teaching hospitals, the sick are assembled in places where students can observe them.

Before Pasteur, enlightened hospital designers arranged long, narrow wards to provide as much external wall surface, natural light, and fresh air as possible. So, for example, both Wren's early-eighteenth-century plan for the Royal Naval Hospital at Greenwich and Durand's ideal hospital plan of a century later are low, sprawling, symmetrical accretions of ward pavilions, courtyards, and immensely lengthy corridors.[26] But since the 1870s, when Pasteur fingered bacteria (rather than foul air) as the agents of infection and Lister developed antiseptic medicine, pavilions have become a thing of the past. Twentieth-century hospitals consist mostly of air-conditioned, artificially lit spaces packed closely together in deep, multistoried blocks to minimize staff, patient movement, and service system runs. The hospital designer's task — much like the task of microprocessor chip layout — has been to arrange a lot of identical storage units and a few specialized, central processing facilities for the greatest possible circulation efficiency under statistically predicted patterns of use.[27] Generally, the resulting places have not been very pleasant.

With the development of advanced telecommunications, bits are now beginning to transform hospital design as profoundly as bacteria once did. Telemedicine is emerging. It brings advanced medical care to widely scattered populations and makes old-style assemblies of patients around specialized medical facilities less necessary. As John McConnell, writing in *The Lancet*, summarized, "For any procedure that involves vision or sound (e.g., monitoring the progress of anaesthesia, or giving an opinion on a biopsy slide, fetal ultrasound, or computed tomography scan) — and potentially even touch — the physician need no longer be present in the same room, or even in the same country, as the patient or specimen."[28]

The simplest and most obvious form of telemedicine is a straightforward extension of teleconferencing. Using video hookups, specialists at major medical centers can examine patients and provide advice to colleagues in remote rural locations. Emergency room physicians can save precious time by examining patients in video-equipped ambulances, and military hospital medics can examine far-off wounded. Where outbreaks of fighting or natural disasters create sudden demands for medical care, capacity can quickly be switched from other parts of the world. Basic models of health care delivery may even begin to change; family practitioners might provide face-to-face patient contact while drawing on the expertise of distant specialists by video as needed. By the 1990s, then, numerous experiments in video-based telemedicine were under way.[29]

But video is only the first step. Since modern diagnostic devices often produce streams of digital data, they can readily be adapted to provide their output remotely through network connections. So stethoscopes, otoscopes, endoscopes, electrocardiography devices, and medical imaging machines can all now be used in remote examinations. As homes get network connections, domestic diagnostic and monitoring devices will begin to allow virtual house calls; when your baby has an earache, you might connect to a virtual clinic and put the otoscope in the baby's ear to let the

practitioner on duty take a look.[30] It's not as good as a real visit, perhaps, but it's a lot better than a telephone call.

By combining electronic viewing and diagnostic devices with appropriate telemanipulators, medical practitioners can begin to make themselves telepresent.[31] Consider, for example, a pathologist examining tissue samples or body fluids under a microscope in order to render a diagnosis; with a telepathology system consisting of a video camera mounted on a motorized microscope, this task can be performed remotely.[32] And with fancier teleoperators, head-mounted stereo displays, and sufficiently precise tactile feedback devices, telesurgery becomes a serious possibility.[33] A typical telesurgery system consists of master and slave units: the remotely located surgeon wears a helmet (the audiovisual master) that controls a stereo video camera (audiovisual slave) observing the surgery, and holds force-reflecting pseudotools that control a surgical robot.[34]

Continuous care — involving constant monitoring and regular medication — might also be provided remotely. (Many of the necessary technologies were originally developed for battlefield use but can readily be adapted for more peaceful purposes.)[35] Houses and beds can contain sensors for tracking the conditions of their occupants and telecommunications for transmitting the information to distant monitoring sites. Electronic scales can log body weight. Noncontact, microwave vital-signs monitoring systems can measure heart rate, respiration rate, temperature, and blood pressure. Smart air-conditioning systems and inquisitive toilets might automatically take samples and perform analyses. Implanted wireless devices might be used for remotely controlled release of precise amounts of medication. Houses seem destined to evolve into increasingly sophisticated components of health care systems.

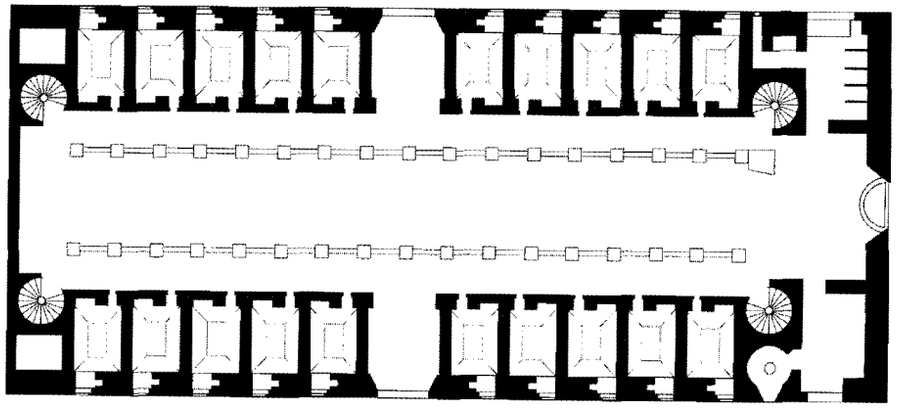
One promise of telemedicine is that the isolated, the immobilized, and those in sudden, acute need will be able to get care without difficult and time-consuming travel. Another is that family practitioners and paramedics who have direct contact with patients will be able to draw more effectively on specialized expertise and advanced medical technology as the traditional doctor's black bag mutates into a sophisticated digital telecommunications device. An obvious peril is that health care delivery may become an even more depersonalized and technocratic process. Either way, the logic of health care facility location and internal organization is changing dramatically; whereas the industrial, antiseptic care, and medical technology revolutions of the nineteenth and early twentieth centuries created powerful incentives to centralize medical care and concentrate it in major urban areas, the digital telecommunications revolution of the late twentieth century creates possibilities for decentralization and more equitable dispersion.

Itinerant healers are returning. They will ride the information superhighway.

Prisons / Electronic Supervision Programs

Prisons, like hospitals, are places for involuntary, supervised confinement. Incarceration is supposed to take criminals out of circulation, punish them for their misdeeds, and perhaps reform them.

Medieval monasteries employed imprisonment in cells as a form of punishment; both Cluny and Hirsau had their windowless *carcer*.[36] And medieval castles were sometimes equipped with dungeons. When Carlo Fontana designed the San Michele prison for young men in Rome (which was to become the prototype for modern jails), he took the cell as his planning unit and provided rows of them on either side of a large central hall with altars at each end. Later prisons of the eighteenth and nineteenth centuries arranged cell blocks in radial or concentric patterns for ease of supervision



San Michele Prison, Rome, by Carlo Fontana (1703–4). Cells for the inmates surround a large, central workroom.

and control, or strung parallel blocks along lengthy circulation spines.

But electronics can now perform many of a prison's traditional functions without cells and walls — discipline and punishment *sans* slammer. Under the Electronic Supervision Program, some American offenders are sentenced to home detention and fitted with anklet transponders linked to telephone modems. A central monitoring station is automatically alerted whenever the wearer moves more than a specified distance from the modem — just as Fontana's unfortunate young detainees were confined to the vicinity of San Michele's altars.[37]

Elaborations of this strategy are easy to imagine and will be increasingly straightforward for enthusiastic law enforcement agencies to implement as wireless telecommunications technology evolves. Already, cops can have "drive-by" units to check on the location of offenders. Stores could have detectors for convicted shoplifters, playgrounds and schools could have them for pedophiles, and abused spouses could have them for their former partners. With more elaborate tracking technology, movements could be monitored continuously and cross-checked against crime scenes and times.

Of course the system would not be complete without effective ways to apply immobilizing force and punitive violence. But that doesn't seem too difficult. Anklets could automatically sound loud alarms when triggered by entry to forbidden places or when activated remotely by wardens. There might be some behavior-monitoring capacity built into an anklet or implant, together with a drug-release mechanism; one advocate of walking prisons imagines that "a sex offender's specific patterns of aberrant sexuality would be recognized by the programmed chip, and the drugs would selectively tone down criminally sanctioned behaviors but allow

normal or acceptable sexuality."[38] For maximum-security offenders, the drugs could be sleep-inducing or even lethal.

So the story that began with Carlo Fontana's schemes for San Michele may be finally drawing to a close. The state will no longer need walls and watchtowers to enact its legal monopoly on confinement and violence. Telecommunications will do the job instead.

Banking Chambers / ATMs

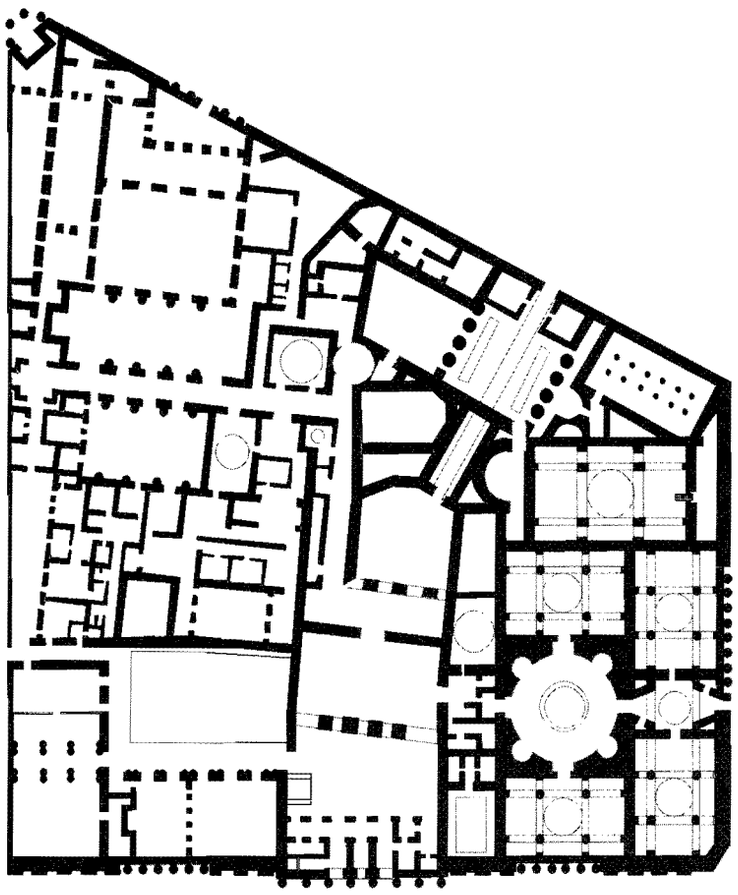
Asked why he robbed banks, the famous stickup artist (and jailbird) Willie Sutton replied, "Because that's where the money is." But postmodern thieves no longer break into vaults or terrorize tellers; bent Baudrillardists, they have learned to bamboozle with floating signifiers instead — because money, too, is now digital information endlessly circulating in cyberspace.

In April 1993, at Buckland Hills Mall near Hartford, Connecticut, some audacious PoMo-kleptos wheeled in a Fujitsu model 7020 automated teller machine — purportedly from a New Jersey bank — and set it in operation.[39] When shoppers inserted their cards in this con-robot, it electronically recorded the account and personal identification number, then simply printed out slips saying that no transactions were possible. Later, using counterfeit bank cards encoded with the pilfered numbers, the high-tech bandits began to make cash withdrawals from ATMs in midtown Manhattan. What was the scene of this scam? Where did the deed of milking the moneypukers actually take place? Not, surely in Connecticut, New Jersey, or New York, but somewhere deep in the cyberspace of the ATM system.

This perplexing puzzle is one result of the wholesale shift of Main Street banking to cyberspace that has taken place over the last couple of decades. The first ATM machines was introduced by Citicorp in 1971; by 1980 there were fewer than twenty thousand ATM machines operating in the United States, but by 1990 there were more than eighty thousand. Today deposits and withdrawals only rarely take place at a traditional teller's window; by 1987 over 80 percent of bank customers used ATMs for more than half their transactions.[40]

When these devices were still new, and not yet well understood, they were sometimes treated as direct robotic replacements for human staff; you found them inside the bank, beside the counters where you filled out your deposit slips. But this missed the point; since ATMs depend on electronic rather than physical linkage to bank records, they do not really have to be inside under the eye of the manager. So they quickly migrated out onto the street, where they could operate twenty-four hours a day, seven days a week. Soon the realization dawned that they did not even have to stay attached to bank building facades; they could more effectively be located where crowds naturally congregated and where people actually *needed* cash — in supermarkets, shopping malls, airports, university student centers, and office building lobbies. Or, as in South Central Los Angeles or on the South Side of Chicago, they might more appropriately be placed in police station lobbies — where it was *safe* to collect cash. National and international ATM networks developed, so that you could get cash from machines that were far away from your hometown. The traditional Main Street bank building disintegrated, and the pieces that remained reintegrated themselves into new settings.

At the same time, electronic funds transfer networks have supplanted traditional heist bait — the stagecoach, the armored truck, and even (to some extent) the pocket full of cash. My paycheck is automatically, electronically transferred to my bank account each month, then some of it gets transferred out to make my mortgage



Bank of England, London, by John Soane (1788–1834). Each type of transaction has its own grand hall, and the various activities are connected through an intricate pedestrian circulation system.

payment. And CHIPS (the Clearing House Interbank Payments System, owned by a bunch of big New York banks) — just a couple of mainframe computers and a hundred or so dedicated phone lines in a nondescript Manhattan office building — processes trillions of dollars in payments, from banks all over the world, every day.[41] In 1980 daily electronic money transfers on CHIPS and the Fedwire network run by the Federal Reserve were about twelve times the balances held in accounts by the Federal Reserve; by 1990 the volume had grown to more than fifty times those balances. Money is no longer bullion in a strongbox, but bits in an online database.

By this point in the evolution of the digital era, we have almost forgotten the original *banchi* — the trestle tables at medieval fairs, where bankers and their clients met face-to-face to exchange promises.[42] Accommodating a bank's operations has ceased to be primarily a matter of providing appropriate rooms and circulation (as it was when Sir John Soane designed the Bank of England on three acres of ground in the heart of the City of London), but of configuring the right computer systems. Gaze in wonder at Soane's plan, noting the precisely differentiated functions of his great transaction halls — the Bank Stock Office, Accounts Office, Discount Office, even Five Pound Note Office; we will never see the like again. In sum, we are experiencing the step-by-step emergence of the soft bank — a round-the-clock facility, accessible from indefinitely many locations, and providing electronically mediated withdrawals, deposits, bill payments, check cashing, point-of-sale transactions, travelers' checks, loan applications, statements, and whatever other financial services the banking industry can dream up and sell.[43]

Even the now-ubiquitous ATMs (in their role as cash dispensers, at least) will become obsolete if coins and bills are eventually eliminated. This is a fairly straightforward technical possibility; a

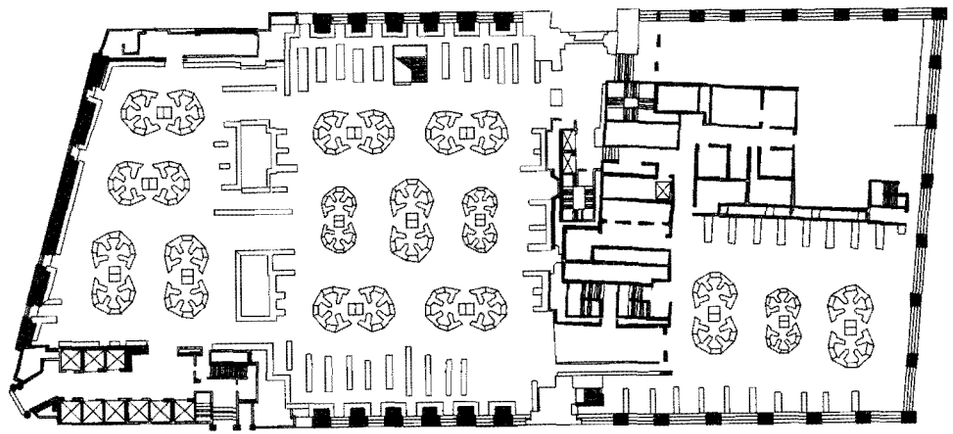
combination of network transfers, checks, credit cards, debit cards, ubiquitous point-of-sale terminals, and replacement of coin-operated gizmos like parking meters with electronic card-reading devices clearly could yield a cash-free society.[44] Personal terminals, for making and receiving payments anywhere, could be integrated with laptop or palmtop computers or could be specialized wallet-sized devices.

Not surprisingly, gambling casinos have led the way toward the cashless world. At Foxwood Casino, on the Mashantucket Pequot reservation in Connecticut, arriving customers obtain a "Wampum Card" — a smart debit card that electronically stores account balances and transaction records. The gaming tables are hooked into a computer network, and, brags the network's director, "We register a transaction every time the handle of a slot machine is pulled."[45]

Bank buildings, then, are no longer where the money is. They are shrinking to the point where they can no longer serve to celebrate financial institutions and transactions as Soane's great design so compellingly did. Indeed, cash money and associated transaction points may soon disappear entirely. Today's Willie Suttons are learning to crack computer security, not safes.

Trading Floors / Electronic Trading Systems

Historically, organized exchanges for common stock, futures, and option contracts have evolved as increasingly elaborate and specialized places for making deals. But they were simple in the beginning. The London Stock Exchange grew out of a coffeehouse where traders could meet. And in Vicenza on Tuesday mornings, in the old basilica that Palladio wrapped with his magical loggia, you can still see how modern commodity markets began: buyers



Trading floor of the New York Stock Exchange by George W. Post (1903) and Trowbridge & Livingston (1923). Trading posts for member firms are in the center, and telephone booths line the walls.

and sellers still transact their business in little wooden cubicles as they have for centuries.

When James Peacock designed a new building for the London Stock Exchange in 1801–2, European exchanges had evolved into voluntary associations of members who came together to trade securities in auction markets. A member would acquire the right to trade on the exchange by buying a "seat." The great exchanges of the nineteenth and twentieth centuries, like H. P. Berlage's monumental brick pile in Amsterdam, were organized around trading floors where the action took place. On Wall Street the floor of the New York Stock Exchange was planned with dumbbell-shaped "trading posts" for member firms in the center, telephone booths around the periphery, and plenty of room for pages to scurry back and forth with orders. The great boards flashed, the brokers shouted their bids and acceptances, and it was the very stuff of capitalist romance.

The telegraph and the telephone gradually began to change all that, of course. Geographically distributed over-the-counter (OTC) markets such as NASD (National Association of Securities Dealers) now bring together dealers who quote prices to buy and sell. They are not located on a trading floor somewhere; they might be anywhere. Seats become virtual.

The computer takes that process a big step further. By the early 1990s, trading floors everywhere were tumbling into obsolescence: the British and French stock markets had transformed into almost entirely computerized operations, the Toronto exchange was planning to shut down its floor, and the Korean and German exchanges were moving in the same direction.[46] Many stock transactions — perhaps the majority of them — had become computer-to-computer rather than person-to-person affairs. The US Treasury announced plans to introduce electronic bond auctions, in which Wall Street dealers would submit bids electronically instead of phoning them in to government clerks, who scribbled them down.[47]

In 1992 Reuters, the Chicago Mercantile Exchange, and the Chicago Board of Trade opened Globex, a very ambitious twenty-four-hour electronic trading system for futures and options contracts. It took about as long to design and build (four years), and cost about as much ($70 million) as a major new trading building. But it has no floor; buy and sell orders are entered electronically into the system, prices are set by a process of computer matching with incoming orders, participants in the trade are properly notified, verification is sent to the Chicago exchange clearing center, and buyers' and sellers' accounts are adjusted — all in a few seconds. Its chairman claims, "This is a way to extend our market around the globe across all borders and time zones."

Globex has had its teething troubles, but it clearly shows us the financial future. Commentators on the financial markets (generally a pretty buttoned-down bunch) can now see a whole new world coming:

> The globalization of financial markets simultaneously fragments traditional financial transactions marketplaces and integrates them via electronic means. Physical marketplaces (the trading floors) are becoming obsolete, while "virtual" marketplaces — networks of computers and computer terminals — are emerging as the "site" for transactions. The new technology is diminishing the role for human participants in the market mechanism. Stock-exchange specialists are being displaced by the new systems, which by and large are designed to handle the demands of institutional investors, who increasingly dominate transactions. Futures and options floor traders also face having their jobs coded into computer algorithms,

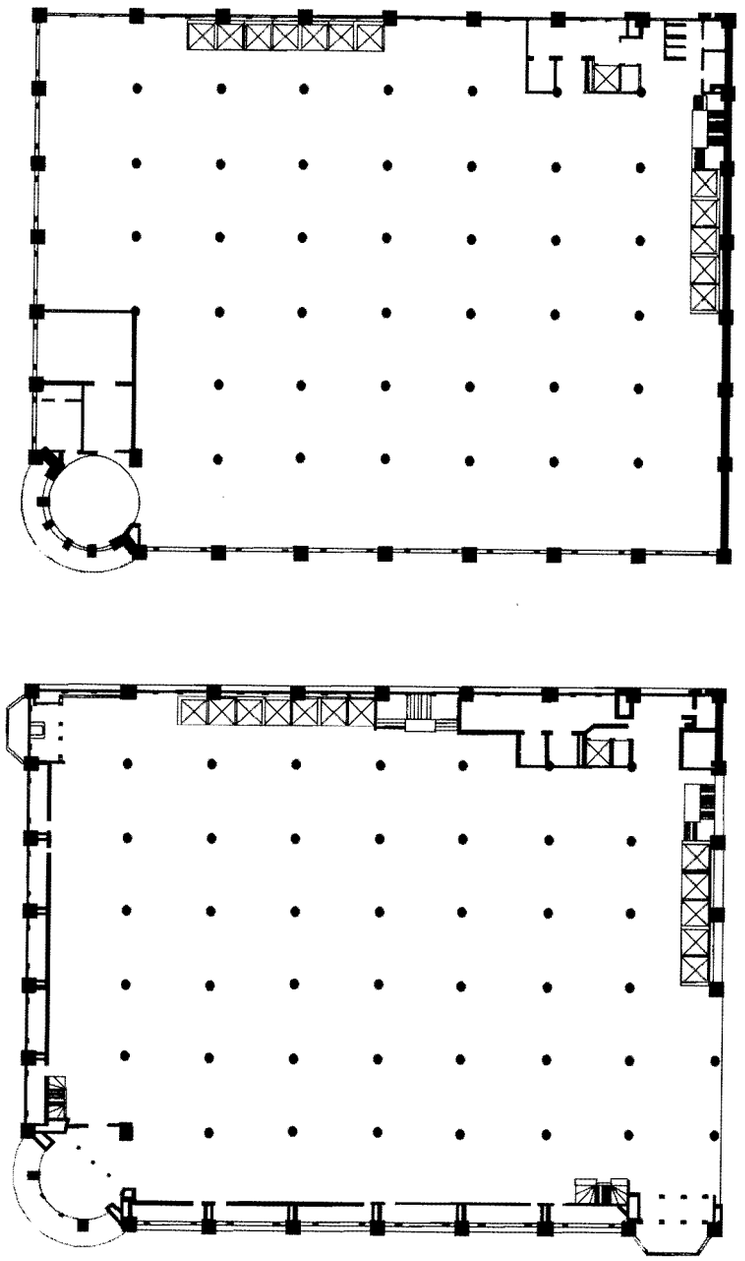
which automatically match orders and clear trades or emulate open-outcry trading itself.[48]

This shift of financial markets to cyberspace has changed what is *being* traded. The 1990s saw the emergence on a huge scale of lightning-fast electronic trading in derivatives — sophisticated, computer-generated financial instruments that would be impossible without networks to move financial data around almost instantaneously and powerful workstations to perform the complex computations on which derivative transactions depend.[49] These pure creations of cyberspace — forwards, caps, collars, swaps, options, swaptions, and more — are essentially carefully calculated side bets on more traditional stock and bond investments. By 1994 the monthly volume of derivative trading on the New York Stock Exchange was running at twice the US gross domestic product.

Once, the canyon of Wall Street at the tip of Manhattan really was *the* place where stocks and bonds were traded — truly the capital of capital. Now (though the old thoroughfare remains and has become increasingly dense with electronics) it is the name of a flourishing region of cyberspace.

Department Stores / Electronic Shopping Malls

Don't make the mistake of thinking that cyberspace marketplaces are all about mathematical whiz kids furiously trading esoteric derivatives, though. Even something as prosaic as the kitchen sink can now be offered and purchased electronically. When Matsushita opened a new-for-the-nineties kitchen showroom in Shinjuku, it was advertised as "the only place in the world where a person can walk in off the street and experience a high-tech Virtual Reality system in a consumer application."[50] You could strap on a headset and a data glove to inspect the appliances on offer. Actually, it didn't



Carson, Pirie, Scott department store (formerly Schlesinger & Mayer), Chicago, by Louis H. Sullivan (1899–1904). Large, open floors linked by vertical circulation systems provide space for displays of goods.

work very well; the crude visual simulations approximated a condition of legal blindness, the gesture sensors recognized only a few simple hand and finger movements, and the heavy apparatus made your neck hurt. But by keeping the show and eliminating the room, it did save lots of very expensive Tokyo real estate.

It was only a transitional step. Once the traditional product showroom has been virtualized — replaced by a set of computer simulations — it can potentially be entered and explored from anywhere. (Elaborate virtual reality interfaces are probably unnecessary; on-command video clips of clothing being modeled, or viewer-controlled video cameras that can be used to inspect products remotely, can probably suffice to create effective virtual showrooms.) When there is enough network bandwidth, and when adequate display devices are sufficiently inexpensive and widespread, Shinjuku rents become irrelevant. The electronic mall becomes the digital successor to the Sears catalogue and the home shopping shows on cable television.

"Going shopping" now means something new.[51] Traditionally, it suggested a trip to market — contact with the historic urban center, a chance to mingle with fellow citizens. Market squares and market days were important spatial and temporal markers. The interface between stall or shop and public place was highly standardized; fronts were either left open to show the goods inside or (from the later seventeenth century) took the form of glazed display windows.[52] Groups of shops might be unified architecturally to yield grander urban elements, as in Giuseppe Mengoni's Milan Galleria. Alternatively, as the opening of the Bon Marché in Paris demonstrated in 1852, a multitude of departments might be combined in a single, great, vertically stacked store — a downtown place to which crowds of shoppers would swarm by train, tram, or bus.[53] More recently, these patterns have largely been displaced by the newer ones of driving to the suburban shopping mall or to the megawarehouse on the fringes of town.[54] But the electronic mall simply short-circuits the trip to a concentration of goods and displays, and replaces the glazed display window facing the street with windows on a computer screen.

Salesperson, customer, and product supplier no longer have to be brought together in the same spot; they just have to establish electronic contact. This idea was successfully pioneered in the phone-order computer business; the "stores" run by companies like Dell consist of toll-free telephone lines or computer network connections, warehouses located conveniently to transportation hubs, and United Parcel Service trucks equipped with wireless computers. A geographically distributed, electronically supported consumer transaction system completely replaces the traditional retail floor.

Even where familiar-looking retail stores remain, they are fast transmuting into computer-intensive network nodes. Bar code scanners at supermarket checkouts, terminals for credit card transactions, and wireless computers at rental car returns are the obvious first steps, but the close coupling of retail space to cyberspace can go far beyond that. Since the 1980s the retail chains Wal-Mart and Kmart have been using VSAT (Very Small Aperture Terminal) satellite systems to link widely scattered stores, delivery trucks, and warehouses into sophisticated computer systems for just-in-time inventory control, price updates, credit card authorization, and videoconferencing.[55] The same systems potentially allow on-shelf LED (light-emitting diode) displays of prices to be changed in all stores in a matter of seconds. Hand-held, wireless, inventory-tracking computers allow store assistants to check stock levels and prices and place orders without leaving the sales floor, and hand-held wireless sales terminals (much like electronic clipboards) are

replacing fixed point-of-sale terminals in some stores.[56] Kmart's ShopperTrak system uses infrared sensors to track where the customers are in the store, to dispatch salespeople and open up checkout lanes when they are needed, and to provide information for setting advertising and display strategies.[57]

Increasingly though, merchants will find that they can dispense with sales floors and sales staff altogether and just maintain servers with databases of product specifications, prices, availability information, images, and simulations. The phone-order business becomes the network-order business. This arrangement potentially cuts overhead, taps into bigger markets, and lends itself to further automation at many levels. Product information can be adjusted instantly as supplies and prices change. Consumers might either "window shop" by remotely accessing such virtual stores, or they might delegate the task to software shopping agents that go out on the Net with shopping lists, inspect the specifications and prices of the merchandise on offer, and return with reports on the best available matches and prices. Closure of a sale can immediately trigger a delivery order at a warehouse, update an inventory database, and initiate an electronic money transfer. So, as the Internet has opened up to commercial use, as commercial online services have grown, and as switched video networks have emerged, schemes for cybershopping have proliferated. Consider some snapshots of pioneering entrepreneurial efforts, circa early 1990s.

Groceries. Plans announced for Time Warner's pilot Full Service Network in Orlando, Florida, include access to an interactive menu of 20,000 products from an online supermarket and 7,500 from a drugstore.[58] In these virtual stores, the act of shopping is scaled down to pointing and clicking; the shopper moves along "shelves" on which realistically rendered packages are displayed, drags items to a "cart," and eventually pays with a credit card. The order is then delivered at a prearranged time.

Automobiles. Contemplate Automall, another service announced for Time Warner's Orlando network. The idea is that viewers will interactively browse through selections of cars and trucks, configure the options, then ask a salesperson to bring a vehicle out to the house for a test drive.

Computers. At the bargain-basement, low-margin end of the computer business, the Internet Shopping Network went online in 1994 with a World Wide Web "storefront" and product catalogue accessed through Mosaic. When a customer selects a catalogue item, the system automatically verifies the customer's credit, scans the current inventory lists of suppliers, selects the lowest-cost combination of distributor, warehouse, and delivery service, and places the order. Delivery is by express package service. "When a customer pushes that button," the proprietor announced, "he's causing a product to be spit out the back of a warehouse with his name on it."[59]

Pizza.[60] Interactive television will replace the telephone. You enter a virtual pizza parlor and see a menu of available toppings. As you choose, a displayed pizza is modified accordingly and the price is tallied. When you are satisfied, the nearest pizzeria is notified and the order speeds to your door.

Clothing. Imagine a virtual clothing boutique. The catalogue is a large collection of video clips showing models wearing the items on offer; these clips can be accessed randomly from your home television set. (The president of Time Warner has commented: "We're talking about a fundamental shift in advertising. . . . You can bring the showroom to your house and take a 15-minute walk through it.")[61] Your detailed measurements are stored in a database somewhere. There is no inventory; when you place an order, computer-controlled machinery accesses these measurements and fabricates the item perfectly to your size. (Fitting rooms become

unnecessary, and your size is never out of stock.) It is then delivered to your door.

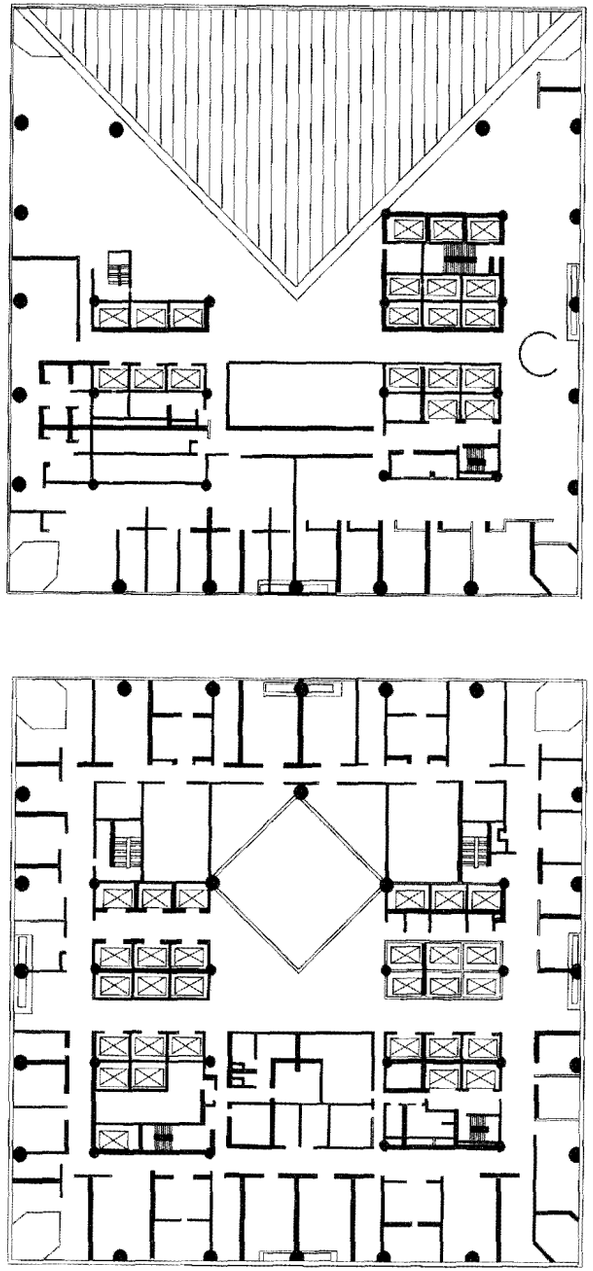
With such soft shops, specialized retail districts and the departments that make up department stores simply become directory categories — logical groupings presented as menu items, icons, or virtual "storefronts" in the interfaces of online services. Retail location becomes a matter of being in the right directories. As with the old telephone Yellow Pages, customers let their fingers (or rather now, their cursors) do the walking. The stock is bigger and the selection larger than in the mightiest big-box off-ramp superstore. The things that remain in physical form are warehouses (which may become smaller as computerized inventory-control strategies become more sophisticated) and delivery vehicles.

From Kmart to Cybermart! Sic transit retail space?[62]

WORK / NET-WORK

Offices are sites of information work — specialized places where numbers, words, and sometimes pictures are collected, stored, transformed, and disseminated.[63] So their tissue is mostly composed of desks equipped with information-handling devices (telephones, computers, fax machines, printers, file cabinets, inboxes and outboxes, and the like), meeting and conference rooms, copying centers and mailrooms, and reception and circulation spaces.[64] From the economist's viewpoint, they are locations where value is added to information.

As information work has grown in volume and importance, and as increasingly efficient transportation and communication systems have allowed separation of offices from warehouses and factories, office buildings at high-priced central business district (CBD) locations have evolved into slick-skinned, air-conditioned, elevator-serviced towers. These architecturally represent the power and



Typical floors of the Bank of China office tower, Hong Kong, by I. M. Pei and Partners (1990). Office workers are tightly packed into a slick-skinned, air-conditioned, elevator-serviced tower.

prestige of information-work organizations (banks, insurance companies, corporate headquarters of business and industrial organizations, government bureaucracies, law, accounting, and architectural firms, and so on) much as a grand, rusticated palazzo represented the importance of a great Roman, Florentine, or Sienese family. So, for example, when the Hong Kong and Shanghai Bank wanted to demonstrate its power and importance, it built a shiny high rise in the heart of Hong Kong's business district. Then the Bank of China trumped it by constructing a much taller tower on a nearby, overlooking site.

From this follows a familiar, widely replicated, larger urban pattern — one that you can see (with some local variants) from London to Chicago to Tokyo. The towers cluster densely at the most central, accessible locations in transportation networks. Office workers live in the lower-density suburban periphery and commute daily to and from their work. This tightly focused arrangement (as opposed to more diffuse distributions) allows considerable scale economies to be achieved in mass transit systems. Downtown services meet the needs of people in their worker roles during weekdays, while suburban services are there for those same people in their roles as residents in the evenings and on weekends.

The bonding agent that has held this whole intricate structure together (at every level, from that of the individual office cubicle to that of CBDs and commuter rail networks) is the need for face-to-face contact with coworkers and clients, for close proximity to expensive information-processing equipment, and for access to information held at the central location and available only there. But the development of inexpensive, widely distributed computational capacity and of pervasive, increasingly sophisticated telecommunications systems has greatly weakened the adhesive power of these former imperatives, so that chunks of the old structure have begun to break away and then to stick together again in new sorts

of aggregations. We have seen the emergence of telecommuting, "the partial or total substitution of telecommunication, with or without the assistance of computers, for the twice-daily commute to/from work."[65]

Gobs of "back office" work can, for example, be excised from downtown towers and shifted to less expensive suburban or exurban locations, from which locally housed workers remain in close electronic contact with the now smaller but still central and visible head offices. These satellite offices may even be transferred to other towns or to offshore locations where labor is cheaper. (Next time you pay your credit card bill or order something from a mail-order catalogue, take a look at the mailing address. You'll find that the envelope doesn't go to a downtown location in a major city, but more likely to an obscure location in the heartland of the country.) The bedroom communities that have grown up around major urban centers also provide opportunities for establishing telecommuting centers — small, Main Street office complexes with telecommunications links to central offices of large corporations or government departments.[66] As a consequence, commuting patterns and service locations also begin to change; a worker might bicycle to a suburban satellite office cluster or telecommuting center, for example, rather than commute by car or public transportation to a downtown headquarters.

Another strategy is to create resort offices, where groups can retreat for a time to work on special projects requiring sustained concentration or higher intellectual productivity, yet retain electronic access to the information resources of the head office. This idea has interested Japanese corporations, and prototypes have been constructed at locations such as the Aso resort area near Kumamoto.[67]

In insurance companies, and other organizations that sell disembodied products or take orders to be filled later, traveling

salespeople can be readily transformed into high-technology nomads who remain continually online and almost never have to visit the home office. For traditional centers of such industries, such as Hartford, Connecticut, the future looks increasingly problematic as the office-in-a-briefcase displaces the cubicle at corporate headquarters.[68]

More radically, much information work that was traditionally done at city-center locations can potentially be shifted back to network-connected, computer-equipped, suburban or even rural homes. Way back in the 1960s, well before the birth of the personal computer, James Martin and Adrian R. D. Norman could see this coming. They suggested that "we may see a return to cottage industry, with the spinning wheel replaced by the computer terminal" and that "in the future some companies may have almost no offices."[69] The OPEC oil crisis of 1973 motivated some serious study of the economics of home-based telecommuting.[70] Then the strategy was heavily promoted by pop futurologists of the Reaganite eighties, who argued that it would save workers the time and cost of commuting while also saving employers the cost of space and other overhead. The federal Clean Air Act amendments of 1990, which required many businesses with a hundred or more employees to reduce the use of cars for commuting, provided further impetus. More sober and skeptical commentators demurred, claiming that savings in commuting costs would be offset and perhaps negated by the increased costs of distributing needed supplies and utilities to workers at scattered locations, and that space and overhead costs would not disappear but be transferred to the workers. But by 1993 there was a clear and accelerating trend: there were 6.6 million home-based telecommuters in the United States, up 20 percent from 1991.[71]

At the same time, many observers have become convinced that the very character of daily work is transforming in ways that reinforce these tendencies. Robert Reich's policy tract *The Work of Nations* made a compelling case that advanced economies increasingly rely on highly skilled "symbolic processors" who deal mostly in information. Others have pointed out that, while information-work organizations once could accumulate and retain in fixed locations, over long terms, most of the expertise that they needed to carry on their businesses, this becomes increasingly difficult in an era of economic globalization and rapid political, social, and technological change. Now it is often better strategy to form multipartner, geographically distributed alliances of various specialist groups (consultants, suppliers, subcontractors, and so on) as needed for particular projects, then to disband and regroup as old projects end and new ones begin. We are entering the era of the temporary, recombinant, virtual organization — of business arrangements that demand good computing and telecommunications environments rather than large, permanent home offices.

In the 1960s and early 1970s, as the telecommunications revolution was rapidly gaining momentum, some urbanists leaped to the conclusion that downtowns would soon dissolve as these new arrangements took hold. Melvin Webber, for example, predicted: "For the first time in history, it might be possible to locate on a mountain top and to maintain intimate, real-time and realistic contact with business or other associates. All persons tapped into the global communications net would have ties approximating those used today in a given metropolitan region."[72]

There is some evidence that these theorists were right. Consider this telling straw in the electronic breeze. In 1974 Sears, Roebuck and Company proudly built Sears Tower in the Chicago Loop — 4.5 million square feet of floor space and the tallest building in the world, right in the birthplace of the office skyscraper. But Sears didn't stay there very long. By 1992 the company had deserted thirty-seven of the forty floors it occupied and sent five thousand

jobs thirty-five miles west to Hoffman Estates in Chicago's suburban fringe.

But the prophets of urban dissolution underestimated the inertia of existing patterns, and the reality that has evolved in the 1980s and 1990s is certainly more complex than they imagined. The changing relative costs of telecommunication and transportation have indeed begun to affect the location of office work.[73] But weakening of the glue that once firmly held office downtowns together turns out to *permit* rather than *determine* dispersal; the workings of labor and capital markets and the effects of special local conditions often end up shaping the locational patterns that actually emerge from the shakeup.[74]

Perhaps the time has not yet come to bid farewell to those vertiginously vainglorious corporate monuments that have defined the great downtowns of the twentieth century. But they no longer seem so inevitable. Given a choice, many of us may prefer working with a net.

At Home / @Home

The domestic living room is emerging as a major site at which digitally displaced activities are recombining and regrounding themselves in the physical world. It's not just in the homes of electroyuppies, digirati, and chiphead hobbyists. In many places now, news and entertainment, education, work, shopping and banking, and lots of general social interaction are starting to flow in and out through small, housebroken, electronic boxes. We are, it seems, seeing a reversal of the "gradual divorce of the home . . . from the workplace" that Lewis Mumford's narrative *The City in History* located in the seventeenth century.[75]

Couch potatoes and cable company executives have been quick to define the consumer electronic appliances that accomplish this as

more intelligent descendents of the television set. But there is much more to them than that; they might equally well be regarded as smart, multimedia telephones or as domesticated computers.[76] They insinuate themselves in among familiar furnishings and appliances and displace or eliminate their roles.

In some ways, an information appliance hooked up to a high-bandwidth cable is a lot like an old-fashioned mailbox. It is where information streams into the house and is decoded, and, conversely, it is where information is encoded and sent out in digital form. But there is, of course, no need to hang it on the front door. It can be wherever cables can reach. It can even be wireless. The postman now knocks anywhere.

When attached to a display device (like a television set or personal computer monitor), such an appliance presents itself as a hearth that radiates information instead of heat. Just as the fireplace with its chimney and mantel was the focus of a traditional living room, and later became the pivot point for Frank Lloyd Wright's box-busting house plans, so the display — the source of data, news, and entertainment — now bids to become the most powerful organizer of domestic spaces and activities. In most rooms, it's what most eyeballs are most likely to lock onto most of the time.

Connected to an appropriate paper-processing mechanism, an appropriately configured information appliance can receive or send a fax, make a copy of a document, or deliver today's newspaper right into your hand. Printer, photocopier, fax machine, and newspaper delivery box all condense into one compact device. It becomes the new reading and writing desk, and it belongs in the study or the home office, beside the recycling bin.

An information appliance can also create electronic stoops — places where you can hear and be heard, or see (on a display) and be seen (via a video camera) without completely relinquishing the privacy

and controllability of the home. But these places need not be positioned (like the old urban stoops lauded by nostalgic planning theorists) at the boundary between private property and the street; they can just as easily be internal, thus restructuring the traditional public-to-private hierarchies of domestic space.

For a designer of domestic space, these differences do matter. When information appliances are treated as interactive televisions or as electronic hearths, small groups of people will sit around them in living rooms, view them from distances of eight to ten feet, and probably control them with hand-held remote devices. Where they are assimilated to the tradition of the personal computer, individuals in dens and studies will view them from distances of about eighteen inches and use keyboards. If they are configured as two-way videophones that create zones of semi-public space, then we will not want them in bedrooms or bathrooms, but if they are equipped with medical monitoring devices, then that is precisely where we will need them.

Increasingly, homes will be places with network addresses as well as street addresses. The functions of the various interior spaces will be established, in large part, through installation of specialized information spigots and collectors. And, as networks and information appliances deliver expanding ranges of services, there will be fewer occasions to go out.

Decomposition / Recombination

This sort of analysis reveals only part of the story, though. Efficient delivery of bits to domestic space will, in addition, collapse many of the spatial and temporal separations of activities that we have long taken for granted. Many of our everyday tasks and pastimes will cease to attach themselves to particular spots and slots set aside for their performance — workplaces and working hours, theaters and performance times, home and your own time — and will henceforth be multiplexed and overlaid; we will find ourselves able to switch rapidly from one activity to the other while remaining in the same place, so we will end up using that same place in many different ways. It will no longer be straightforward to distinguish between work time and "free" time or between the space of production and the space of consumption. Ambiguous and contested zones will surely emerge.

Imagine, for example, that you are in your living room at eight o'clock in the evening. One window on your screen connects you to a database on which you are paid to work, another shows the news from CNN, and another puts you in a digital chat room. You switch your attention back and forth — mostly dealing with the database, but keeping an eye on the news and occasionally interjecting a comment into the interesting conversation that is unfolding in the chat room. Children come and go, making their usual demands, and you sometimes turn your attention to them. Are you at work or at play? Should you be charging your time (or some percentage of it) to your employer? If so, is your supervisor entitled to check up on you by monitoring the screen display? Are you occupying tax-deductible work space or nondeductible living space?

Such instabilities and ambiguities in space use also challenge traditional ways of representing social distinctions and stages of socialization.[77] In many societies there are well-defined, separate places in the dwelling for men, women, and children and for family members and for guests; different information circulates in these different spatial settings. Young children may be isolated and protected in nurseries and playgrounds, and there may be architecturally differentiated places for adolescents, adult breadwinners, and retirees. At an urban scale, prisons, convents, residential colleges, orphanages, hospices, halfway houses, official residences for political and religious leaders, and low-income housing projects make vivid social distinctions by creating readily identifiable, physically

discrete domains. But categories lose their clarity, and rites of passage require redefinition, when the uses of built space are no longer permanently assigned and depend from minute to minute on software and the fleeting flow of bits.

Thus there will be profound ideological significance in the architectural recombinations that follow from electronic dissolution of traditional building types and of spatial and temporal patterns. Opposing ideologues have lost no time in pressing upon us their tendentious visions of this restructuring.

To the right, some futurologists (particularly Alvin Toffler)[78] have painted a neo-Norman Rockwell picture of cozy electronic cottages that "glue the family unit together again." As Toffler sees it, "The electronic cottage raises once more on a mass scale the possibility of husbands and wives, and perhaps even children, working together as a unit." With the anticipated decline in commuting to work, and the increasing possibility of changing jobs without changing houses, we can expect "greater community stability" and "a renaissance among voluntary organizations like churches, women's groups, lodges, clubs, athletic and youth organizations." He imagines a cozy return to the days of the loom in the living room, the farmhouse dairy, and merchants who lived above the shop, and to the community structures that accompanied these arrangements.

From the left, eliminating the spatial and legal distinctions between home and workplace usually looks more like an insidious strategy to decentralize and proliferate the Dark Satanic Mill. It removes the possibility of finding any refuge from the workplace, encourages long and irregular work hours, impedes organization of workers and regulation of workplace conditions, and puts women right back in the home. Domestic space becomes electronic sweatshop. In the resulting digital dystopia, "Landmarks are likely to be financial complexes and electronic skyscraper-fortresses, cordoned off from depleted and decaying inner city residential areas," while more affluent private estates and apartments are "sealed off from the surrounding community by elaborate surveillance and security systems."[79]

We can formulate these issues in social equity terms. Shall we allow home-based employment, education, entertainment, and other opportunities and services to be channeled to some households and not to others, thereby technologically creating and maintaining a new kind of privilege? Or can we use the infobahn as an equalization mechanism — a device for providing enhanced access to these benefits for the geographically isolated, the homebound elderly, the sick and disabled, and those who cannot afford wheels?

We can also formulate them as questions about architecture's fundamental representational role. If we can no longer make the traditional urban distinction between, on the one hand, major public and commercial buildings that represent institutions, and, on the other hand, relatively uniform and repetitive housing areas, how shall we make social organization and power legible? Going out, going to work, going to school or to church, going away to college, and going home are economically significant, socially and legally defining, symbolically freighted acts. To change or eliminate them, as electrocottages and cybercondos promise to do, is to alter the basic fabric of our lives.

PROGRAMMABLE PLACES

Building type by building type, the story is much the same. The floor plan of a traditional store, library, theater, school, bank, stock exchange, office, home, or any other kind of building clearly shows how it works: you see particular places for the various activities that are to be housed, together with a circulation system of doors and passageways that integrates these parts into a functioning whole. If you look at the site plan, you can also see how entry and exit points,

windows, and walls relate the whole composition to its natural setting or urban context. And at an urban scale, streets and public places interconnect buildings. Classical architects of the eighteenth and nineteenth centuries handled the task of putting spaces together by creating hierarchies of great and small spaces around axial, symmetrical circulation systems connected to grand, formal entries and public open spaces.[80] With the aim of being as logical and efficient as possible, functionalist modernists of the twentieth century have often derived their less regular layouts directly from empirically established requirements of adjacency and proximity among the necessary spatial elements.[81]

But when telecommunication through lickety-split bits on the infobahn supplements or replaces movement of bodies along circulation paths, and when telepresence substitutes for face-to-face contact among the participants in activities, the spatial linkages that we have come to expect are loosened. The constituent elements of hitherto tightly packaged architectural and urban compositions can begin to float free from one another, and they can potentially relocate and recombine according to new logics. Perhaps it is not too romantic to imagine that unique natural environments, culturally resonant urban settings, and local communities that hold special social meaning will increasingly reassert their power. Perhaps we will find compelling advantages to putting together spaces — like living spaces and work space — that were once thought to belong in different buildings located in different zones of the city. In any case, the old bonds break down and new groupings can begin to form.

Simultaneously, the fresh requirements of the infobahn age suddenly kick in. Buildings and parts of buildings must now be related not only to their natural and urban contexts, but also to their cyberspace settings. Increasingly, they must function as network interfaces — loading docks for bits. They must be equipped with electronic sensors and effectors, onboard processing power, sophisticated internal telecommunications capabilities, software, and capacity for getting bits on and off — much like computer screen space that can be programmed for many different uses. Instead of living rooms, we will have domestic spaces that can be programmed for work, education, and entertainment. In place of today's centralized schools and hospitals, we will have systems for projecting specialized expertise into many different places — from airplane seats to isolated rural community centers — wherever and whenever it is required. Instead of building huge suburban theme parks filled with different rides, entertainment moguls will construct networks of much smaller, reprogrammable, simulation rides.[82] Rooms and buildings will henceforth be seen as sites where bits meet the body — where digital information is translated into visual, auditory, tactile, or otherwise perceptible form, and, conversely, where bodily actions are sensed and converted into digital information.

Building these programmable places is not just a matter of putting wires in the walls and electronic boxes in rooms (though that is a start). As the relevant technologies continue to develop, miniaturized, distributed computational devices will disappear into the woodwork. Keyboards and mouse pads will cease to be the only bit-collection zones; sensors will be everywhere. Displays and effectors will multiply. In the end, buildings will become computer interfaces and computer interfaces will become buildings.

Architects of the twenty-first century will still shape, arrange, and connect spaces (both real and virtual) to satisfy human needs. They will still care about the qualities of visual and ambient environments. They will still seek commodity, firmness, and delight. But commodity will be as much a matter of software functions and interface design as it is of floor plans and construction materials. Firmness will entail not only the physical integrity of structural systems, but also the logical integrity of computer systems. And delight? Delight will have unimagined new dimensions.