On Cyberspace and Virtual Reality[1]

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by

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I am going to talk about Cyberspace and VR in some detail, but I want to start from the broadest possible perspective, esp. as we prepare for the next session on the ethical issues fo information technology.

In fact I want to try to paint two pictures, one broad and historical and the other deep and rather technical. The first will be a speeded up movie—like time lapse photography—of the history of *communications media* so that we can see where cyberspace fits into overall social evolution. The second picture focusses on some simple mathematical properties of cellular automata and then will move by analogy, to the site of a single human mind in a complex world of things and other minds. The phenomenon of cyberspace, and virtual reality, arise out of the intersection of these two realms: the socio-technological and the socio-psychological.

For the third and final part of lecture, I shall show some slides (and, if we have time, a video).

First: The Media

By the the history of communciation media I simply mean the history of the technical means by which absent and/or abstract events, experiences, ideas become symbolically represented,

"fixed" into an accepting material, and thus conserved through time as well as space. Although the topic is largely sociological, it is also extremely deep and infinitely ancient, for the secret life itself is wrapped up in the mystery of genetic encoding and in the replication and motility of molecules which orchestrate each other's activity. Genes are information; molecules are media as well as motors, so to speak. . .

But I shall not begin here, where Professor Edelman is situated. Our story best begins with man's conscious co-option of the physical environment for his own informational and communicational uses. Not every part of the natural world will do, but specifically those parts which are blank themselves and that best receive *markings*--such as sand, wood, bark, bone, stone, and the human body. Thes markings were for the purpose of preserving and delivering messages. They were signs, not unlike spoors, tracks, or tell-tale colors of vegetation or sky, but now rendered *intentional*, between man and man, and man and his descendants.

The step that followed was inspired: to begin to *produce* the medium, to create smooth plastered walls, thin tablets, and papyrus, and to reduce the labor of marking which was required--such as carving, chiseling--to the deft movement of a pigmented brush or stylus. As society elaborated itself and as the need to keep records and to educate grew, it became more efficient first to shrink and conventionalize the symbols themselves, from pictograms into phonetic alphabets, then to crowd these markings in into rows and layers, and then into "paper-thin" scrolls and stacks.

At this early stage already, we can see a double movement (1) towards the dematerialization of media and (2) towards the reification of meanings. All that remains to us of the ancient world is some writing and painting and sculpture and architecture: solid and material objects, all. It would be wrong to underestimate the vaster traffic of information in more ephemeral media that sustained day to day life: from scratched clay tablets and bark shards, to graffitied walls, counters, and papyrus cloths, from diagrams in the sand to banners in the wind. Myriad gestures, demonstrations, performances, and of course, the babble of song, gossip, rumor, and instruction continuously filled the air. The sounds of every century before this one are gone for ever, as well as almost all of the sights that together constituted the medium of social interchange.

But with the development of writing and counting and modes of graphic representation, and then, centuries later, with the invention of the printing press and the spread of literacy beyond the communities of religious scholars and noblemen, the din of ephemeral communications came to be recorded at an unprecedented rate. More importantly for our story, these "records" came to be easily duplicable, transportable, and broadcastable.

After printing, life would never be the same. The implications of the print revolution and the establishment of what McLuhan called the "Gutenberg galaxy" can hardly be overestimated. Not the least of these implications were (first) the steady, *de facto*, democratization of the means of idea production and dissemination, (second) the

exponential growth of that objective body of scientific knowledge and diverse cultural practices which Karl Popper called*World 3,* and, (third) the fact that this body of thought, containing both orthodoxies and heresies, could neither be located at any one place, nor be entirely controlled

Although "printed matter" from proclamations to bibles to newspapers could, in principle, be taken anywhere a donkey, and truck, a boat or an airplane could physically go, however, there was a *limit*, namely, *time*. No news is fresh days or weeks later. The coordination of goods transportation in particular was a limiting case, for if no message could travel faster than that whose imminent arrival the message was to announce…then of what value the message? Hence the telegraph, which was the first "medium" after semaphore, smoke signals, and drumming, to connect distant "stations" on the model of a permanent *network.*

Another constraint related to time was *expense* due to the sheer expenditure of energy required to convey even paper across substantial terrain. The kind of unity made possible in small communities by the near-simultaneity and near-zero-cost of natural voice communications, posters and leaflets, collapses at the larger scale. Social cohesion at any scale is a function of consensus, of shared knowledge, and without constant updating and interaction, such cohesion depends crucially on early, and strict, education in--and memory of--the culture. Social flexibility, conversley, depends on forgetting and cheap communication.

With the introduction of the *telephone*, both the problem of speed and the problem of expense were largely eliminated. Once wired together, the energy expenditure was trivial to relay a message, and it was soon recognized (interestingly only in the nineteen-thirties and -forties) that the telephone need not be used like a "voice-telegraph," which is to say, sparingly and for serious matters only. Rather, it could be used also as an open channel for constant, meaningful, community-creating and business-running interchanges of the sort characterizing ancient urban life. Here was a medium, here *is* a medium, whose communicational limits are still being tested, and these quite apart from what can be accomplished using the telephone system for computer networks.

But this was paralleled by a perhaps more significant development: *wire-less* broadcasting, i.e. radio and television. Soon, encoded words, sounds, and pictures from tens of thousands of sources could invisibly saturate the world's "airwaves," every square millimeter and without barrier. From every radio came the very sound of life, and from every television set the very sight of it : car chases, wars, laughing faces, oceans, volcanos, crying faces, tennis matches, perfume bottles, singing faces, accidents, diamond rings, faces, steaming food, more faces. . .images, ultimately, of a life not really lived anywhere but arranged for the viewing. Television became less a medium of *communication* than a medium of *communion,* a place and occasion where nightly the British, the French, the Germans, the Americans, the Russians, the Japanese, the Swedes. . . settle down by the million to watch and ratify their respective national mythologies: nightly variations on a handful of

dreams being played out, over and over, with addicting, tireless intensity. Here are Marshall McLuhan's acoustically structured global villages (though he imagined only one). And here is support for the notion that the electronic media, and in particular television, provide a medium not unlike the air itself, surrounding, permeating, cycling, invisible, without memory or the demand for it, conciliating otherwise disparate and perhaps antagonistic individuals and regional cultures.

With cordless and then private cellular telephones, and "remote controls" and then hand-held computers communicating across the airwaves too, the very significance of geographical location at all scales begins to be questioned.

We become nomads. . . who are always in touch.

All the while, material, print-based media were and are growing more sophisticated too: "vinyl" sound recording (a kind of micro-embossing), color photography, offset lithography, cinematography, and so on…the list is long. They became not only more sophisticated but more egalitarian. The general public not only "consumed" ever greater quantities of magazines, billboards, comic books, newspapers, and movies but also gained access to the means of production: to copying machines, cameras, movie cameras, record players and the rest, each of which soon had its electronic/digital counterpart as well as a variety of hybrids, extensions, and cross-marriages: national newspapers printed regionally from satellite-transmitted electronic data, facsimile transmission, digital preprint and recording, and so on.

And now, today, with the advent of fast personal computers, digital television, and high bandwidth cable and radio-frequency networks, so-called post-industrial societies stand ready for a yet deeper voyage into the dematerializatio of information, the 'permanently ephemeral,' the realm which people call **cyberspace.**

Now what is cyberspace?

In my book I define cyberspace as:.....

a globally networked, computer-sustained, computer-accessed, and computer-generated, multidimensional, artificial, or "virtual" reality. In this reality, to which every computer is a window, seen or heard objects are neither physical nor, necessarily, representations of physical objects but are, rather, in form, character and action, made up of data, of pure information. This information derives in part from the operations of the natural, physical world, but for the most part it derives from the immense traffic of information that constitute human enterprise in science, art, business, and culture.

The dimensions, axes, and coordinates of cyberspace are thus not necessarily the familiar ones of our natural, gravitational environment: though mirroring our expectations of natural spaces and places, they have dimensions impressed with informational value appropriate for optimal orientation and navigation in the data accessed.

In cyberspace, information-intensive institutions and businesses have a form, identity, and

working reality--in a word and quite literally, an *architecture*--that is counterpart and different to the form, identity, and working reality they have in the physical world. The ordinary physical reality of these institutions, businesses, etc. are seen as surface phenomena, as husks, their true energy coursing in architectures unseen except in cyberspace.

So too with individuals. Egos and multiple egos, roles and functions, have a new existence in cyberspace. Here no individual is appreciated by virtue only, if at all, of their physical appearance, location, or circumstances. New, liquid, and multiple associations between people are possible, for both economic and non-economic reasons, and new modes and levels of truly interpersonal communication come into being.

Cyberspace, I say, has a geography, a physics, a nature, and a rule of human law. In cyberspace the common man and the information worker--cowboy or infocrat--can search, manipulate, create or control information directly; he can be entertained or trained, seek solitude or company, win or lose power. . . indeed, can "live" or "die" as he will.

The Second part of my talk now goes a little deeper. I want to talk about information and consciousness.

We shall first need to agree--or you will have to grant me as an assumption--that the amount of information that can be stored in a space depends critically upon four things:

- first, the dimensionality of the space,
- second, the inner or intrinsic dimensionality of what we want to call a *point* in that space,
- third the overall size/capacity the space which is the same as stating the ratio of its smallest to largest measurement, or grain, since this gives us the number of distinct points available, and
- fourth, the precision with which the intrinsic dimensions of the point can be specified.

Of course, a true point, mathematically speaking, has no intsinsic dimensions, and can be oin only one state, which is "on" or merely existing. If the point did not exist, points around it would swallow it up, like an ocean. If the point had one intrinsic dimension and two values, shall we say "1" and "0" both of which exist in some sense *on top of* the mere existence of the points, then our "points" would really be infinitesimally small *dots*. It follows that to store a given large amount of information, that information can be distributed according to two policies: one is to have a large or high-dimensional space and minimally simple dots, the other is to have a relatively small or low dimensional space and to *bury*--as it were--the information in the complexity of the dot, giving it many inner dimensions with very fine precision. Indeed, *within a dot* there can exist,

compacted, in a sense, another coordinate system with lower dimension-dots, and so on down.

Now if we can think of the *world as a whole* as consisting of patterns of information, then we can ask, how big is the world? The answer is: *no bigger and no smaller than it needs to be to express or contain the amount of information in it without loss or redundancy*. This insight is not mine but Leibniz's Principle of the Identity of Indiscernibles, which survives in modern physics as the principle of Maximal Variety.[2] What it says is that at the deepest level, and to the extent that we believe the world to consist geometrodynamically of fundamental particles whose only intrinsic attribute is existence and momentum, that the size of the universe is a function of its complexity. If almost nothing more can be buried in a dot but a single bit, then space--space "out here," real space, perceivable space with its three dimensions--then *space* and *information* are the same thing. Over the same period of time, to have more of one is necessarily to have more of the other.

Now at a higher level of analysis of reality than particle physics, "dots" are both finite in size and more-or-less stuffed with information: information that appears to us as "properties," "qualities," "conditions," and "behaviors," and so on. What are examples of such dots? They might be grains of sand, color pixels on a screen, computers in a network, biological cells in a body, or minds in a society. In each case the uniqueness of each is expressed in two ways rather than one as was the case with atomic-bits: First: in uniqueness of spatiotemporal location "out here," and second in the qualititative differences between each, "in there." But this assumes that what is out here has nothing to do with what's in there, which in many cases is not true, and finally we are ready to make our move.

We look to the new subdiscipline situated at the intersection of biology and computer science which goes by the name of Artificial Life (AL), or Cellular Automata (CA) theory , the latter term going back to John von Neuman's ground-breaking work in the 1950s. In both, life processes such as reproduction, group interaction patterns, and evolution are simulated by allowing a computer to "play out" simple programs assigned to "cells" over time. Always, each cell's behavior depends not only on its inner, given program but on the condition or state of its neighboring cells. As the immediate environment of each cell changes, the cell responds by changing *its* state or behavior accordingly. It thereby constitutes part of the altered environment of the cells to which it is neighbor in turn.

Acting *en masse*, as you all no doubt know, results are often marvellous and unpredictable. When each cell is represented by a group of pixels, large scale patterns can spontaneously develop on the computer screen. Whorls and waves develop, clusterings, migrations, and

dispersals. Individual digital "creatures" evolve and die off, to be replaced--in certain systems--by smarter ones. There can be predators and parasites, eras of calm, eras of warfare…etc. etc. And all this, as I noted, can come about with rather elementary beginning programs, programs in the order of 20 to 40 lines of code assigned to each cell. As with natural evolution, complexity not apparent at the start develops over time by leaps and bounds, and all the more so if the initial cell programs are revisable by certain events in the cell's history in a sort of Lamarkian hurrying up of the process.

Now, for many people it would be too far fetched to draw analogies between cells in a AL/CA system and individuals in a society or neurons in the brain. Part of the excitement of Dr. Edelman's research lie precisely in the leap implied here. The far-fetchedness of an analogy depends, however, on the specificity of its claims. In this case, I believe, something rather interesting and relevant can be said about *all* social organizations before the limits of plausibility are reached.

For example, consider some simple informational accounting:

Let B be the number of behaviors (or states) that a cell can display, both to us, as observers, and to its neighbors in "screenworld." Let X be the number of cells in the effective neighborhood of any given cell. If the particular behavior of a given cell *depends* on the combined behavior of the ones around it--i.e. the ones in its effective neighborhood--then each cell must have, by virtue of its program, the capacity to perceive, remember, and process the B^X possible states of its effective neighborhood in order to decide what to do next. Now if $x > 1$ and $B > 1$ then clearly B^X is a quantity greater than B, easily much greater. From this we learn *that no cell can behave in as many distinct ways as the ensemble of its similarly adept neighbors can.* Each cell('s program) therefore must engage in some sort of decision making, filtering, or blurring process that *reduces* B^X to B. Each cell must be able to register $X\log_2 B$ bits of information, manipulate it--condense it, add it up, average it, even discard parts of it--and then *produce* $\log_2 B$ bits of information for display.

What does this mean for *us*? Think of a cell as a human individual. The greater the number of behaviors she allows herself and others to engage in and display ("B"), and the greater the number of friends, neighbors, and objects she interacts with ("X"), then, quite precisely, the exponentially greater ("B^X") is the possible complexity of the environment she must deal with. And if what I said earleir I holds any water, then greater too is the amount of *space* that is required for that information to exist.

Space? Just where *is* this space? *What* is this space?

It is not the space of "screenworld." Screenworld acts out another, global history (which is interesting enough). It is, rather, the space locked up, as it were, in the domain of each cell, in the imagination of each mind. Seen from above, from outside, the abstract motion

of data-points within intrinsic dimensions is visible as "behavior" of $\log_2 B$ bits in complexity. But *inside*, the remaining $(X-1)\log_2 B$ bits are at play.[3]

I am in an open air market in Rome. It is April. Heaps of fruit and vegetables—tomatoes, squash, red peppers, no two the same—shine in raw wooden boxes under yellow canvas awnings. Water glistens, black, between the cobblestones under me. The air is filled with the sounds of traffic and voices, each from a unique direction. The smell of fresh fish wafts in a wayward breeze, and then the smell of coffee. To my right is a fountain and sculpture in white marble: figures caught in ecstatic agony, struck in sunshine against a shady Baroque facade, and in the blue, blue sky I see the contrail of a jet headed west, away from the sun.

Why do I see all this, this excess of detail that I can do nothing about? Precisely because I can do nothing about it! I am a dam, a delay; and this information is accumulated behind me and in me like a lake. *A* world is constituted in me because *the* world cannot flow though me unjudged, unreduced. I can respond with actions and thoughts to a vanishing fraction of the welter of information I can perceive, and I "perceive" only because I cannot respond fast enough. Think: were it not this way, were to I have a specific and instant response for every bit of data entering my system, then I would be nothing but a "throughput" device with a passive display; I would be like a billion-stringed puppet, a crazed switchboard, a rail-yard of lightning-quick trains, like a pile of mirrors or a glass chandelier in the sun…each quite beautiful perhaps but quite dead, without consciousness. There would be no world in me, pooled in me, circulating, evaporating, being filtered.

The street market in my head was a holding action.

In other words, just as stomachs make it possible for creatures not to eat all the time, so consciousness makes it possible for us not to *react* all the time, to hold a world behind our eyes and posit it before our eyes…while we decide what do next.

In sum: the production of spatiotemporal consciousness of a "world" is a consequence--though no *mere* consequence--of surfeit, of the surplus of information that surrounds each one of us relative to our capability of answering to it: $B^X >> B$. My argument, then, is not about data representation alone but about its accumulation and processing. Both of these require not just sufficient neurological/computational complexity—a question of hardware—but also, phenomenologically, sufficient *imaginal space* for it to take place.

Moreover, as time goes by in an *evolving* CA system, the whole system grows rapidly in complexity. If cells' programs are revisable, then the short-cuts, summaries, and decision routines which the first programs employed and which capitalized upon the redundancy in the cell's environment, soon cease to be effective. No longer can they hold and

conserve and distill all the information about the environment that they need to. Rather, if the cell is to survive and proliferate, these programs are obliged to become more complex, longer, "smarter," and it does. As screenworld—and, dare I say now, as *society*—complexifies in its external, spatiotemporal dimensions, and as individual (cell) behaviors increase in number and complexity and range of perceptibility, then so too, and ever faster, must the internal world of each individual cell expand in order to embrace the new information.[4]

In all, this is a model of *space producing itself* as a correlate of the proclivity of complex, dynamical systems to generate more complexity, more information, in themselves. It is also, I think, a model of what Henri Lefebvre's wants to call *social space*, i.e. the space that exists chiefly by virtue of minds in a nexus of information exchange with one another, and that exists chiefly *in* those minds rather than in the physical world.

Now, you may wonder why I have gone to such lengths and technicality to elaborate upon what amounts to a quite modest claim…the claim, that is, that as environments become more complex, and as effective neighborhoods become larger and/or more complex, individuals within them are apt to have, and to *need* to have, "more on their minds." Indeed. To this self-evident insight I am adding only the notion that 'more on our minds' means more in our minds, and that this means more space in the world in a very important sense. For if we can say that "the world" [either reduces to, or that it] contains as part of itself, the set-theoretic union of all inner worlds, we need only now relax our strictures as to the legitimacy of sources of information to see that cyberspace, [which Gibson once called "a consensual hallucination,"] is but a pattern woven of and into the same informational tapestry as once caused in me the experience of the market place in Rome.

On the largest view, the advent of cyberspace is apt to be seen in two ways, each of which can be regretted or welcomed: either as a new stage in the *etherealization* of the world we live in, i.e. the real world of people and things and places, or, conversely, as a new stage in the *concretization* of the world we dream and think in, the world of abstractions, memory, and knowledge.

Both views are useful. But both are misleading in so far as they are both implicitly modeled on the historical processes of transformation, usurpation, and replacement rather than those of evolution, speciation, and displacement. With cyberspace the real world does not *become* etherealized and thereby less large or less real; nor does the "mental" world *become* concrete and thus, itself, less mental or spiritual. Rather, with cyberspace, a whole new space is opened up by the very complexity of life on earth, another venue for consciousness itself. And this emergence, proliferation, and complexification of consciousness must surely be this universe's project.

Cyberspace unfolds in an expanding new landscape of ideational and electronic complexity, but one not in any sense ideal, transcendental, or beyond reality. Just as printing did not *re*place but *dis*placed writing, and writing did not *re*place but *dis*placed story-telling, and

just as movies did not *re*place theater, nor television replace movies. . . cyberspace will not replace either objective, physical reality or dreaming and thinking in their historical modes. Cyberspace will not replace art museums, concerts, parks, or sidewalk jugglers. It will not replace sex, books, buildings, or radio. Each of these earlier media and activities will move over a little, as it were, free--indeed obliged--to become more themselves, more involved in their own artistry and usefulness. Each will be dislocated in certain dimensions but freed in others, as Innis, McLuhan, and Carpenter so clearly predicted thirty years ago.

I should like now—finally!—to turn to some of what cyberspace might look like, images created by myself and colleagues and students. Much of this work is closer to art than to engineering or science, although in many cases tremendous rigor with the medium of computers was required to program and produce the images, and substantial intellectual effort was required to think out an think through as far as possible a logic for it all.

NOTES:

1. Sections of this talk are adapted from my book *Cyberspace : First Steps* (MIT Press, 1991) and my chapter "City-space and Cyberspace," in M. Gandelsonas and C. Boyer, Eds., (Princeton University Press, in press).

2. See Julian Barbour, "Maximal Variety as a New Fundamental Principle in Dynamics", *Foundations of Physics,* Vol. 19, 1989, pp.1051--1073.

3. $(X-1)\log_2 B$ is a very conservative number of course, something of a minimum, since it excludes the contents of memory as well as the process of self-perception.

4. It is, of course, a hopeless quest: B^X is always greater than B, and we do not have the space here (!) to go into the various strategies that people actually use subjectively to balance the equation nonetheless, this in order to live without the feeling of being overwhelmed or incompetent.