Biology, Evolution and the Global Brain

By Howard Bloom.

A History of the Global Brain I

Sara Rogenhofer

It might come as a surprise to the prophets of the global brain to discover that the researchers and theoreticians who specialize in evolution would sneer at the fundamental assumptions underlying this vision. The reason for the evolutionary community's contempt? A concept called individual selection. An idea which has provided powerful new ways of looking at human behavior since it was first codified roughly 30 years ago. But a concept which since then has partially degenerated from an intellectual lens to a set of blinders. Howard Bloom is seeking the roots of the concept of a superorganism in the biology and suggests a new fascinating evolutionary theory based on psychoneuroimmunology.

The Lucifer Principle

A recent issue of Telepolis carried a from Peter Russell's book, The Global Brain Awakens. In this excerpt, Russell predicted the coming of a worldwide intelligence networked by computer web.

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This article will expose the shaky roots of individual selectionism. And it will summarize one model- my own- which could provide a missing bridge between the skeptics - evolutionary scientists - and the believers- computer specialists who envision a planet pulsating with shared information. A planet, as Russell puts it, which has grown a global nervous system.

The scientific credentials of those who predict a worldwide intelligence are impeccable. Peter Russell studied mathematics and theoretical physics at Cambridge, worked with Stephen Hawking, obtained a post-graduate degree (once again at Cambridge) in experimental psychology, and also has a degree in experimental psychology. , author of the 1986 book Le Cerveau Planétaire (The Planetary Brain), has been Director of Research Applications at the Pasteur Institute, a research associate in biology and computer graphics at MIT, and was instrumental in the creation of France's Center for the Study of Systems and Advanced Technologies. Valentin Turchin, a key member of the international "Global Brain Study Group," holds three degrees in theoretical physics. Gottfried Mayer-Kress, author of The Emergence of Global Brains in Cyber Space, holds a doctorate in theoretical physics from The University of Stuttgart and has been associated with such prestige institutions as CERN, Los Alamos National Lab, and the Santa Fe Institute. , another catalytic member of the "Global Brain Study Group," possesses a doctorate in physics from the University of Brussels and is, among other things, associate director of Brussels' multi-disciplinary Center Leo Apostel.

Why, then, would an international fellowship of equally august specialists be likely to deride as naive pseudo-science the notion of superorganismic intelligence?

The individual selectionists who dominate today's "Neo-Darwinism" believe that all human and animal behavior is the result of genetic avariciousness. Even the most seemingly self-sacrificial deed is the result of a hidden calculation of genetic costs and benefits. A gene sufficiently greedy to guarantee that two copies of itself make it into the next generation will rapidly expand its numbers. Genes which program for self-denial will give up resources to help others. As a consequence, some of these group players will launch no copies of themselves. The population of unselfish genes will dwindle generation after generation until the contributors to the larger good have philanthropized themselves out of existence. And the long-term survivors will be pre-programmed to commit an act of cooperation only if the price of what they are forced to relinquish pays off in a genetic profit.

Meanwhile, another school of evolutionary thought has been driven underground. It is known as group selectionism. Those few evolutionary scientists willing to admit to their belief in group selection aver that individuals will sacrifice their unique genetic legacy in the interests of a larger whole. Such a need to cooperate and converge would be necessary to make the global brain and the planetary nervous system possible. On the other hand, if the individual selectionists prove correct, humans will be unwilling to share knowledge which might give others an edge. The cyber-ocean of the worldwide web and its technological successors will be a barracuda pit rather than a meta-intellect.

Numerous academics in journals which shun emotionally biased language have labeled group selectionism "a heresy." Robert Wright, the chronicler of individual-selectionist evolutionary psychology, is more gentle in his condemnation. Group selectionism, he says, is simply a seductive "temptation." Robert Wright calls individual selectionist psychology "the new paradigm." But the concept of individual selection is showing the rigidity of age. The view that all behavior is ultimately based on self-interest began its climb early in the 20th century. Cloaked as "the survival instinct," it dominated another questionable orthodoxy-the fight or flight syndrome hinted at by William McDougall in 1908 and popularized by Walter Cannon in 1929. As research psychologist Robert E. Thayer says, "certain aspects of the fight or flight response were never supported by scientific evidence." What's more, the fight or flight model can be only partially correct. Creatures confronted with an overwhelming threat are frequently immobilized by anxiety, resignation and a variety of related physiological mechanisms. In other words, instead of battling or running to save their lives, they leave themselves open to the jaws of the predator. So much for the ubiquity of the survival instinct! Yet fight-or-flight remains gospel to this day. Over thirty years after Cannon, however, W.D. Hamilton and others had the courage to face at least one small fly in the self-interest ointment. If individual survival is the be all and end all of existence, how could one account for altruism?

During the early '60s, Hamilton focussed on the selfless manner in which female worker bees sacrifice their reproductive rights and chastely serve their queen. His triumph was a mathematical demonstration that the workers were carrying essentially the same genes as their queen. Hence when an individual lived out her life on behalf of her monarch, she only appeared to be ignoring her own needs. By pampering the colony's egg-layer, each worker was coddling replicas of her own biological heritage. Altruism, asserted Hamilton, was genetic self-interest in disguise.

Hamilton's ideas and those built upon them have contributed mightily to our understanding of evolutionary mechanisms in fields from medicine, ecology, and psychology to ethology-the study of animals in the wild. But roughly 25 years after the Hamiltonian epiphany, examination of real world bee colonies demonstrated that William Hamilton's mathematics did not correspond with fact. There was far more genetic variety in societies of unselfish insects than the equations would allow. Individuals were not abjuring their interests simply to protect near-clones of their own genomic material. Apparently something else was going on.

Nonetheless, concepts based on what became known as individual selection hardened into dogma. And many of those tempted to posit non-Hamiltonian approaches have been stopped by the quiet threat of exclusion from professional respectability, of expulsion from career advancement, and of prohibition from the achievement of academic tenure.

In the mid-90s a growing group of scientists have risked ridicule by arguing for the simultaneous validity of group and individual selection. State University of New York evolutionary biologist David Sloan Wilson, who has produced papers championing group selection for over 25 years, is this band's acknowledged pioneer. I have been the organizer of one of its guerrilla brigades - "The Group Selection Squad." And my theoretical work indicates strongly that the social and biological sciences may benefit enormously from a selectionist reappraisal.

David Sloan Wilson has pointed to over 400 studies which support the group selectionist point of view. He has concentrated his attention on research indicating that among humans, those who pool their reasoning usually make far better decisions than those who keep their thoughts to themselves. I've focussed my efforts elsewhere, introducing to the debate a scientific discipline whose data individual selectionists refuse to take into consideration. This obdurately-overlooked field is psychoneuroimmunology - the study of the interplay between physiology and conditions in the "mental" or psycho-social environment.

As we've already seen, individual selectionists insist that a creature-be he man or beast-will only sacrifice his comfort if the payback to his genes is greater than what he gives up. His self-abnegatory behavior must benefit close relatives, the carriers of genes like his own. This is called "kin selection." A living thing can give up an aspect of its welfare on behalf of a non-relative...but only if it has reason to expect that this favor will be returned. This theoretical loophole is known as "reciprocal altruism."

Yet as long ago as the early 1940s, researchers like Rene Spitz were already discovering that among humans the genetic survival instinct had a counterpart of an unexpected nature. It was a physiological twin of Freud's supposed Thanatos, the death wish. The new empiricists lacked Freud's genius for coining catchwords. They merely noted what occurred and came up with separate labels ("anaclitic shock," "learned helplessness") for each instance they identified. In my book The Lucifer Principle: a scientific expedition into the forces of history, I've taken the liberty of introducing a blanket designation. Each investigator from Spitz to Harry Harlow to Lydia Temoshok to Martin Seligman and Robert Sapolsky has unearthed an example of a "self-destruct mechanism."

Let's take a typical example. Numerous investigations performed by scientists of widely varying points of view have revealed that the hospital patients who need help the most-those submerged in depression-are the least likely to receive aid. At first glance, it appears to be their own fault. Depressed patients behave in a manner which makes doctors and nurses avoid them. They become incommunicative and irritable. They upset others through every means from facial expression and verbal intonation to body language. An individual selectionist would explain that such self-damaging behavior must be the result of an adaptive response-one which relieves close relatives of a burden or confers upon them a benefit ("kin selection") or one which stores up the good-will of someone who will compensate the self-victimizing individual or other carriers of his genes in the future ("reciprocal altruism").

However empirical studies show the opposite. The patients with the greatest number of relatives and friends are the least likely to be depressed. Instead they tend to be the cheerful souls who, even in the face of death, remain charming and bring doctors and nurses flocking sympathetically to their bedside. So those who according to the individual selectionists could benefit replicas of their genes through their demise are the least likely to be stricken prematurely by the axe of death.

On the other hand, both animal and human studies demonstrate that depressed beings flirting with the grim reaper are those the individual selectionists would least expect-those least likely to benefit genes similar to their own. Their family ties are either malformed or non-existent. The immune systems of creatures with few or no friends and intimate kin shut down, while the immunological resistance of those who are part of a social web remain far more vigorous. In other words, isolated individuals undergo a strictly involuntary surrender to disease and bodily dissolution. They are seized by something akin to the suicide mechanism called apoptosis, a sequence of self-destruct events pre-programmed into nearly every living cell and activated when the cell receives signals that it is no longer of use to the larger community of which it is a part. Between their self-crippling immune-systems and their self-defeating conduct, isolated individuals vastly increase their odds of death. The payoff to copies of their genes is likely to be zero. None of this squares with the elaborate dogma of individual selectionism.

When caught in a bind, individual selectionists frequently claim that we are witnessing an instinct which was helpful during our days in hunter-gatherer tribes-an instinct which, under Pleistocene conditions, genuinely did enhance the survival chances of those with similar genes. However, these apologists proclaim, what benefitted the genes at our core in the days of the first stone axe has been perverted in its purpose by modern industrial civilization.

This argument is unlikely to hold water. The isolation of chimps, dogs, laboratory mice, and a wide variety of other animals leads to depression, a down-shifting of the immune system, and a failure to either see or use avenues of escape. Like us, creatures without industrialism dramatically increase their odds of death when they are severed from their social bonds, not when their disappearance stands to benefit the carriers of genes like their own.

This is where the new model of the evolutionary process I've introduced in The Lucifer Principle and will elaborate further in an upcoming volume called The Irrational Invention Machine may come in handy. Let us suppose for a moment that group selectionists are correct. Individuals will sacrifice themselves for the good of a larger whole. Those larger wholes compete. When groups struggle, the ones which boast the most effective organizational, strategic and technical advantages win. Individuals who contribute to their group's virtuosity will be part of the team which survives. And in this manner does evolution proceed.

Now let's add to the group selectionist claims another concept-one familiar to the mathematicians of complexity. Complex adaptive systems are learning machines made up of numerous components. Neural nets and immune systems are particularly good examples. Both apply an algorithm best expressed non-mathematically by Jesus of Nazareth: "To him who hath it shall be given; from he who hath not even what he hath shall be taken away."

The neural net has an extensive population of individual switch points-electronic nodes whose connection to the larger grid can be increased or radically diminished. An immune system takes the principle a step further. It has between ten million and ten billion different antibody types alone. In addition it possesses a flood of entities known as "individual virus-specific T cells." Both the immune system and the neural net follow the Biblical precept. Elements which contribute successfully to the solution of a communal problem receive resources and influence. But deprivation is the lot of those elements unable to assist the group. In the immune system, T cells encounter the MHC insignia of an invader. A small proportion of the would-be defenders discover that their unique receptors allow them to help defeat the attackers. These champions are allowed to reproduce with explosive speed, and are given the raw material they need to increase their numbers. T-cells of no use in confronting the current assault are robbed of food, of the ability to procreate, and often of life itself. Each is subject to destruction from within via the "pre-programmed cell death" of apoptosis.

In the neural net, nodes whose collaboration contributes to the solution of a problem are rewarded with more electrical energy and with connections to a far flung skein of recruits. The nodes whose efforts prove irrelevant to the problem at hand are fed less electrical juice, and their ability to connect with and arouse others is dramatically decreased. Both T cells and network nodes compete for the right to commandeer the resources of the larger system. And both show a seeming "willingness" to abide by the rules which dictate denial. This combination of competition and selflessness turns an agglomeration of electronic or biological components into a learning machine whose totality possesses an adaptive power vastly beyond that of any single element within it.

The same modus operandi is built into the biological fabric of most social beings. Look, for example, at evidence from the phenomenon which its discoverers call "learned helplessness." Animals and humans able to solve a repeated problem remain vigorous. But mice, monkeys, dogs and people who cannot get a handle on recurrent misfortune become victims of the self-destruct mechanisms mentioned above. Let's be more specific. Experiments on the physiological impact of mastering a problem began in the 1950s, when Joseph Brady and his colleagues devised a cruel but clever mechanism. They placed two small chairs side by side. The chairs were wired into an electrical circuit which would deliver simultaneous shocks of identical voltage to each of the contraptions' loungers. The experimental subjects destined to be strapped into these hot seats would be monkeys. Only one thing made the monkey on the left different from that on the right. The right-hand monkey was given a button with which he could solve the pair's joint dilemma. With it, he could turn each shock off when it arrived. Investigators assumed that the primate with the switch would develop severe health problems. He was the "executive monkey," the one of the pair weighed down with responsibility. The beast sitting next to him was relieved of his pain at the same instant. But this free-rider had to exercise no judgement or effort. Surely the creature without the switch would thrive more readily, unencumbered by the double burden of distress and vigilance. Indeed, early analyses seemed to demonstrate that this assumption had been correct. The monkeys with the ordeal of decision making were declared to have a far greater tendency to develop ulcers.

But later inquiry showed that the executive monkey experiments had fatal design flaws. Their results had been invalid. Twenty years down the road, variations on the experiment demonstrated something rather different. When put into adjacent shock cages, one of which had a control switch and one of which didn't, two lab rats would at first scurry and jump attempting to find a means of escape from the arbitrary administration of Thor's lightning. The rat in one cage would soon find his control button. When the current sizzled his soles, he would lunge for the switch and turn it off, rescuing both himself and his comrade. The rat whose frantic search resulted in no discovery of a means of control, on the other hand, would eventually give up his struggle, lie down in the cage, and accept his jolts with an air of resignation.

As "learned helplessness" experiments continued, it was discovered that more than mere laziness was crippling the beast unable to contribute to the resolution of the shared dilemma. His immune system no longer protected him from disease. If given a way to escape his situation, his perception was too bleary to see it or to register its utility. His self-destruct mechanisms had taken control. All indications were that these self-maiming reflexes were physiologically pre-programmed. Most telling was the fact that the beast able to cope with the slings and arrows of a researcher's outrageous fortunes retained a vigorous immune system, a relatively keen perception of the world around him, and remained active and energetic-despite his periodic spurts of torment. How might his neighbor's internally-inflicted disablement aid the projection of the victim's genes into the next generation? Apparently no one bothered to ask.

A naturalist named V.C. Wynne Edwards, however, had already observed the effects of these phenomenon in a social context. Under feral conditions innumerable species are not isolated by a cage but live as part of a larger group. Edwards studied wild grouse in the Scottish moors. Here, punishments and rewards were handed out not by scientists, but by the natural and the social environment. Male grouse whose mastery of their surroundings enabled them to find good provisions of food and safe sleeping conditions became strong and self-confident. Those less able to forage successfully or to find the safest roost became less physically robust. Weakened, they entered the seasonal competition for females. They fought their problem-mastering flockmates in one-on-one battles, and usually lost. Their failure to find a way to dominate their natural environment led to a corresponding failure to gain control in their social environment.

The successful birds ended up with avian harems, access to even more food than before, and an increased level of pep and acumen. The losers had insult heaped to their injury. As their self-destruct mechanisms kicked in, they showed symptoms which comparative psychologists have called a direct analog of human depression. Like the rats with no handle on their fate, these unfortunates gave up, resigning themselves to a position on the outskirts of the flock-the very location in which they would be most tempting to a passing fox. They lost appetite. As their immune systems shifted into low gear, they grew unhealthy. And in times of scarcity, they were the first to die.

Wynne-Edwards theorized that he was watching group selection at work. The birds whose failure had led to a physical decline, he felt, were sacrificing themselves to adjust the group size to the carrying capacity-the amount of food and other necessities-in their locale. The Scot announced his conclusions in 1962. By 1964 William Hamilton's equations had taken the evolutionary community by storm. Wynne Edwards became the poster boy for group selection and was driven from scientific respectability. He is cited in current textbooks primarily as an exemplar of scientific error.

What Wynne-Edwards had seen at work was a complex adaptive system devilishly similar to a neural net. Those individuals within the group capable of finding solutions to the problems of the moment were rewarded with dominance, desirable food and lodging, and sexual privileges. The weak links in the group's neural net, the individuals who had not found a means of solving the environmental puzzles thrown their way, were isolated and impoverished by the social system and disabled by self destruction.

In other words, the group had shown all the key characteristics of a functional learning machine, a complex adaptive system, or, if you prefer, a superorganism. Later, Israeli naturalist Amotz Zahavi would demonstrate that groups of birds function as communal information processing apparatuses. However Zahavi failed to put his observations together with those of Wynne Edwards, with those of the "learned helplessness" experimenters, and with the principles of complex adaptive systems.

My work since 1981 has been to demonstrate that these elements are parts of a single puzzle. The existence of self-destruct mechanisms, the fact that they are turned on and off by control of circumstance, and the fact that social animals are linked in information-exchange networks explains the mechanism behind David Sloan Wilson's research-survey conclusion that a group usually solves problems better than the individuals within it.

In short, if one acknowledges that individuals like the grouse do indeed compete for reproductive advantage (remember the seasonal tournaments which determined which avian males would receive mates), but that their competition takes place within the framework of a connective intelligence, the idea of group selection seems a necessity. Pit one massively parallel information processor against another-a constant occurrence in nature-and that which most successfully takes advantage of complex adaptive system rules, that which is the most powerful cooperative learning machine, will almost always win.

It is time for evolutionists to open their minds and abandon individual selectionism as a rigid creed which cannot co-exist with its supposed opposite, group selection. For if I am right, the networked intelligence foreseen by computer scientists and physicists as a product of emerging technologies has been around a very long time. In fact, it has sculpted the perverse physiological makeup which manifests itself in our depressive lethargy, our paralyzing anxiety, the irritability which drives others away when we need them most, our resignation when attainment repeatedly eludes us, and the failure of our health when we become victims of overwhelming loss or crisis. These physiologically pre-wired features have made us microprocessors in the most intriguing form of parallel computer ever constructed on this earth. Without transistors, they have turned each one of us into cells of a networked brain.

1 Three questions and Howard Bloom's responses

Are scientists like Gerald Edelman with his neuronal darwinism concept also suggesting group selection within populations of neurons?
Howard Bloom: Yes and no. First, you are wise to connect Edelman's work with complex adaptive systems principles. You probably know that 50% of the brain cells are killed off through apoptosis in the first year of life. Those which don't match the challenges in the baby's environment are the ones to go. It is the principle of "to him who hath it shall be given, from he who hath not even what he hath shall be taken away" at work. However individual selectionists would scoff at the idea that this represents group selection - though discrete populations of neurons compete and live or die by the results of their success. Individual selectionists would say that since all the neuronal cells involved in this battle carry the same genetic content, the principle at work is the same as that in Hamilton's original (and inaccurate) model of an insect colony. That is, each instance of self-sacrifice represents kin selection in which a suicidal cell commits an altruistic act to benefit copies of its genes within other cells of the macro-organism. If this sounds a bit like the hair-splitting of the medieval scholastics, it is. However too often scientists become so obsessed with squabbling over the knothole in one pine tree that they utterly fail to register the existence of the forest of which that tree is a part. In fact, they may even claim that the tree itself does not exist.
Do you think that group selection is also behind recent social developments and now again visible with the destruction of the social welfare state coming along with the globalization?
Howard Bloom: Yes, very much so. The proliferation of and competition between subcultures is one form of group selection which powers the machinations of the collective brain. I will demonstrate how in my next book, The Irrational Invention Machine. In addition, social critics like America's John Naisbett (Megatrends) and several major historians have claimed convincingly that one social current leads to the birth of its opposite. Hegel would have approved. Today's globalization is spawning an opposite but equal reaction - tribalization, the fragmentation of society into increasingly self-contained mini-groups. However it is through this manner of differentiation and competition that a complex adaptive system proceeds to invent new modalities for altering its environment. In other words, your supposition, in my view, is accurate. What economists call constructive destruction is integral to the operation of the group brain.
Group selection and a self destroying mechanism in individuals seem to be a very cruel procedure in an ethical context and it reminds at the concept of social darwinism. What status could an ethical approach have in this point of view and which kind of ethics could fit within the context of group selection?
Howard Bloom: Nature, in the words of The Lucifer Principle, is not the benevolent mother that her proponents think. In fact, she is a parent who exults in child abuse. Her viciousness is built into our biology at so many levels that it has become integral not only to our physiology but to each and every human culture. All societies, including the pre-colonial Inuit so often lauded for their peaceful ways, designate groups of people it is permissible to hate. Hatred of outsiders, in fact, has been proven by innumerable scientific studies to be one of the strongest bonds holding a cultural or subcultural group together. Though it has been imposed on us involuntarily, this modus operandi is morally despicable. As a consequence, it is incumbent on you, me, and everyone else with a moral sensibility to do the following: Rebel against nature and her ways. Stop violence wherever you can. If you pass a mugging in the street, end it (I always do...and I am both puny and unathletic). If you see mass murder and fail to try to bring it to a halt, you are an accomplice in its execution. And so am I.
Most importantly, watch out for the dark side of your own idealism and of your moral sense. Both come from our arsenal of natural instincts. And both easily degenerate into an excuse for attacks on others. When our righteous indignation breathes the flames of anger against a "villain," we all too often become a fang in nature's scheme of tooth and claw. No martians or heavenly saviors will arrive to save us from our inborn evil. We must battle the nature outside of us and within us in order to save our selves.

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Creative Nets in the Precambrian Age

By Howard Bloom.

A History of the Global Brain II

For roughly ten years authors and scientists have been churning out books on the subject of a coming global brain strung together by computer networks. The Internet, the

Worldwide Web and its successors already allow a neuroscientist in Strassburg to swap ideas instantly with a philosopher of history in Siberia and an algorithm juggler in Silicon Valley. But that, the visionaries of worldwide meta-intelligence say, is just the beginning of a looming human transformation. But a networked intelligence is very much older. In fact the origin reaches back in the beginning of life. Howard Bloom presents impressing insights into the world of networked bacteria - a fascinating new perspective which could change deeply our view of life.

Cells Alive

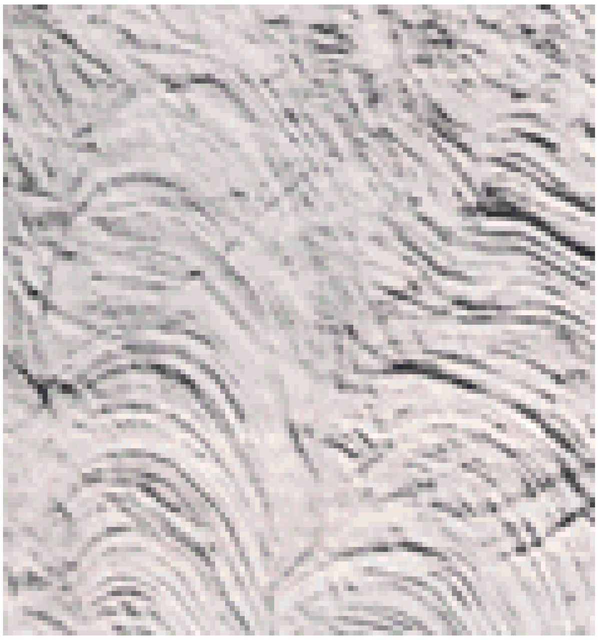
prokaryotic microorganism

My sixteen years of interdisciplinary work seem to demonstrate something very different. Yes, the computerized linking of individual minds is likely to bring considerable change. But a worldwide neocortex is not a gift of the silicon age. It is a phase in the ongoing evolution of a networked intelligence which has existed for a very long time. And it is neither uniquely human nor a product of technology. Nature has been far more clever at connectionism than we have. Her mechanisms for information swapping, distributed data processing, and collective creation are more intricate and agile than anything the finest computer theoreticians have yet devised.

The first shock to the theorists of electronically-networked intelligence might well be the biotic counterpart's age. Gravity pulled this earth together 4.7 billion years ago. A mere 500,000 years after the new sphere's crust had stabilized, the powers of chemical attraction yanked together the first detectable life. And a geological wink after that - in roughly 3.5 billion b.c.- the *first communal "brains"* were already making indelible marks upon the face of the waters. Those marks are called *stromatolites* - mineral deposits ranging from a mere centimeter across to the size of a man, and even to the vastness of a reef. Stromatolites were manufactured by cooperating protist colonies with more microorganisms per megalopolis than the human population of Mexico City. These prokaryotic communities throve in the shallows of tropical lakes and of the ocean's intertidal pools.

prokaryotic microorganism

The rocky deposits ancient stromatolites have left behind were created by legions of *cyanobacteria*, organisms so internally crude that they had not yet gathered their DNA into a nucleus. But in their first eons of existence, these primitive cells had already mastered one of the primary tricks of society: the *division of labor*. Some colony members specialized in photosynthesis, storing the energy of sunlight in the ornately complex molecules of ATP. The sun-powered assemblers took in nutrients from their surroundings and deposited the unusable residue in potentially poisonous wastes. Their vastly different bacterial sisters, on the other hand, feasted on the toxic garbage which could have killed their photosynthetic siblings.



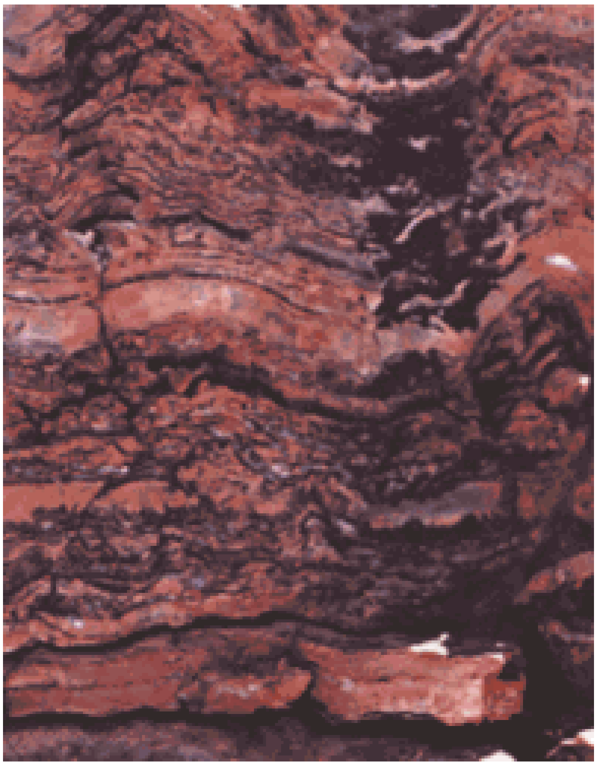
stromatolite

The mass of these interdependent beings were held together by an overarching shelter of their own construction. A mini-lasagna of interlayered cyanobacteria would begin a circular settlement. The waters within which the homestead was established would wash a layer of clay and soil over the nascent encampment. Some of the bacteria would send out filaments to bind these carbonate sediments in place. Tier by tier, the colony would create its infrastructure, an undulose or dome-like edifice which could easily become as large compared to the workers who had crafted it as Australia would be to a solitary child with pail and sand shovel.

Many stromatolites carry a peculiar clue whose meaning has gone overlooked. Their fossilized remains spread from a common center in ripples - a pattern extremely familiar to the handful of scientists studying a previously unsuspected bacterial property - *social intelligence.*

1 THE NETWORKED BACTERIAL "BRAIN"

Eshel Ben Jacob, at the University of Tel Aviv, and *James Shapiro* at the University of Chicago have been studying bacterial colonies from a radically original perspective - and have emerged with surprising results. Their findings explain why the ripple effect is a mark of **bacterial networking** - and of much, much more.

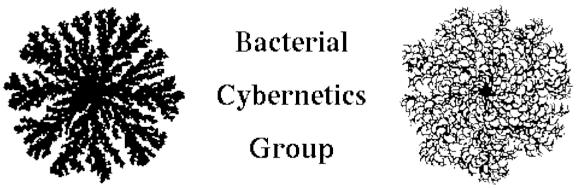


stromatolite

For generations bacteria have been thought of as lone cells, each making its own way in the world. Ben Jacob and Shapiro, on the other hand, have demonstrated that few, if any, bacteria are hermits. They are extremely **social beasts**. And undeveloped as their *cellular* structure might be, their *social* structure is a wonder. The ripple effect is one manifestation of a colony's coordinated tactics for mastering its environment. We could call it the probe and feast approach.

A bacterial spore lands on an area rich in food. Using the nutrients into which it has fallen, it reproduces at a dizzying rate. But eventually the initial food patch which gave it its start runs out. Stricken by famine, the individual bacteria, which by now may number in the millions, do not, like the citizens of Athens during the plague of 430 b.c., die off where they lie. Instead these prokaryotes embark on a joint effort aimed at keeping the colony alive.

The initial progeny of the first spore were sedentary. Being rooted to one spot made sense when that microbit of territory was overflowing with edibles. Now the immobile form these first bacteria assumed is no longer a wise idea. Numerous cells switch gears. Rather than reproducing couch potatoes like themselves, they marshall their remaining resources to produce daughters of an entirely different kind - rambunctious rovers built for movement. Unlike their parents, members of the new generation sport an array of external whips with which they can snake their way across a hard surface or twirl through water. This cohort departs *en masse* to seek its fortune, expanding ring-like from the base established by its ancestors. The travels of the fortunate lead to yet more food.



Eshel Ben-Jacob

Successful foragers undergo another mass shift. They give birth to daughters as determined to stick to one spot as their grandparents had once been. These stay-at-homes sup on the banquet provided by their new surroundings. Eventually their perch, too, is sucked dry. They then follow bacterial tradition, generating a new swarm of outbound pioneers. Each succession of emigrants leaves behind a circle thinned by its spreading search. And each generation of settlers accumulates in a thick band as it sucks nourishment from its locale. The ripples of ancient stromatolites are proof positive that life three and a half billion years ago already took advantage of *social cooperation.*

The work of Ben Jacob and Shapiro has demonstrated that bacterial communities are elaborately interwoven by *communication links.* Their signalling devices are many: chemical outpourings with which one group transmits its findings to all in its vicinity; fragments of genetic material, each of which spreads a different story from one end of the population to another. And a variety of other devices for long-distance data transmission.

These turn a colony into a collective processor for sensing danger, for feeling out the environment, and for undergoing - if necessary - radical adaptations to survive and prosper, no matter how tough the challenge. The resulting modular learning machine is so ingenious that Eshel Ben Jacob has called it a **"creative net."**

Take, for example, a process which may have led to the fossilized stromatolites that snake like epileptically misshapen sausages over a distance of two meters or more. All bacterial colonies do not use the round ripple strategy to explore and exploit. Some, like aquatic *myxobacteria* - gang-hunters which pursue prey ranging from fellow microorganisms to fish - will stretch and twist until they catch the chemical scent of a victim. But to understand the internal workings of one of these writhing cooperatives, it is wise to peer over Eshel Ben Jacob's shoulder as he carries on his seven-year study of *bacillus* and discovers how individual bacteria are "pre-wired" to be components of a larger information processing machine.

When famine strikes, some bands of bacterial outriders blaze a long trail which leads to territory as barren as that from which they have fled. But they do not suffer their fate in silence. For they are the sensory tentacles with which the larger group feels out its landscape. As such, they must communicate their findings. To do so, they broadcast a chemical message: "avoid me." Other exploring groups heed the warning and shun their sisters stranded in the desert. By releasing chemotactic repulsers, the failed scouts have sealed their fate. They will die in the Sahara into which they've wandered - unaided and alone. But their suicide has served the collective information-gathering process - adding survey reports to an expanding knowledge-base about the surrounding terrain.

Other bacterial cells encounter turbulent conditions which destroy them before they can transmit their chemical evaluations. But they, too, manage to ship back information about their findings. For the fragments of their shredded genomes filter through the colony, carrying a message of danger. Then there are the voyagers whose trek takes them to a new promised land. These send out a chemical bulletin of an entirely different kind. Loosely translated, it means, "Eureka, we've found it. Join us as quickly as you can."

In all this, the bacterial colony is displaying the classical characteristics of a **complex adaptive system** - a collaborative learning device. As *John Holland*, an early pioneer of complex adaptive systems studies, puts it, the "behavior of a diverse array of agents" when merged results in "aggregate capabilities" far beyond those of any individual. These are the powers of a massively parallel distributed system - another example of which is the modern supercomputer.

But Ben Jacob's studies suggest that the bacterial colonies of 3.5 billion years ago had taken giant strides beyond any computer man has yet built. For the informationally-linked microorganisms under Ben Jacob's microscope demonstrate a skill exceeding the capacities of any device from Cray Research or Fujitsu. Working as a group, bacteria possess a transformative knack long thought impossible. Not a random process like mutation, but a *goal-driven, "teleonomic" talent.* They are capable of acting as their own genetic engineers. In fact, they utilize the same tools as modern science's genetic tinkerers: plasmids, vectors, phages, and transposons. Should the colony's strategy of group hunt and peck prove useless, the messages sent back to the center do not unleash new waves of migrants. They become the raw data for genetic research and development.

Ben Jacob was curious to determine just how inventive the genomic-resculpting process could be. Did bacteria with their backs to the wall merely plug in prefabricated twists of DNA and revert to ancestral strategies? Or could they create solutions which were entirely new? The Israeli physicist-turned-microbiologist explains how he administered microbial ingenuity tests.

We tried exposing bacterial colonies

> to conditions so novel that the creatures could never have encountered them before. Tough conditions, conditions of life and death. We wanted to know how inventive they could be in reworking their genetic code. For example, we took bacteria that can't move on agar but are able to roam freely in liquid. We put them on the wilderness of their worst nightmares, agar, and deprived them of food. The need to branch out in search of grazing land was a true creative challenge.

Ben Jacob
By forming a modular network beyond the supercomputer and retooling the very genome at their heart, the massed experimentation teams were able to solve the problem. So the networked minds of computer visionaries' dreams replicate one of the most ancient life strategies on this earthly sphere.

2 COMMUNICATION LINKS

Beyond mere networking lies another futuristic vision - that of the **global brain**. Here, too, the microbe has by far outdistanced humankind. Bacteria and their frequent enemies, the viruses, have long since mastered the art of worldwide information exchange. Both swap snippets of genetic material like humans trading how-to books. This system of molecular gossip allows microorganisms to telegraph an improvement from continent to continent. And the nature and speed of communication can be awesome. Let's take some modern examples. Viruses are such effective collectors of genetic parings that they've been known to clip and paste molecular material from whales to sea gulls, from monkeys to cats, and in the lab can transfer firefly genes into the cellular control panel of tobacco leaves, inspiring shaggy greenery to glow in the dark. Bacteria also benefit from this worldwide system of genetic mix and match.

In modern times, members of the microbial sisterhood have demonstrated the power of their *information splicing.* During the 1980s, newborns in modern hospitals unexpectedly died of pneumonia. Adults recovering from surgery came down with mysterious infections. The problem was not limited to one small spot. Patients in Germany, France, the United States, and Japan were besieged by new forms of bacterial attack. Most baffling of all was the fact that the bacteria pulling off these surprise assaults seemed capable of developing resistance to half a dozen antibiotics nearly overnight. A clinic in Tokyo would report that bacteria had suddenly shown an ability to storm the defenses erected by the formerly impregnable drug streptomycin. At almost the same time, a hospital in San Francisco would announce that the bacteria in its corridors seemed to have mastered the same dismaying trick.

The genetic equivalent of *data-base sharing* had allowed viruses and bacteria to outrace scientists networked by telephones, computers, international conferences and journal articles. And the new techniques the global microbial brain concocted were devilishly clever. For example, beta-lactam disrupts the construction of the bacteria's outer wall. Once pharmaceutical companies had perfected beta-lactam-producing antibiotics, they regularly changed their discoveries' composition to overcome bacterial evolution. The race between researchers and their microbial adversaries began in 1942. Scientists were in the lead for decades. Then the bacteria finally outpaced the researchers.

The beta-lactam antibiotic functioned by destroying a bacterial enzyme called beta-lactamase. Infectious bacteria countered by borrowing the instructions for impervious forms of beta-lactamase from non-infectious strains or by developing impregnable new varieties of their own.

Tetracycline, another formerly sure-fire disease killer, had been a drug of choice in the '60s, '70s and '80s. But by the '90s tetracycline was almost entirely ineffective. This antibiotic did its trick by sabotaging bacteria's pivotal protein synthesizers. The bacteria countered by developing a pump that literally spat the antibiotic out.

Today's microorganisms can move so quickly because they piggyback on two advantages their primordial relatives did not have - the ability to snatch useful genetic twists from millions of different species; and the helpfulness of high speed aircraft in transporting innovations from one population center to another.

But do not underestimate the potential reach of the microbial net in pre-Cambrian times. The odds are good that the earliest microorganisms rode planet-sweeping currents of wind and water. And scientists have already discovered eleven different bacterial types whose age seems to go back well over three billion years. Given the newness of these findings, this eleven are likely to be revealed in the next decade as the merest sliver of proto-biotic life's diversity. In all probability, then, the microbial global brain - gifted with long-range transport, data trading, genetic variants from which to pluck fresh secrets, and the ability to reinvent the genome itself - came into existence some 3.5 billion years before the birth of the Internet.

Ironically, future *multi-cellular* forms would come to land and sea with a plethora of new capabilities. Their microbial neighbors would continue to use the global brain. But despite the fact that networked intelligence would remain a key to the more "advanced" species' survival, it would take roughly 1.5 billion years of trial and error before the *global* brain would rise among the "higher animals"... along with the early spread of tools of stone.

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Networking in Paleontology's "Dark Ages"

By Howard Bloom.

History of the Global Brain III

Since software innovations - new forms of behavior and interaction - leave few fossil records, and since paleontologists have been virtually blind to proterozoic social activity, the record *seems* barren. But evidence indicates that intimate forms of organization were undergoing long and ever more intricate trial periods, resulting in multi-cellular life forms and brains as internets.

> Vitalism is not the only alternative to Darwinism. I propose a new option, that of cooperative evolution based on the formation of creative webs. The emergence of the new picture involves a shift from the pure reductionistic point of view to a rational holistic one, in which creativity is well within the realm of the Natural Sciences.

Eshel Ben-Jacob

In our , I laid out evidence indicating that the global brain foreseen by computer-futurists already existed 3.5 billion years ago. I attempted to demonstrate how the biology of the primitive *cyanobacterium* equipped it to act as a component in a parallel-distributed intelligence. The result: a social colony capable of networking data, solving problems, creatively retooling genomes, and of transmitting and receiving genetic upgrades via a worldwide web.

But 3.5 billion years b.c. was long ago. What, if anything, has happened to the global brain since then?

The story is a strange one. Evolution went on to produce life forms with radically new powers. Many of these retained the ability to operate as local networked intelligences. But in the course of their development, an ironic slippage took place. Bacteria and viruses, those stalwart veterans of the days shortly after the earth's crust first formed, held on to their global research and development system. But "higher" life forms, gifted with capacities whose full potential would ripen only with time, took what seems on the surface to be a large step backward. Yes, they preserved their ability to cluster in social groups and act as communal information processors. But high-speed global data pooling would remain a microbial specialty, one which the "advanced" species would take at least 2.1 billion years to reinvent. This is the next episode in the story of how and why.

1 Early Networking

The picture of early life is currently in flux, with new discoveries and fresh theories emerging month by month. But despite the shifting collage of guesswork and evidence, two facts stand out:
1) Each find pushes life's evolution further back in time. In November, 1996, the age of the first cells leaped from 3.5 billion years to 3.85. In the decade from 1986 to 1996, the age of the first nucleated cells bounced from 1.6 to 2.1 billion years.
2) More important, networking, often called synergy, has been a key to evolution since the universe's first second of existence. Roughly twelve to twenty billion years ago, a submicroscopic pinpoint of false vacuum arose in the nothingness and expanded at a rate beyond human comprehension, doubling every 10-34 seconds. As it whooshed from insignificance to enormity, it cooled, allowing quarks, neutrinos, photons, electrons, then the quark-triumvirates known as protons and neutrons to precipitate from its energy. A neutron is a particle filled with need. It is unable to sustain itself for longer than ten minutes. To survive, it must find at least one mate, then form a family. The initial three minutes of existence were spent in cosmological courting, as protons paired off with neutrons, then rapidly attracted another couple to wed within their embrace, forming the two-proton, two-neutron quartet of a helium nucleus. Those neutrons which managed this match gained relative immortality. Those which stayed single ceased to be. (Roughly twelve billion years later, the universe remains 25% helium.) Protons, on the other hand, seemed able to survive alone. But even they were endowed with inanimate longing. Flitting electrons were overwhelmed by an electrical charge they needed to share. Protons found these elemental sprites irresistible, and more marriages were made. From the mutual needs of electrons and protons came atoms. Atoms with unfinished outer shells bounced around in need of consorts, and found them in equally bereft counterparts whose electron protrusions fit their empty slots (and vice versa). Through these connective compulsions, to paraphrase Yeats, "a terrible beauty was born."
And so it continued. A physical analogue of unrequited desire was stirred by allures ranging from the strong nuclear force to gravity. These drew molecules into dust, dust into celestial shards, and knitted together asteroids, stars, solar systems, galaxies, and even the mega-matrixes of multi-galactic whorls. Theories like those of *Claude Shannon* imply that the

intertwined elements were bundles of information - skeins of data whose proliferation of plugs and sockets disgorged newnesses at every turn.

One of the products of this inorganic copulation was life. The latest findings suggest that shortly after the molten earth began to harden its shell and massive rains of planetesimals ceased smacking this sphere like a boxer pummeling the face of his opponent, RNA paved the path for DNA. Massive minuets of deoxyribonucleic acid generated the first primitive cells - the prokaryotes - by 3.85 billion b.c. And 350,000 years later, unmistakable signs of complex social life - the multi-million-inhabitant bacterial megalopoli called stromatolites - appeared. Then paleontological dogma has it that virtually nothing of significance occurred until the Cambrian explosion roughly 535 million years ago. One popular science writer, summing up the opinion of the experts, calls this interim "three billion years of non-events" (*Karen Wright*, "When Life Was Odd," Discover Magazine, March 1997, p. 53). Oh, there was the occasional burp, say the yawning authorities. But such moments of evolutionary indigestion are hardly worth mentioning.

2 Confederations of smart molecules

The hints are many that there was little to yawn about. Since software innovations - new forms of behavior and interaction - leave few fossil records, and since paleontologists have been virtually blind to proterozoic social activity, the record *seems* barren. But evidence indicates that intimate forms of organization were undergoing long and ever more intricate trial periods.

The first cells - the prokaryotes - were highly coordinated confederations of what, for lack of a better term, we would have to call "smart molecules." Each of these molecular agents was dedicated to a vital function. Some pumped sugars and amino acids, responding to needs in the locations they served. Others reacted to power demand, disassembling molecular fuel to liberate its energy. Still others tuned the chemical balance, assembling proteins, amino acids, nucleotides, vitamins, and fatty acids even a human body cannot make by itself. (We use prokaryotes - bacterial colonies in our guts - to handle some of these manufacturing chores for us). Molecular groupings within the prokaryotic cell sensed food or danger and passed the message along to other molecular squadrons which created movement, allowing their host to pounce or to race away.

This coordinated operation of molecular agents resulted in such prokaryotic beings as bacteria, entities far more flexible than any mere computer net. Bacteria have populated the earth for at least 82% of its existence. Today, they are still going strong. However the fossil record shows new forms of interaction emerging as early as 2.1 billion years ago, when the first macroscopic organism, *grypania*, makes a hesitant appearance. This hoop-shaped relative of cyanobacteria, the size of a wire wrapped around a penny then let loose, is thought to have been the first eukaryote. If this hypothesis is true, *grypania* represents not only a major leap in size, but a form of life which thrived on radical breakthroughs in biological intranets.

3 The Invention of Intranets

Eukaryotic cells were bacteria capable of taking on fellow bacteria as boarders. They made permanent residents of such visitors as *mitochondria* (proteobacteria-like energy generators), *chloroplasts* (cyanobacteria-like solar converters which handle photosynthesis), and, most important, *spirochetes*. Spirochetes - wiry and multi-talented - were commandeered as struts for an intra-cellular skeleton, as contractile fibers for internal transport, as whirling oars for external movement, and as organizers for the reproductive splitting of the eukaryote's enormous genetic mass. All these former guests were now reproduced along with each replication of the host cell. It was largely this merged approach which, according to biologist *Lynn Margulis*, allowed life to survive the first toxic pollutant holocaust - the spread in the atmosphere of a gas lethal to previous life, oxygen. For mitochondria gulped oxygen and turned it into fuel. And other members of the new intracellular commune were able to clean up the poisons which oxygen left behind.

As so often happens in examining life, computer metaphors are too limited to describe the result. Even a bacterial colony is a flexible, self-organizing, self-repairing, and self-improving parallel processing device which not only reprograms and computes but acts out its calculations, then responds to the consequences. While a single bacterium is a biochemical net, the eukaryote is the web which emerges when masses of biochemical nets fuse.

At level after level, purposeful assemblies mesh to form a processor/responder which, in turn, becomes a module in the next step up the networking ladder. One of these modules is the gene. Another is the chromosome - a lengthy chain of genes which not only work together, but are welded into a single molecule. (Contrary to the implication of the phrase "the selfish gene," all genes function in teams. Even the genes of a bacterium are welded in a circular chromosome.)

A prokaryotic bacterium, with its free-floating single ring of DNA, could not accomplish the elaborate form of cell-division known as meiosis, a highly orchestrated process which would eventually make sexual reproduction - a key form of information mixing and matching - possible. This revolution in data-exchange would emerge from a eukaryotic invention - the marshalling of multiple chromosomes into files arrayed within a nucleus. Chromosomes regimented like well-drilled parade teams could mass in genomes literally a thousand times larger in size and infinitely greater in complexity than their predecessors.

Margulis contends that the eukaryote's tamed spirochetes could not perform the interior superintendence of replication and the exterior job of propulsion simultaneously. Leaving a cell immobilized through its "pregnancy" was a dangerous business. The dividing eukaryote could not aggressively seek food. Nor could it avoid the attacks of predatory fellow-eukaryotes whipping through the water in search of victims. The solution: to concentrate spirochetic propellers on the outside of one cell, then to generate an attached cell whose spirochetes could remain indoors handling reproduction. Thus, according to Margulis' spirochete hypothesis, the communal gathering within a cell led to another massive leap in the evolution of networks: multicellularity.

Colonies of single-celled organisms could be sieved apart, then if given freedom, were (and still are) able to reconstruct their shattered *polis*. The multicellular entities which emerged at the end of the paleoproterozoic era had lost that option. In exchange, they had gained the opportunity to perform far grander functions.

The first possible remains to be found so far of multicellular organisms, crudely called carbon films, were probably the leaves and strands of *early seaweeds* - 1.6 billion year old amalgamations of the prokaryotic algae to whose category *cyanobacteria* belong. These precocious eukaryotes were, according to some paleontologists, passive multi-cellular sheets which could only wave in the currents or settle on seabed rocks.

But the fossil record hints that a billion years ago, *single-celled eukaryotes* lifted themselves from the solar submissiveness of plants and showed the aggressive and restless characteristics we associate with animals. The one-celled rovers possessed internal skeletons of former spirochetes, external "shells" called pedicles, and the ability not only to whisk through water but to crawl along thanks to spirochetic microtubules which pulled one shell segment together with another then relaxed the pair again. Helping these protozoans achieve size and new functions were breakthroughs like a system of inner pipes and bladders which collected water and spat it out before an overload could bloat the cellular interior. This bilge-pump anticipated the later invention of the kidney. Another major advance was "development" - the ability to assume a succession of physical forms each dedicated to a different purpose. A protozoan might begin life as a fast *moving flagellate*, seek out new territory to mine, then settle down to the slow moving but powerful *blob of an amoeba* - a supreme environmental exploiter. This is the equivalent of being a scout plane early in life and a harvesting machine once a field of grain has been found.

4 The Advent of the Nervous System

There are tantalizing hints of innumerable as-yet-undiscovered steps in another key networking technology - the advent of a nervous system. 3.5 billion year old *cyanobacteria* were already capable of transmitting data from sensory molecules within the cell to molecular motion-makers, allowing a bacterium to scoot from trouble and zip toward opportunity. Cyanobacteria in colonies evolved the ability to broadcast data using chemical transmissions and genetic bits which travelled like messages in a bottle through the community and beyond.

But the eukaryote - an assembly of formerly independent beings which must live and die in unison - is a far larger and more intricate beast. Its equipment for internal communication includes the cytoskeleton - a tubular matrix alive to the nature of its surroundings. The *cytoskeleton* is such an agile coordinator that some audacious theorists have called it a cellular "brain." Interior data traffic is also aided by "second messengers" like cyclic AMP, which collects bulletins arriving at the ports of the outer membrane and rushes them to their targets, readjusting the operation of membrane channels, turning on energy-producing mechanisms, activating specific enzymes, and even changing the cell's speed and direction - literally altering its mission. Cyclic AMP's travels are notable not only for the accuracy of their routing but for the cluttered distances they cover. The average eukaryote is ten times the size of a prokaryote - and some eukaryotes are many thousands of times that of their cellular predecessors. Rapid detection by the membrane and the equally swift reactions made possible by second messengers proved extremely necessary.

Protozoans are endangered by fast-moving cousins, the carnivores of their world. Some *eukaryotic hunters* are equipped with poison launchers (toxicysts) on their exterior along with the flagella and cilia needed for brisk movement. A protozoan on the prowl needs to coordinate a host of spirochetic whips and propulsive whiskers (cilia) to produce precision movement. Its potential prey, provided with similar propulsion devices, has to be equally exact in marshalling its organs for evasion.

But more indicates that the prototype of a nervous system was in the making. The primary sensory ability of a prokaryote like a bacterium seems to have come from its ability to detect chemical gradients - flows whose growing weakness or strength allowed the bacterium to determine whether it was swimming toward or away from a chemical beacon's source. Single-celled eukaryotes moved a giant step further, developing specialized sentinels. One example is the eyespot of the *Euglena*. Some Euglena use this photoreceptor in tandem with another light-detecting speck on one of the flagella near their mouths, thus evolving an early forerunner of stereoscopic vision - dual-organ phototaxis.

Each bacterium had carried its own microprocessor - its single chromosome. A bacterial colony networked these isolated calculators into an awesome creative brain. But once again eukaryotic animals leaped ahead. They went from a single internal processing, programming and reengineering unit per cell to a tightly knit machine of many bound together in the nucleus. To generate additional information processing power, some cells had two or more of these multi-tiered thinking centers. A standard arrangement was to allocate the task of reproduction to a micronucleus and move the job of controlling daily cell life to a macronucleus up to forty times larger in size. Two proto-brains for the price of one.

What's more, single-celled eukaryotic protozoa, like their bacterial predecessors, were highly social beings. Extrapolating backwards from their behavior today, we can infer some of the resulting benefits. The 65,536 semi-independent cells in a *Volvox* took a major step toward a hitherto unknown pleasure - sexual reproduction. Gathered in a pinpoint-sized (1 mm.) hollow ball, the colony members divided into two different forms. One group concentrated on composing the cooperative's balloon-like body. The other, located prophetically in the posterior, focused on reproduction. Thus began the differentiation between somatic and germ cells which would be critical to the development of "higher" organisms. Volvox were apparently not content with one proto-sexual invention. They also were among the first forms to generate male and female colonies.

Prokaryotic *myxobacteria* form a "fruiting body" when they congregate - however it is so small that it must be magnified roughly 200 times before its details become clear. The height the tree-like structure can provide as a takeoff point for its spores is minuscule. However eukaryotic amoebas can join together in a giant cell roughly a foot (30 centimeters) across. That blob, called a *plasmodium*, holds within it literally billions of nuclei, and is able to undergo either sexual reproduction or to take another route and become a fruiting body immensely loftier than that of its bacterial counterpart. Should it "choose" sexuality, the plasmodium is able to complete a host of radically new processes which, in more advanced beings, would allow for the creation of an embryo. This has led some scientists to conclude that plasmodial slime molds - as these colonies of talented eukaryotic amoeba are called - may be a missing link between single-celled animals and such multi-celled beasts as you and me.

The jump in information exchange between eukaryotes showed yet another step toward the development of a nervous system. Several forms of cilia-powered protozoans (*Carchesium* and *Zoothamnium*) produced a second generation which, unlike their unicellular parents, did not totally wall themselves off at birth. Their direct connection to each other allowed one cell to sense an obstacle or an opening and to flash the data so fast that the multitude could react almost instantly and in total coordination. The "wiring" between cells prefigured neural components. Both were remodeled spirochetic microtubules , and both shared roughly 100 signal-transmission proteins The odds are good, then, that in the 2 billion years now blank to us, numerous further elements of primal nervous systems were developed through trial, error and occasional purposeful invention. (See my for evidence of purposeful invention among the earliest bacteria.)

These evolutionary achievements were incremental steps toward multi-cellularity. And as Wurzburg University biologist *Helmut Sauer* puts it, "Once multicellularity is established, all kinds of fungi, plants, and animals can evolve...."

5 Agglomeration of Machines within Machines

True to Dr. Sauer's words, 1.4 billion years after the new eukaryotic refinements had begun, the first truly exotic multicellular beings appeared. One recently discovered *fossil clam* dates to over 720 million years ago. The clam was a terra-flop ahead of anything seen before, dwarfing interlaced protozoans in size, complexity, and internal wiring. It possessed two hinged shells operated by a pair of powerful muscles capable of opening with exquisite control and clamping shut with massive power; a tongue-like foot of muscle able to dig a hiding hole in the sea bottom; a tube to penetrate above the marine floor and siphon oxygen-and-food-rich water below the surface when the being buried itself; and a filter-system of cilia through which the clam could pump the liquid it had sucked, and with which it could then sift out protozoans and other edibles, passing them via mucous carrier to the mouth. The early mollusk even possessed a heart with three chambers. All of this had to be wired to a host of sensors and a nervous system whose central direction was handled by three processing clusters (ganglia). Without exquisite synergy, these separate components would have been useless. When networked, they constituted something truly unprecedented: an immense and purposeful union of interacting parts - a nearly infinite agglomeration of machines within machines.

The era of this bivalve's birth was dominated by strange and as-yet-little understood creatures - the *Ediacarans*. These wildly varied higher life forms were apparently soft-bodied beasts living near the ocean's surface or crawling on its bottom. The complex multi-legged physiology of some indicates advanced data transmission between the billions of cells which made up each creature. Alas, the Ediacarans' full story and any hints it may carry regarding their mechanisms for information exchange is still shrouded in ignorance.

Yet we do have unmistakable indications that sociality continued. *Trilobites* dominated the period from 600 million to 500 million years ago. These armored sea scourers had not only heads, eyes, sensory antenna, and all the indications of a nervous system centralized in a brain, but their fossils tend to be found in groups. Some paleontologists, extrapolating backwards from the behavior of such trilobitic living relatives as horseshoe crabs, suspect that the armored ancients gathered for mating orgies in which they shed their shells for maximal body contact. Trilobite-specialist *Kevin Brett* cites evidence that males may have been larger than females (or vice versa), and that many trilobites were, in his words, "quite ornate." From that and the positioning of trilobites in fossil beds, he proposes the sexual festivities may not have been entirely promiscuous. Modern "toads," he points out, "will mate with just about anything - so they don't necessarily recognize members of even their own species." Brett suspects that trilobites were a bit more discerning.

Noted invertebrate zoologist *K.B. Clark* theorizes that the foot-and-a-half long (.5 meter), torpedo-shaped *Anomalocaris canadensi* swam in feeding herds. "The largest animals in most ecosystems are typically herding herbivores," he notes, "and I see nothing about Anomalocaris that precludes this." However Dr. Clark admits that science has neglected the study of the fossil indicators which could reveal further details of Cambrian social life.

One thing seems certain: a huge step forward was also an enormous step back. As *Lynn Margulis* and *Dorion Sagan* point out in their brilliant book **Microcosmos**, multi-celled organisms lost the rapid-fire external information exchange, extemporaneous inventiveness and the global data-sharing of bacteria, which continued living side by side with macrobeasts as both helpers and adversaries. Physicist-turned-microbiologist Eshel Ben Jacob argues that multi-celled eukaryotes did at least continue to exchange and reengineer genes, maintaining local versions of what he calls "creative webs." Communicating over small distances, however, the metazoans made awesome contributions to the elaboration of intranetting.

Ilya Prigogine, the Nobel Prize-winning pioneer of self-organizing systems, has observed that a breakdown of progress is frequently an illusion. Under the shattered fragments new structures and processes ferment. And from those innovations come fresh orders whose wonders seem without number. The new organisms had vastly increased their capacities as individual information processors. If these advanced modules could be linked worldwide, the nature of the game would change for good.

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The Embryonic Meme

By Howard Bloom.

History of the Global Brain Part IV

When we last left off, bacteria and viruses had developed both local networked intelligence and the grander web we call a global brain. Meanwhile new, highly complex cells - the eukaryotes - had broken fresh ground in intranetting. Half a billion years of eukaryotic upgrades (2.1 billion b.c. to 1.6 billion bc) had led to multicellular creatures-beasts of infinitely greater talent than the prokaryotes preceding them. But the new macro-organisms were missing something: the worldwide information swap available to their microbial competitors. They had gained innumerable gifts, but had lost their worldwide mind!

One of the dramatis personae with which we ended was the clam, which bowed into the fossil record at 720 million B.C. That bivalve probably possessed an information processing device we failed to mention - memory. Memory exists in insects, mollusks, and many of the life forms which came into existence during the Cambrian explosion. Recent research has demonstrated that even the lowly fruit fly, a relative of Cambrian antecedents, has a storage system which works in the same stages as ours - short term memory leading to mid-term memory and finally long-term memory - all made possible, as with humans, only if the fly does not cram its lessons but sips them slowly, taking periods of rest for data digestion.

Researchers have recently pinpointed the pre-Jurassic genes responsible for this sequence in insects, shellfish, chicks, and humans. Recall another actor in our previous episode-the internal cellular messenger known as cyclic AMP. Cyclic AMP was a holdover from bacterial days, one which became even more essential to multicellular beings, and which continues to carry out its roles in you and me. Researchers at the Cold Spring Harbor Lab are convinced that sometime before 200 million years BC, a knowledge-accumulator gene called dCREB2 harnessed cyclic AMP for a new purpose-rapid data storage. (CREB stands for cyclic-AMP-responsive element-binding protein.)

Before eukaryotic cells emerged, information had been saved in chromosomes-welded chains of coded nucleotides. In bacteria, altering these genetic files had been relatively easy. But the complexity of eukaryotes had a drawback: their DNA archives were a thousand times vaster than those of their predecessors. This size had pluses and minuses. The functions eukaryotes could handle expanded exponentially. But their flexibility and swiftness of adaptation underwent a staggering decline. The genetic libraries which had been RAM now approached the immobility of ROM.

When neural memory appeared, the effect was dramatic. A multi-celled creature could quickly store experience in flexible circuitry. Hardware alteration led to equally startling software. A new data device augmented the gene. Zoologist Richard Dawkins calls it the meme.

Memes were not transmissible via inch-long chains of adenine, cytosine, guanosine, and thymine corkscrewed in a microscopic clump. They were relayed via scent, sight and sound. Memes were form indifferent to the substance which carried them. They would provide the key first to a knowledge explosion, and later to the evolution of a whole new style of worldwide web.

This episode will chronicle the early rise of memory's child-learning - the medium in which memes thrive. It will also move from the networks which turned several trillion cells into a larger organism to the meta-networks which could knit a group of 30,000 or more multi-cellular animals into a superorganism, one endowed with 60,000 eyes, 60,000 ears, trillions of scent receptors, and 30,000 brains.

Virtually all the phyla swimming, walking, flying and crawling the earth today arose in a blink of geologic time. The event-the Cambrian explosion-lasted a mere 40 million years.

Fossil evidence of information networking among Cambrian creatures has not yet been subjected to systematic analysis. But we have a tool with which to probe their data-connection systems. That is inference. Many of the behaviors dominating Cambrian descendants today were likely to have contributed to the evolutionary success of their venerable ancestors.

Cambrian parvenus included: relatives of choanocytes (sponges); onychophorans (worm-like beasts with 14-43 pairs of legs found mostly today in Australia); mollusks (snails, squid, octopi, oysters and clams), echinoderms (starfish, sea urchins, sea cucumbers, and sea lilies); and perhaps most important, crustaceans (spiders, shrimp, crabs, and insects); and chordates (early vertebrates).

Among the Cambrian crustaceans were the Eurypterids, prototypes of the scorpions which may well have been the first land-walkers. How modern were these seven-foot-long, twelve-legged beasts? Skeletal remains indicate they carried the equipment standard to even the lowliest contemporary arthropod: a digestive tract beginning in a mouth, leading to a stomach and ending in an anus; a central nervous system complete with brain; a focal ganglionic cable similar to the chord innervating your spine; and an extensive lace of wiring which delicately controlled the limbs and everything between them. In addition, these proto-scorpions of the Cambrian possessed sensors to detect internal movement, orientation in space, and the visual, tactile and smell-detecting contraptions necessary to pinpoint any scourge or temptation gliding in the waters around them. Some of these sensory organs were astonishingly intricate. Eurpyterid eyes, according to invertebrate zoologist Dr. Kerry B. Clark, could be six inches long. Their size, Clark feels, indicates that there was "one hell of a lot of neural processing going on in there."

Once you have visual detectors and a central nervous system, you are equipped to do elaborate versions of something individual bacteria could only master in a limited way. Take, for example, a descendent of the pre-Cambrian mollusks-the octopus. Put a modern octopus in a large glass jar. Give it lots of room to move. Dangle something harmless outside the walls of its receptacle. Don't worry, it can see. Try, for example, a teddy bear. Whenever the stuffed animal appears, electrically zap the octopus. After a bunch of tries, unplug your shock producers, pop the Steiff bear within the octopus' viewing range, and whomp-the beast will jet itself in the opposite direction. Learning!

But can this form of prudence be networked-can it be passed from one octopus to another? Most certainly. Bring in an equally transparent container housing a second octopus. Place it next to the octopus you've trained. Now show the pre-punished tentacle-bearer the stuffed toy. As it whooshes back in panic, its naive neighbor will be watching. Try the experiment a few more times, just to make sure the newcomer gets the message. No, it has never been stung by shock. But yes, it has seen its fellow water denizen indicate that when a cuddly bear appears there may be trouble in the offing. Now isolate octopus number two and show it the plaything. It will follow the lead of its more experienced conspecific and recoil with a speed that will astonish you. What's more, it will catch on faster by following the cues of another octopus than if forced to learn on its own. Congratulations. You have just uncovered one synapse of a social brain-imitative learning.

You have also witnessed the operation of a primordial meme. No cellular material was exchanged. Only photons connected the two creatures. Yet the neural response of one octopus was reproduced in the brain of the other.

Alas we have no Cambrian trilobites or proto-scorpions on which to run this experiment. However the number of Cambrian creatures with a central nervous column and a brain was vast. The eyes and sensors of these creatures were intricate and varied. It is a distinct possibility that some of them may have been among the first practitioners of monkey see, monkey do.

The emulative compulsion is one of the critical immaterials from which collective brains are made. Shortly after 500 million b.c., there arose the fish...emulators par excellence. Schooling is one of a fish's most pivotal defenses. A mob of potential fillets swims together in unison, each carefully heeding the cues it gets from others. As long as the frontal portion of its brain is intact, it will slavishly follow the crowd. The advantage: a group of relative midgets can ripple like a giant sheet, light glinting off its scales in such a way that a predator is dazzled and has difficulty focussing attention on any single victim.

How much do fish rely on imitative learning? To what extent can their neural settings be rearranged by proto-memes? Regard the guppy-one of evolution's early experiments in fish morphology. Female guppies are instinctively biased to prefer males of a deep orange hue. But this does not mean they are immune to the imitative learning we call fashion. Isolate a guppy from the crowd and train her to prefer a male who is paler than the normal sex-arousing shade. Let her loose again among her sisters. They will watch her amorous attraction to suitors they had previously shunned. Calibrating their behavior to that of the taste-maker, others will soon begin a piscine swoon over the formerly repulsive pallid beaus. Dawkins gives the memetic example of a melody which infects one human mind after another. But in guppies, movement cues and preferences in skin tone are equally contagious.

Once a social group, no matter how primitive, possesses imitative learning, the modern data network has begun. Individuals become components of a collective intelligence, one which, like a colony of bacteria, is expert in what Eshel Ben Jacob calls "quorum sensing"-summing individual decisions to arrive at a cooperative-conclusion.

Extrapolating backwards once again we can deduce that another Cambrian descendant introduced a second essential tool into the life of the sea: the social hierarchy.

Among the first crustaceans were tiny Cambrian shrimp. Their later relatives, crayfish and lobsters, emerged sometime after 260 million b.c. These decapods most likely had mastered imitative behavior. Among the first to evolve were spiny lobsters. Some spiny lobsters engage in an imitative seasonal migration, parading substantial distances through the seas in single file, each following the path and demeanor of the one before it. It has been hypothesized that spiny lobsters (Panulirus argus) evolved this slavish march to cope with periodic glaciation.

Dominance hierarchies extended these creatures' capabilities by delegating specialized responsibilities to seemingly identical group members. Bacteria had divvied up tasks, but they had done it by altering the genetic content of a newborn, committing it to a specific social purpose for life. Inherent in lobsters and crayfish, on the other hand, was the capacity to assume any role the group needed, and the set of switches it took to turn those abilities on or off. This gave a cluster of crustaceans the capacity for a rapid reprogramming which, in bacteria, had depended on population turnover. (Bacteria spawn a new generation every 20 minutes.)

Lobsters live in clusters of cave-like dugouts beneath the sea. At night, the males grow restless and roam about, tapping on the door of each neighbor. The lobster inside comes to the entrance and faces off with the intruder. The showdown's goal is to see who is larger. If the visitor can tower over his rearing host, the apartment dweller vacates his home. The larger lobster knocks around the new abode for a bit, then goes off to the next cave for a visit. If the Homarus making these night-time rounds is large enough, by evening's end he's flushed all his neighbors from their lairs. Later, he lets them return. But he's proven a point. He is in charge. Gradually we will see the impact of this ritual-repeated in forms right up to office politics-on collective intelligence.

Next comes the role of hormones in temporarily restructuring the individual. After a pushing match in which the combatants whip their antennae and lock claws, the winner struts regally on the tips of his toes. The loser slinks subserviently backward. The victor's confidence comes from serotonin. The loser's dejection from octopamine. Studies of equivalent clashes in crayfish reveal that serotonin alters neuron activity so significantly that Stanford University's Russ Fernald says "the animal in some sense has a different brain...." Serotonin remains a critical hormone in human beings. It is regulated by dominance or submission. From episode to episode we shall see the importance of serotonin in the unfolding group mind as well.

In 350 million B.C. another Cambrian descendent appeared-the insect. At first, says legendary entomologist E.O. Wilson, insects were probably solitary. The fossil evidence supporting this conclusion is strong but not definitive. Invertebrate zoologist Dr. K.B. Clark points out, "The most primitive living insects are very similar, morphologically, to the oldest fossils. They're solitary. These are things like springtails. But social behavior has arisen convergently in Hemiptera, Hymenoptera, Lepidoptera, Isoptera, and maybe a couple of other orders, so might occur earlier than noted." Clark adds that even springtails are not as individualistic as they are generally portrayed. Their fossilized remains are often found in herd-like clumps. In Insect Societies and his much later book The Ants, Wilson groups together those contemporary insects which live on their own, those which have a rough-hewn sociality, and those which have taken their social structures to the nth degree ("eusociality"), then assumes that the loners must have evolved first. Frankly, this is questionable. As we've seen, grouping has been inherent in evolution since the first quarks joined to form neutrons and protons.

Similarly, replicators-RNA, DNA, and genes-have always worked in teams. Often teams so huge as to defy description. The bacteria of 3.5 billion years ago were creatures of the crowd. So were the trilobites and probably the echinoderms (proto-starfish) of the Cambrian age. It is entirely possible, then, that the first insects may well have been social, and that their more solitary relatives could have been later offshoots who had mastered the difficult trick of survival in relative isolation. One indication comes from evidence that 300 million years ago, proto-cockroaches (Cryptocercidae-like insects) occupied tunnel-like group homes in dead tree ferns.

The discovery of 100 fossilized nests in Arizona's Petrified Forest hints that one extremely social insect may have been building hives as early as 220 million b.c.-Apoidea: the bee. Thomas Seeley, perhaps the leading contemporary expert on bee behavior, has been awed for over a decade by the extent to which colonies of swarmers pool their meager intellects to create a vaster calculating mechanism. Seeley presented a sophisticated account of this observation in a 1987 article he called "A Colony of Mind: The Beehive As Thinking Machine," (co-written with Royce A. Levien, The Sciences, July/August). Seeley's 1995 The Wisdom of the Hive fleshes out the details of the theme.

Like guppies, bees are slaves to meme contagion. In one experiment, researchers put two dishes of sugar water close to a pair of hives. Each solution was equally nutritious. Then the scientists trained a few bees from hive A to visit dish A. The bees of hive A obediently followed their pre-trained scouts. Despite the high caloric content of the second dish, all ignored it and drank only from the "pre-approved" container, carrying drops of its contents back to their home base. The bees in the second hive were tricked by the same technique into following the leader and visiting only dish B. There was no significant number of deviants in either hive. In a very real sense, the bees had been transformed from a chaos of individuals to a single mind. Their transmuter: imitative learning.

The result is capable of remarkable "mental" feats. I described in my book, The Lucifer Principle: a scientific expedition into the forces of history, an experiment in which apian flyers were given an inadvertent group IQ test. A dish of sweetened-water was placed outside the hive. The bees soon found it and, following the leader, concentrated their collective attention on mining every glucose molecule within it. The next day, the dish was moved to a location twice as far from the hive. The bees used two of those tricks which make a group brain function-hierarchy and task specialization-to pinpoint the new target area. While the mass of followers clung meekly to their honeycombs, a handful of "independent thinkers" flew about at will, testing one spot then another for food. The division of labor soon resulted in the discovery of the sugar dish's location. Now the herd instinct which results from imitative learning took over. The sheep-like multitude followed those who had made the find and combined their efforts to exploit the food source for all it was worth.

The following day, the experimenters once again set the dish twice as far from the hive as on the previous occasion. And once again the scouts fanned out, a myriad of eyes and antennae gathering input for a collective mind. Once again the dish was spotted and the herd of follower bees swarmed to maximize their prize.

Then came the part that astonished the researchers. Each day they doubled the distance from dish to hive. The flight path's length followed a simple arithmetic progression. After several days the swarm no longer waited for its scouts to return with news of the latest coordinates. Instead, when experimenters arrived to set down the sugar water, they found the bees had preceded them. Like multiple transistors crowded on the chip of a pocket calculator, the massed bees had predicted the next step in a mathematical series. But unlike the electronic calculator, they had perceived the existence of that series without the aid of a human pushing buttons.

There are more secrets to apian collective intelligence than division of labor, hierarchical organization, and the efficiency imparted by imitation. A fourth is quorum sensing. Each scout fans an eccentric path in search of food. If she spies a promising cache, she does not operate on impulse. She doubles and triple checks her conclusions, reflying the path several times to memorize its bearings. She returns to the hive interior and uses one of the first forms of symbolic representation known in evolution-the waggle dance. Cakewalking on an upright wall of the hive's lightless interior, she performs a figure eight. Its orientation indicates the direction of her find relative to the position of the sun. The speed of her movement, the number of times she repeats it, and the fervor of her noisy waggling indicate the richness of the food source and the difficulty in flying there (half a mile in a stiff wind consumes far more energy than the same distance cruised through placid air). Her audience follows her, sniffing the scent of food she carries, feeling her movements, alert not only to the instructions each motion imparts, but to the judgements implied in the performer's "enthusiasm."

Despite the initial messenger's caution in verifying her conclusions, the masses are not easily swayed. Other scouts make the trip, reach their own judgements, then return to waggle-dance their verdicts. The more vigorous and numerous the corroborative performances, the more persuasive is the data. Several bees usually make separate discoveries. Some of the finds are richer and easier to reach than others. The greater the payoff, the more scouts are impelled to fly out and verify the reports for themselves. The more returning skeptics who stage confirmations, the more bees are allocated to working the patch. The number of converts is affected by the fact that a bee who has discovered a jackpot will jitterbug far longer than one who has encountered a mediocre flower zone. The longer the shimmy, the greater the number of indecisive foragers able to catch the show.

This process consumes time, but its accuracy and its ability to retune as one patch of flowers is exhausted and another discovered is critical. A hive has just a few short months in which to store a supply of honey. If it fails to gather the necessary minimum, it is likely to run out of supplies before winter ends. This means certain death-not just for the frailer bees among the bunch, but for the entire community. It means the extinction of the superorganism's gene lines and of its collective mind. Each incoming scout's dance has contained small errors. By pooling and averaging inputs, onlookers are able to home in on their destinations with impressive accuracy. The mass mind has once again made calculations beyond the capacity of any single bee.

Division of labor has also played its role-nonconformists performed the risky task of exploration. And conformists ensured that a crush of crowd power would be unleashed on the most advantageous missions.

Statistics may give a sense of how critical cooperation and hierarchy are to this collaborative task. It takes 50 bees and a queen before the workers feel impelled to build the combs of a new domicile. Without a queen, it takes 5,000. When a colony runs out of resources, it splits. A huge swarm chooses a queen of its own and leaves the old queen's hive in search of fresh quarters. Hanging in a balled clump from a branch, the homeless pioneers execute a technique like that which allowed them to zero in on food patches. Scouts comb the landscape for a location which will be safe from predators, will provide protection from blustery winds, and will be near fresh food. Then the surveyors deliver their conclusions. Crowds gather around the several spots in which the advocates of each location are dancing. Hyper-energized acrobats promoting the same destination gradually entice bees away from weaker groups of publicists. Finally, the swarm calculates which homestead is best, then heads out en masse to build a new hive.

Numbers are critical to the execution of this process.

Bees cannot hunt for new real-estate-much less carry out the ensuing comparisons-until they reach a minimum of 200.

Ants, whose signs of sociality appear after 80 million b.c., use their networked mind for yet another purpose-warfare. So vital are the coordinating mechanisms which wire a crowd of Formicidae into a thinking machine that the most effective strategy is to attack a population without notice and cause a panic, breaking the bonds which connect the victims. But often, two ant armies meet unexpectedly. The shock scatters each phalanxed legion in a frenzied route. Victory belongs to the group which can reconstitute its links with the greatest speed.

While octopi and fish use collaborative information processing, their networks remain remarkably local. Insects, on the other hand, show signs of developing something old among bacteria but new among eukaryotes-a cosmopolitan web. The most important means of transmission among ants is chemical. A maverick ant, nosing about in unexplored territory, will stumble across food, eat her fill, then head slowly back toward the nest, hugging the ground and extruding her sting. This is not post-meal lethargy. The ant is laying a liquid attractant for her sisters, who cannot resist the compulsion to follow in its wake. If they, too, find that the pickings at trail's end are good, they will return in the same manner, sprinkling the chemical traces of their jubilation behind them. Thus a widening or waning scent trail encodes data on the richness of a food source, its ease of exploitation, and its gradual depletion. A team of Belgian biologists has called this odor track, which summarizes the experience of hundreds or thousands, a form of collective memory.

Equally important to the ant colony are its alarm sprays-pheromones which alert the legions to danger. Ants are able to read alarm signals sent by other species, thus picking up on the fact that there's trouble in the neighborhood, and turning nearby colonies into sensory extensions. In turn, they act as sensors for nearby populations of "foreigners." A patchwork of rival ant cities is thus able to form a primitive internet.

We have now reached a point 1.9 billion years after the emergence of the first eukaryotic cells and 1.4 billion years after the first multicellular film. Those bacteria which were able to absorb internal guest workers have churned out beasts with brains. And now, with learning and new forms of information exchange, multicellular animals have begun their advance toward the creation of a whole new kind of global intellect.

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From Social Synapses to Social Ganglions: Complex Adaptive Systems in the Jurassic Age

By Howard Bloom.

History of the Global Brain, Part V

Howard Bloom is reflecting in this chapter why birds congegregate in huge flocks. He describes the advantages of flocks as collective learning machines and explains the main principles of these collective adaptive systems.

> "How ya gonna keep 'em down on the farm, after they've seen Paree?"

For most of human history, the need to eke a living from the earth kept over 90% of the human population in the countryside. But once a small number could produce food for multitudes, a formerly repressed desire went hog-wild - our urge to cram together. Today, more than 75% of Europeans and North Americans have crowded into cities. In Belgium the figure tops 95%. This lust for company has hit the developing world even harder. In a measly two generations, Mexico's urban congregants have leaped from 25% to 70% of the population. Mexico City is now jammed with 27 million human beings, roughly three times the worldwide number of Hominids alive at even the lushest moment of the Paleolithic age.

1 Bird Flocks

Many species of birds are as attracted to their equivalent of the big city as we are, and given the chance, will congregate in the largest clusters they can possibly form. Some bird flocks outdo the largest human municipalities by a factor of two - reaching 50 million or more. This sociable overcrowding seems to court extraordinary risk. The larger the flock, the larger the territory it must cover to feed itself, and the greater the chances of encountering a famine. So why do avians become hypnotized by the urge to join a crowd?

The first guess ornithologists came up with was warmth. In winter, they reasoned, the birds could huddle, providing each other with protection from freezing cold. When researchers compared the energy costs of joining a roost to the energy saved by communal heat, the results were rather surprising. If the roost is thickly populated, the daily distance from home base to food is likely to involve an arduous commute. The calories burned in travel by far outweigh the pittance saved by toasty snuggles, swallowing 27% of a starling's entire intake for the day. Overnighting alone in a sheltered hollow - despite the need to generate extra body heat - would exact nowhere near that price.

Why then, do birds congregate in avian megalopolises? There is something far more critical than energy to be gained - information. Birds rely for their perception of the world on those around them. If you recall the experiment on imitative learning among octopi from our previous episode, this will sound like deja vu all over again. Experimenters put a young, inexperienced blackbird and an older, wiser flier in cages side by side. The savvy elder was shown an owl, and attacked the potential killer furiously. The youngster couldn't see the predator. Sly experimenters had placed a partition in his line of sight. But he definitely could witness the emergency response.

Not that there was nothing to surprise the junior bird as well. On his side of the opaque divider appeared a stuffed honey eater, a congenial creature which does not feast on blackbird meat. The setup was designed to convey the impression that the elder's pugnacity had been roused by the harmless sweet-snacker. Later the young bird was put next to an unseasoned fledgling like itself. Both were shown the honey eater. The newcomer was indifferent. But the bird who'd seen his elder go into a rage flew at the bee-juice connoisseur, assaulting it with might and main. Soon the novice picked up the message and joined in. Then it, too, was paired with a naive bird who couldn't have cared less. Like his teacher before him, the bird who'd learned his lesson demonstrated the importance of mobbing honey eaters to his pupil, passing the tradition on. Erroneous as it was, this response was reproduced in six blackbird generations before the researchers called it quits.

OK, birds have imitative learning. What's so astonishing about that? We've already shown the imitative passage of data in creatures as primitive as spiny lobsters 260 million years ago. And we've explained how emulative absorption acted like a synapse, allowing information to leap the gap from one creature to another. But a whole new kind of information processor arises when neurons or independent beings join more than mere bucket brigades. Huddled like roosting birds in the brain-precursor called a ganglion, neurons can swap and compare data by the batch, arriving at something far beyond mere linear transmission. Each adding to the mosaic, they can see the big picture. Or, to switch from church floor imagery to that of the kitchen counter, when kneaded, stretched and rolled by a social cluster, you never know what forms of output input will become.

In 1973, *Amot Zahavi*, the eminent Israeli naturalist, posited that the roost was an "information center." From 1988-1990, *John and Colleen Marzluff* of the Sustainable Ecosystems Institute in Meridian, Idaho, and Bernd Heinrich from the University of Vermont attempted to test the notion. They focussed their attention on ravens (Corvus corax) living in western Maine's pine forests. Their technique was to capture wild ravens and to keep these carrion consumers caged until all their existing knowledge about food locations was thoroughly out of date. Then the experimenters put a fresh carcass - the ultimate raven cold-cut buffet - in a previously unused site, let the birds in on its coordinates by showing them the lump of meat as the sun was setting, and set the newly enlightened ravens free. The next day, only one of the 26 birds let in on the secret showed up - leading 30 ravens from a roost over a mile away. During the next few days, two more of the experimentally isolated ravens also came back to feast on the cadaver. Each had a trail of roostmates in its wake. From this and a variety of other experiments and observations, the three researchers concluded that "Raven roosts are mobile information centres" in which the birds, by means unknown, swap data on where succulent cadavers are to be found, then follow the bird most in the know the next day when the flock takes off. In addition, the ravens share their information with others far away, engaging in a "social soaring display" which can attract hungry and clueless conspecifics from up to thirty miles.

So Zahavi had been right. Roosts, at least among ravens, are collective data processors. What's more, they are part of local networks, pooling data between strangers for the sake of all.

Somewhere between 145 million years ago, when the first feathered reptile, the archaeopteryx, arose, and 120 mya when modern birds appeared, imitative learning among vertebrates went from serial to parallel wiring, making a social group a learning machine. The mechanism for massed learning and collective adaptation was apparently at work in the herding and hunting beasts we know as dinosaurs. Paleontologist *Robert Bakker* hypothesizes that the herd allowed dinosaur herbivores to pool the input from their eyes, ears and nostrils, then mount a carefully phalanxed defense. Dino-carnivores were even subtler in their use of networking. Bakker suggests that like today's lions, they teamed up to stage elaborate stratagems. One Utahraptor might act as a decoy, distracting the attention of a brontosaurus pack. Meanwhile its huntmates would surround the prey and take it from behind. But how did communal learning machines arise among Jurassic kings and queens?

To understand the global brain's anatomy as it continues to unfold, we will have to take a side trip into theory. Specifically we've got to machete further down the path of complex adaptive systems. Later we will once again resort to theory, proposing a new model of cosmic basics. But one new concept at a time.

The exploration of adaptive systems I'm offering you does NOT come from complexity's Mecca, the Santa Fe institute. And unlike other theories on the subject, it is not based on computer simulations. It is the result of 29 years of fieldwork observing the real thing - social nets in action. The insights of Santa Fe systems modelers like *John Holland* have helped me greatly in this enterprise. But the principles I will enunciate emerge from a more elemental technique - that which Darwin used - venturing first-hand into the wilderness, accumulating reports from other empirical frontiersmen, and running vast quantities of data through numerous conceptual sieves in an effort to isolate nuggets of gold.

2 Essentials of a Collective Learning Machine

The result is a five-element dissection of a collective learning machine. The quintet of essentials: (1) conformity enforcers; (2) diversity generators; (3) utility sorters; (4) resource shifters; and (5) intergroup tournaments.

1. 2. *Diversity generators* spawn variety. Each individual represents a hypothesis in the communal mind. It is vital for the group's flexibility that it have numerous fallback positions in the form of participants sufficiently different to provide approaches which, while they may not be necessary today, could prove vital tomorrow. This can easily be seen in the operation of one of nature's most superb learning machines, the immune system. The immune system contains 10(7)-10(8) different antibody types, each a separate conjecture about the nature of a potential invader. However diversity generators take on their most intriguing dimensions among human beings.

2. 3. Next come the *utility sorters*. Utility sorters are systems which sift through individuals, favoring those whose contributions are most likely to be of value. These pitiless evaluators toss those who personify faulty guesswork into biological, psychological and perceptual limbo. Some utility sorters are external to the individual. But a surprising number are internal. That is, they are involuntary components of a being's physiology.

3. 4. Fourth are the *resource shifters.* Successful learning machines shunt vast amounts of assets to the individuals who show a sense of control over the current social and external environment. These same learning machines cast individuals whose endowments seem extraneous into a state of relative deprivation. Christ captured the essence of the algorithm when he observed "to him who hath it shall be given; from he who hath not, even what he hath shall be taken away."
4. 5. And bringing up the rear are *intergroup tournaments*, battles which force each collective entity, each group brain, to continually churn out fresh innovations for the sake of survival.

To understand how these five principles affect you and me, it may be helpful to reexamine the workings of a group brain in an organism normally thought to have no intelligence at all: our old friend the bacterium.

3 Bacterial Group Brain

In the late 1980s, two scientists we've frequently met before, University of Tel Aviv physicist *Eshel Ben-Jacob* and the University of Chicago's *James Shapiro*, were perplexed. Those supposed lone rangers known as bacteria actually lived in colonies which established elaborate designs as they expanded. Some rippled in ringlets. Others snaked in symmetrical tracery like that generated by graphic depictions of fractal equations.
Ben-Jacob detoured from normal physics and spent five years studying bacillus subtilis. Meanwhile Shapiro focused on such organisms as E. coli and salmonella. Unlike the traditional biologists who had preceded him, Ben Jacob applied an unconventional tool to his data: the insights he had absorbed from the mathematics of materials science. New developments in this field suggested that the elaborate patterns formed by bacterial colonies might be the result of the same processes which produce patterning in water, crystals, soil and rocks. The Israel physicist felt that this was wrong and set out to separate the products of "azoic" (non-living) processes from those which he suspected were the results of microbial hyperactivity.
Meanwhile among microbiologists another mystery was gumming up the works. Standard neo-Darwinism said that bacteria stumble from one innovation to another by random mutation. But a growing body of evidence was accumulating to indicate that bacterial mutations are not completely random. Seemingly every month fresh studies continued to suggest that these mutations might, in fact, be genetic alterations "custom-tailored" to overcome the emergencies of the moment.
Ben Jacob confirmed what he had suspected all along. Something far more than the principles which shape inanimate matter was at work within the petri dish. Separate investigations by Shapiro and Ben Jacob uncovered a surprise, one which answered the puzzle of bacteria's seemingly purposeful alterations and now threatens to topple long established evolutionary models. Rather than being a mere carrier of construction plans, the package of genes carried by each individual bacterium functioned as a computer. What's more, the genetic-bundle seemed to accomplish something even computers cannot achieve. Says Ben Jacob, "the genome makes calculations and changes itself according to the outcome." Unlike an assembly of silicon chips, the genome adapts to unaccustomed problems by reprogramming itself.
Reaching this conclusion left a puzzle. Godel's theorem implies that one computer cannot design another computer with more sophisticated computational powers than its own. So how does the individual bacterium's central processing unit confront large-scale catastrophe, natural disaster so overwhelming that it dwarfs the bacteria's solo computational abilities? The answer, Ben-Jacob hypothesized, lay in networking - in knitting the colony's multitude of genomic personal computers into something beyond even the massively parallel distributed processor known as a supercomputer. A supercomputer is only faster than its less sophisticated cousins, but does not transcend many of the smaller machine's most basic limitations. At heart both are merely diligent instruction repeaters. However the "creative net" of the bacilli, unlike a machine, can invent a new instruction set with which to beat an unfamiliar challenge.
Ben-Jacob has now analyzed thousands of colonies of bacilli to find out if his creative network hypothesis is true, and if so what makes the collective information-processor work. We've seem some elements of his conclusion in earlier chapters: bacilli are in constant contact, communicating through a wide variety of means, measuring their environment's limitations and opportunities, and feeding their data to each other, then finally summing the product through collaborative decision. In short, bacilli engage in many of the basic activities we associate with human beings.
Here's how Ben-Jacob's work appears when filtered through the lens of a social learning machine's five principles:

1. Bacillus subtilis colonies employ a variety of *diversity generators.* Says Ben-Jacob, bacterial clones (genetically identical offspring of the same mother) can assume intriguingly different variations. Which form each dons depends on the chemical signals it picks up from the herd around

it. These cues activate or deactivate individual genes, redrawing a bacteria's design and replacing its old operations manual. In the best of times, when food is plentiful, the colony clumps together for the feast. Divergent appetites and digestive abilities are vital to a gorging group's survival. The bacteria which concentrate on mining the new food source produce a poisonous by-product - bacterial excreta, the equivalent of feces and urine. Other bacteria adopt an entirely different metabolic mode. To them the excrement is caviar. By snacking heartily on toxic waste, they prevent the colony from killing itself. More diversity generators kick in when the colony's glut runs out. We've already seen some of them at work in 3.5 billion year old stromatolites. As famine approaches, individuals send out a chemical signal which makes them socially obnoxious, a "body odor" that says "spread out, flee, explore." This prods roughly 10,000 groups of cells to act as scouting parties, setting forth in a trek which unfolds before the human eye in the forms which had first caught Ben Jacob's attention, concentric circles, thick fingers flaring from a central core, or a spreading circle of fractal lace. Meanwhile other cellular cohorts apparently set up posts in the wake of the outward advance and channel the findings of the explorers toward the center.

2. At this stage the teams of pioneers (technically called "random walkers") utilize the third principle of a complex adaptive system: the colony's *utility sorters*. Those exploration parties which find slim pickings have an internal device, the bacterial equivalent of what British theorist Michael Waller, writing about human beings, has called a "comparator mechanism." This gauge determines that the outriders have chanced across parched and dangerous territory. Their mission, in short, has failed. The unfortunates send out the altruistic repellent which makes others in the group avoid them, leaving them to starve in isolation. Conversely, discoverers which encounter a cornucopia of edibles have their comparator mechanisms tweaked in the opposite direction. They disperse an attractant which makes them the star of the party.

3. Now the fourth principle of the complex adaptive system enters the petri dish: the *resource shifters*. Those stranded in the desert are deprived of nutrients - which their location cannot provide - of companionship, and most important from the point of view of the group brain, robbed of what might best be termed popularity. Meanwhile, those who find an overflowing buffet eat their fill and command the attention and protection of a gathering crowd. They are transformed into leaders, guiding the group mind. "To him who hath it shall be given; from he who hath not even what he hath shall be taken away." Should things prove truly grim, however, and even the most strenuous searchers confirm that food is nowhere within reach, another diversity generator, the most startling of them all, may rouse to meet the challenge. It is that mechanism which James Shapiro calls the "genetic engineer." Let us allow Ben-Jacob to repeat something we've already touched upon: "the cell carries a complete set of tools for genetic self-reconstruction: plasmids, phages, transposons and too many others to mention...the same tools, in fact, used in the lab today for genetic engineering." A microscopic research and development squadron goes to work recrafting its own genetic string. Which raises a question: does the genomic skunkworks merely trot out pre- fabricated parts which have worked in the past? Or is it capable of true innovation? This is when Ben-Jacob devised his tests of bacterial ingenuity, putting the poor creatures into nightmare environments whose like they'd never encountered before. If all the microbial team could do was recycle ancient programs, it would be finished. But that is not what happened. Through data pooling, experimentation, and tests of novel strategies, the bacteria managed to refashion themselves in radically new ways. This was not traditional random mutation at work. This was driven, inspired conception. Thanks to the synergy of the conformity enforcer, the diversity generator, the utility sorter, and the resource shifter, the colony was capable of something numerous humans never achieve - creativity.

4. In a natural environment, the fifth of a complex adaptive system's principles would presumably come into play: the *intergroup tournament*. Alas, until recently Ben Jacob has studied each colony isolated in its own petri dish, sealed off by plastic walls from competing groups. But as the resources which feed the bacillus subtilis run out, imagine what might happen if a spore of another bacterial species were to drop in, a species which found the inedible plateau on which the subtilis was stranded to be more nourishing than sauerbraten. The race would be on. While the bacillus subtilis reworked its genome in an effort to gain sustenance from the now (to it) barren waste, the newcomer would rush to reproduce, taking advantage of the fact that subtilis' inedible slabs are its entrée du jour. As the two groups struggled to take over the petri dish, would a new innovation emerge from

the contest, an innovation of the sort which enriches the fate of a species for eons? One which adds abundance to the environment, complexifying the planetary biomass, transforming ever more of this once barren planet into food for life?

4 Learning Machine in Raven Colonies

We have already seen these principles at work among crayfish, birds and bees. The raven who succeeds in spotting a banquet gains followers and magnetism. It is quite likely that he also wins the privileges of hierarchical rank - first dibs on mates, food, and the most comfortable overnight accommodations. The genes which make him a raven like his brethren are conformity enforcers. So are the tugs of imitative learning which pull him toward flying meekly with the flock. The maverick nature which causes him to buck that impulse is a form of diversity generator. It allows him to soar over territory his fellows have not explored, and thus to make new finds.

When his search is victorious, utility sorters shift the raven's hormonal gears, giving him internally-generated strength and confidence. Biology rewards him with an attitude which will draw a following. Cockiness is his equivalent of a bacteria's chemical attractor. This is equally true for innumerable species. The amount of chemotactic allure a bacteria can generate determines its leadership. The enthusiasm of a scout bee advertising a new find determines the number of followers she will attract. The regal strutting of a spiny lobster winner almost certainly helps captivate adherents who will follow him in his trek away from a glacial freeze. Each of these creatures has been turbocharged internally by success. And that endogenous upgrade makes all the difference in the world.

Meanwhile social machinery outside the new leader's physiological fabric sets the resource shifters into motion, honing to unbeatable sharpness his or her edge in nutrition, reproduction and influence. Very simply put, as the champion's hormones give him a boost, other inner chemicals downshift his former rivals and impel them to defer to him, funneling the group's bounty in his direction.

Finally, intergroup tournaments increase the odds that those groups which stumble in their use of the previous four mechanisms will also fail to survive. If faulty physiology draws you to the wrong leader, you are likely to leave no genetic or memetic legacy in your wake.

So ravens pool their findings and follow those who have demonstrated a record of meaty discoveries and of organizational savvy beneficial to the bunch. Raven flocks even share news of their richest treasures with aggregations from miles away, as if they knew that through this worldwide- webbish generosity, they would survive the famines which permanently down those who selfishly hog their data.

These are some of the secrets of the nascent global brain. Robert Bakker has inferred that this quintet of principles was at work among velociraptors and astrodons 120 million years ago. New finds of early birds (Confuciusornis) from the same era also hint that the beasts with the novel feathers may have used the five principles of a complex adaptive system in their group behavior. And we will soon see how the learning machine's pentagram extended its embrace to human beings.

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Mammals and the Further Rise of Mind

By Howard Bloom.

History of the Global Brain, Part VI

It's currently popular in evolutionary psychology to believe that the modern mind evolved in the Pleistocene, the hunter-gatherer stage of man's existence. Yet most of what we are, of our personal emotions, our ways of doing things, and the manner in which we transmit and sum them, we share with far more primitive relatives.

Sara Rogenhofer

Memes are one key to the next jump in networking. And memes come in two stripes: implicit, that means those which belong to the animal brain; and explicit, those which depend on hominid neural add-ons, the cranial gizmos responsible for syntactic speech.

Implicit memes - the ones transferred by spiny lobsters, birds, octopi and squid - are housed in a very old part of the brain indeed. Yet they dominate our lives, handling everything from the way we drive to our autopilot greetings, quarrels, reconciliations, unspoken cultural quirks, frustrations, and our joys. Even language is less our monopoly than we think. And the very queen of the brain's humanity, the cerebral cortex, home of that narrative summarizer we call our consciousness, is not entirely human either.

So before we can understand ourselves, we must stick to our task and continue to dissect the past. We are new, but not as startlingly so as we would like to think.

1 Mammal Sociality

Mammals appeared 210 million years ago. Vertebrate paleontologists have closed their eyes to the rise of mammal sociality. They have a good excuse. The fossil record isn't kind to those drawn to a sociological prize. Ancient mammals are almost never found intact and thronged like trilobites. Instead a triumphal dig turns up an isolated bone or two. Perhaps a single shin or tooth. Fleshing out the shape of the creature who left behind these pitiful remains is almost beyond the grasp of the finest explicit human brains. Only Argentina's Jose Bonaparte seems to have found half a dozen early mammals huddled together in a truly ancient burrow. And even this jewel failed to wrench his colleagues from the rut of their routine pursuits.

Way back in 1982, John F. Eisenberg stepped bravely from the paleontological pack and summed up his theories on mammalian collegiality in an article he wrote for the "Oxford Companion to Animal Behavior". Though Eisenberg has abandoned the quest for the origins of social networking since then, he made several important claims which have been echoed by other scientists in more recent years. Among them, that gregariousness between multi-celled eukaryotes must at the latest have begun with the birth of sexuality, some 800,000 years before the first mammal ever appeared. Said Eisenberg, sexuality forces animals of opposite gender to get together. No meeting, no mating.

Eisenberg put forth another proposition. To guarantee that discombobulated creatures do not miss their tryst by a month or two, the beings must communicate and synchronize. Courtship struts and battles set individuals to a public timer much like the clock which orchestrates computer components so they can waltz together. Flaring armored skulls and other signs of mating tournaments appear in abundance among dinosaurs. Brontotheres, behemoths with the horns and bodies of rhinoceroses, continued this Jurassic tradition. But brontotheres were not saurians. They were mammalians. Their armaments clearly showed that they were ticking to a social metronome.

The sexual embrace led to another superorganismic braid, that which bound the generations together. Quoth Eisenberg, parents and their young "can...exchange...stimuli which coordinate their activities." Among mammals, contact between mothers and their brood was cemented by a unique form of food relay. Matriarchs shuttled the nutritional mix we know as milk from a specialized gland into their infants' mouths. This coupled one temporal cohort to the next like a prong and socket. "Lactation," to quote geneticist and evolutionist Timothy Perper, "represents an embodied nexus of sociality." With mammals Legolinkage was the name of the game from the moment after birth.

The dairy innovators' tendency to long life and lengthy childhoods stretched the time when young and old were thrown together, encouraging another adaptive advantage - the storage of new data needed by the immature in parental memory. What's more, mammalian communication systems would prove unbeatably flexible. With hard-won ancient lessons and newly minted tricks cartwheeling through the group and across each generation gap, a family or far larger horde could resculpt its lifestyle swiftly, making itself at home in a previously impossible environmental niche.

During the last eons of the dinosaurs, insect eating mammals , still eking out an existence in the shadows of the walking monoliths, already resembled modern shrews and hedgehogs. Then 65 million years ago, environmental catastrophe drove the dinosaurs from their homes and left the last remnants of them to starve in bleak and unfamiliar surroundings, their adaptive capabilities overwhelmed by circumstance. But in socially networked animals with larger brains, catastrophes are creative opportunities. Mammals , freed from hiding in bodies smaller than a dino-snack and in holes and crevasses too narrow for a dino's claws, were challenged to let the full range of their flexibility run free.

2 Conformity Enforcers

The five principles of the complex adaptive system aided the survival of these rodent-like creatures.

Mammals like whales and bats, which appeared roughly 55 million years ago, have oodles of conformity enforcers, homogenizers which allow for common language and for the alignment of behavior between individuals. Information transmission among social mammals - whether handled by scent, sound or visual codes - tends to be swift. Rats avoid a strange food until they smell it on the breath of a den-mate. Then, assured by the survival of the poison-tester, they pounce on the previously suspicious morsel. This slavish timidity can save their lives. Squirrels also pool information, using their tail as a semaphore to signal trouble and to rally their companions. A twitching of this fur-fringed nether flag may mean there's a snake around and bring others running to the rescue. A team of squirrels can track and isolate a snake more effectively than one squirrel on her own. Tail wagging in dogs seems to be a recruitment signal linked to celebration - one of many canine body codes. One wild dog cannot bring down a zebra. But a pack working together can. The striped and panicked prey is defeated not just by a myriad of teeth and claws, but by the operation of collective brainwork, the second-by-second tactical turns which fine tune the hunting tribe.

The urge to follow in the tracks of someone else - a consummate conformity enforcer - also speeds the spread of information among primates . When one baboon emits a warning call, it inspires others nearby to repeat it. So a necessary bit of news ricochets rapidly around the baboon territory.

Among monkeys, pioneering primatologist K. Ronald Hall noted how a bit of rubbish every beast despises can suddenly become popular. If one animal shows an unexpected interest in the detested thing, friends are likely to fall in line and become intrigued as well. 'Tis another instance of that antique conformity enforcer: imitation .

The impulse to follow the crowd turns perception to a herd phenomenon even among baboons. Knowing how addicted baboons are to meat, primatologist Shirley Strum tried to make friends with a troop she called "the Pumphouse gang" by bringing them a carcass. At first, the baboons shied away from the flesh that had arrived in this strange manner. Then one savvy individual tried a bit of the food. After they saw one of their tribe eating the alien offering, the others descended to get their share.

3 Networked Intelligence

As among bacteria and bees, there is solid evidence that individual mammal brainpower is often less important than networked intelligence. K.R.L. Hall points out that on their own, chimps are more intelligent than baboons, even making their own tools. But baboons have been more successful than the brainy junior apes. Baboons have spread over far more territory and have occupied a greater variety of homes. Lone baboons may be rather dumb, but their group creativity is so great that on a continent most of whose exotic creatures are being wiped out, baboons have spread like cockroaches. Their secret is to find the potential bonanza in every new twist introduced by man. In the dry thorn veldt baboons use cattle drinking troughs and handle temperature extremes that go from 80 degrees by day to freezing at night. They live along the banks of the Zambezi and in the southern woodland savannahs. In fact, they're "the most widely distributed non-human primates" in Africa. Why? Despite their skimpy endowment of solo smarts, baboons have something chimps lack - a vastly superior social organization . The average group of chimps is a mere 40 or so. Baboons, on the other hand, hang out in crowds three to six times that size.

Why does a heightened craving to hobnob give baboons an edge over chimps? Predators on the prowl usually only manage to snatch one member of a pack. So the bigger the assembly, the less chance any single member has of entering the day's menu. This simple fact helps drive many animals into substantial groups. But once the resulting communities have formed, they take on a role we've examined in our previous episodes - as cauldrons of information exchange.

Early mammals are endowed with another of the complex adaptive system's quintet - diversity generators. Baboon social learning is aided by an itchy creator of behavioral twists - curiosity. Some baboons will toy with nearly anything that comes across their path. Says Hall , baboons "push over slabs of rock" yank at telegraph wires, pry their way through the doors and windows of empty huts and cars, and overturn, crack open or "fiddle with and try out" nearly anything in sight. This restless test of oddities helps a baboon find new ways to get the most from almost any environment.

Conformity and diversity work together for the betterment of the larger whole. Like bacterial and honeybee scouts, baboons spread out in small groups during the day. The foolhardily inquisitive among them comb the possibilities of the landscape. Bacteria pool their exploratory discoveries via long-distance chemical communication. But baboons , who are a good deal more mobile, gather at night in sleeping clusters which may include hundreds. These overnight conventions breed data processing. In the morning, the troop's males confer, swap their "ideas" about the direction in which the richest potential new food sources can be found, manage, according to one researcher, to create visions in the minds of their council-mates of the routes and potential rewards to which they imagine those trails will lead, then make group decisions on which way to go next.

Says USC's Jane Goodall Research Center director Dr. Christopher Boehm , "in cases of emergencies (e.g., a river that floods and blocks the most likely direction of travel) this pooling of information can lead to significant conservation of energy for the entire troop. Because such emergency decisions seem to be influenced by males who have extensive experience with the environment, and because each individual's experiences will differ, it is easy enough to imagine that different Hamadryas troops might make different tactical decisions about direction of travel under similarly threatening circumstances - for better or worse."

4 Learning Machines

Another diversity generator - cultural separation - works hand in hand with imitative learning to enrich the knowledge of the tribe. When the Pumphouse gang was in danger of being shot as pests by the inhabitants of a new army barracks who resented having their homes entered, tossed and probed for edibles, rescuers flew the crowd to a distant location. The displaced baboons had no idea of the groceries in the new landscape and of the best way to get at them. But they watched and followed native troops to learn their ways. And young local males looking for new homes gravitated to the exotic band of strangers. One "applicant" for Pumphouse Gang admission dug for salt near a watering hole, something the new arrivals had never seen before. When the immigrants followed this native's example, they added yet another skill to their repertoire. Hall

has said that baboon groups provide "the essential setting for each and every act of learning by the individual...the group is the basic unit for... learning processes." In short, baboons are more successful than the wiley chimpanzees because their troops are better learning machines.

Pre-human mammals not only network their informational breakthroughs across substantial distances, they also spread the tendrils of what they've learned into the future, thus penetrating both space and time. Elephants , for example, pass behavioral memes from one generation to the next. In 1919, the citrus farmers of South Africa's Addo Park wanted to get rid of a herd of 140 elephants who'd been wreaking havoc with their crops. They called in a hunter who shot the elephants painfully, one by one, while their family members watched the dying agonies. After a year, only sixteen to 20 elephants still remained. But they had adapted their lives to the hunter's presence. In a most un-elephant-like manner, they had become nocturnal, hiding in the bush until night fell, and stealing out to feed in utter darkness. The adaptation worked. The hunter eventually gave up. Then, in 1930, the elephants were granted permanent sanctuary. There were no more gunshots, no more attacks by murderous human beings. Yet 45 years later, the elephants retained their reclusive, night-time way of life. The veterans of 1919 had died off, but the group held on to patterns designed to cope with a danger that had long since past. Those patterns leaped the boundary from generation to generation and mind to mind. Implicit memes had shaped communal sensibility as surely as genes sculpt the rippling canyons of the brain.

Advanced brains were, in fact one key to the elephants' multi-generational memory. The other was the bond of motherhood and matriarchy. Elephants, like the humans who would not appear for over 20 million years, possessed a cerebral cortex of substantial size. This is less unusual than it seems. Biological anthropologist Robin Dunbar has shown that the larger the size of a social unit, the larger the cortex of each member. This is even true within a single species. Bats were one of the earliest mammals to evolve. So ancient is their pedigree that many scientists have referred to them as "living fossils." Like elephants, these flying mammals live long lives (one tagged wild bat in New England survived well over 31 years).

Most mothers nurture just one youngster at a time and do it for a lengthy span. A few bat species live solitary lives. The cerebral cortexes in these flying hermits are very small. Others live in colonies of up to 20 million. The vampire bat hunkers down in a cluster of 200 or so, yet each mother is able to find her own child when she returns at night from a lengthy flight, despite the fact that her son or daughter is hidden like a lost toddler on an overcrowded beach. What's more, before she settles down, sated with her pickings, she will seek out the adult "babysitter" who tended the children while others were away and repay her with a bit of regurgitant. To top it off, if an unrelated neighbor has had slim pickings in its search for blood, a returning mother will disgorge some of her stomach contents to the needy. On a future night the bat who was aided when she was down on her luck will make her way through the bewildering mob to pay back her benefactress by offering her fresh food if she, too, has been starved by snarls of fortune. A cerebral cortex of substantial size makes it possible to pinpoint patrons and trade favors as if in a commodities exchange.

Elephant groups are also highly interlaced. Each troop focuses upon a female elder, relying on her strength and wisdom. Her cerebral cortex is enormous, holding lessons learned 40 years ago and shuttling them down the line to generations newly born.

To knock our homo chauvinism down a peg further, even language is not totally unique to us. Robert Seyfarth and Dorothy Cheney have shown that though monkeys don't gush a steady stream of nouns, verbs and sentences, they do erupt with symbolic sounds which act as words. Most famous are the vervets, whose distinctive chutters and whirs warn of killer birds circling the skies, lethal snakes slithering on the ground, and leopards stalking at eyeball height. Each word must be different, for the response that would allow escape from a cat - going high into a tree - is a surefire way to become an eagle canape. Even more remarkable is the fact that vervets have more than a single term for each of their dangers. Every call has synonyms - different sounds with the same meanings. One more element of human uniqueness anticipated long before we first walked this earth.

Through three diversity generators–curiosity, cultural separation, and novel attempts at behavior (like those of the elephant who first became nocturnal) - early mammals generated implicit "behavioral" memes, improvising tricks which could be passed from one brain to another. Those memes, wafting wordlessly through a group, took advantage of conformity enforcers to shape the behavior of a mass. At least two of the elements of the complex adaptive system were at work in mammals long before the appearance of the first Homo sapiens. We'll soon see how the other three petals of the adaptive pentagram were snapping into place as well. Just as they had among bacteria, networking and the group brain were busy doing their thing in the Age of Mammals 60 million years ago.

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Tools of Perception - The Construction of Reality

By Howard Bloom.

History of the Global Brain - VII

Between 65 million years ago and the present, collective intelligence tentatively stretched toward globality once again. The bird species salaciously called tits showed up on the scene roughly ten million years ago. Airborne, they were high-speed spreaders of behavioral memes. It is difficult to tell what kinds of tricks these creatures passed to one another in prehistoric times.

Some idea about the tricks comes from an incident famous among animal behaviorists . During the late 1940s, London's milk vendors replaced cardboard bottle caps with aluminum foil. A few blue titmice figured out how to pierce the flimsy metal so they could sip the liquid's crown of unhomogenized cream. So rapidly did this innovation spread that seemingly overnight dairy robbery was fattening the bellies of titmice the length and breadth of the British Isles. Conformity enforcers had spread a potent meme.

The diversity generator of competition between feathered flocks launched new variations on antique ploys. To get a notion of how this must have worked, it's useful to eyeball another modern example. The oystercatcher, whose ancestors evolved roughly 50 million years ago, lived on seacoasts and used a flat, knifelike bill to dig worms and shellfish out of sand. Evidence suggests that during the last five hundred years some Scottish and British oystercatcher flocks were crowded out of easy pickings on the beach and forced to look for feeding grounds in savagely unfamiliar terrain. They moved upriver - an unheard of step for birds adapted to the edges of the sea. Eventually, the homeless wanderers discovered a paradise not presaged by instinctual memory: irrigated farm lands and riverine wetlands perfect for the excavation techniques built into their genes. Like bacterial "random walkers," they'd opened a vast new resource to the species. In this way non-conformists had made their contribution to a planetary software pool.

The contagious ways of doing things called "behavioral memes" knitted separate species together. Pleistocene mammals still live side by side in the Serengeti plains of East Africa: the zebra, the wildebeest and the Thompson's gazelle. When the dry season sucks life from their flat pastures in the southeast, these animals make a hundred mile procession north to hilly Kenyan woodlands rich in watered meadow. Zebras lead, each year improvising a new track, but always with the same destination in mind. The herd of wildebeests - a potential chaos of a million animals - is conformity enforced to follow the striped equines. Then the delicate gazelles, taking their memetic cues from the zebras and the wildebeests, are swept by imitative drives to bring up the rear. When the immense migration reaches its goal, the diversity generator of speciation fits these varied animals into a megapartnership. The first arrivals, zebras, crop the roughest and tallest grass - food too tough for wildebeests to eat. This browsing exposes tender mid-height shoots upon which wildebeests can make their feast. By the time the gazelles appear, the turf is sufficiently low to offer their favorite dish, ground-hugging vegetation. Though memeless, the grasses join the multi-species circle dance, repaying the pruning they've received by sending up fresh shoots and stalks. Chimpanzees

, which became a separate species roughly six million years ago, developed flourishing cultures - inventing memes and passing them down the generational chain. The chimps of Gombe and of today's Tai forests created sets of tools for opening palm-oil nuts. The implements of the Tai, Mahale and Gombe chimps are subtly different and used in different ways. All three groups have learned the handiness of sticks. But only the Tai have figured out that twigs and branches can be used to pull the marrow from the hollow of a bone. Mahale and Tai chimps use their fingers to nab the protein snacks we call termites and ants - stoically enduring their victims' bites. The Gombe residents have mastered the knack of dipping sticks into the fortress entrance of a mound and harvesting bugs in painless quantity. Gombe chimps also use sticks to scratch and clean themselves. Their Tai and Mahale counterparts haven't yet attempted this hygienic art. Even the use of stone hammer and anvil to crack nuts - dependent on techniques so intricate that they can take seven years for a young chimp to fully master - are radically different in each group. There is, however, one stark uniformity - each troop has seized the "concept" of tool use.

The strangest networkers of all first climbed to their feet roughly four million years ago. Their hands were more dexterous than those of chimps. Chimpanzees tossed stones and sticks at tigers and others who invaded with potentially evil intent. But their aim was pathetic and the distance they could clear was barely 20 feet. Proto-humans had a hurling arm and an aim sufficiently sure to bring a bird down in mid-flight. Their fingers were nimbler too. Chimps primarily use stone tools ready-made by nature. Humans took a far more active role in this technology. Chimps had already invented weaving (though birds had beaten them to it). Every night the mini-apes interlaced leafy boughs to make a sleeping nest. Humans were equipped to knit far more than this one artifact.

Roughly 2.7 million years ago, Homo habilis began to crank out tools from stones and bones. In the beginning, this was largely a matter of finding a rock which was already sharp or a cracked rib with an accidental point, techniques on a par with those of chimpanzees. Our shallow-skulled ancestors (their thinking apparatus was half the size of what we carry in our skulls today) had figured out how to use crude implements to dig and grind. The technology spread from group to group, but only reached from Ethiopia to adjoining Kenya, a distance animals like birds would have found disdainfully small. It took a million years or so before the communal intelligence of proto-humans stretched its scope. Then Homo erectus, with a 56% larger brain, came up with two new breakthroughs - tapping one stone with another so skillfully that the target rock's lines of stress fractured, dislodging flattened slivers small and large. Later the new hominids devised a second step: creating hand axe blades by tapering each side of the rocky sheet. Now the spread began to leap. Early flaking travelled from Northern Africa to the continent's far south. From 1.8 million years ago to roughly 500,000 years ago, it somersaulted the thousands of miles to Europe far in the northwest and China in the almost unimaginably distant east. The hominid collective mind was going global, carried by what archaeologist Clive Walker calls "timewalkers" - those of our ancestors seized by travel lust. African tool making forms (termed Oldowan) were used from England, Hungary, Germany and Israel to Peking. Separation did not create major change, nor did time. The Acheulean-style stone axe was in use from 1.5 million b.p. until a mere 4,000 years ago.

As humans spread, so did other signs of their unfolding global mind. Fire was popular in both Africa and China over 400,000 years ago. The axon of travel had spread Promethean flame across a walking distance of over 10,000 miles. The stone tool kits of that period, whether in Africa, Europe, or Asia, were very much the same. Again, the glial tissue of learning had shuttled a common pattern across a far flung neural weave. Wherever men and women went, they carried their emulative memes. So fiercely did the conformity enforcer work that it guaranteed a common shape for tools during 1.5 million years.

The environments over which men swept spurred diversity generators too. In Southeast Asia many anthropologists are convinced men learned how to fashion their hunting tools not from stone and wood, but from a plant able to take a sharp, hard point - bamboo. 100,000 years ago more regional variations cropped up. This took another 20% boost in brain size - brought by our immediate predecessor and near lookalike, Homo sapiens sapiens . In the north, men contrived ways to cope with vicious cold . Weather shifted cataclysmically, lakes of immense size appeared and disappeared, new lands opened as oceans shrank then closed again beneath returning waves, and even the Mediterranean Sea changed and rechanged utterly. All this provoked new forms of flexibility. Proto-humans echoed the ancient patterns of bacteria, which triumph over catastrophe by forging whole new ways of life.

Chimpanzees and baboons long ago learned to hunt in groups. The meat of colobus monkeys is a favorite among chimps, who cleverly deploy in squadrons to corner their elusive prey. Baboons occasionally invent team tactics to bring down a small gazelle or wild pig. But after several years, the males who bring home bacon move on and forget this social skill, only to eventually create it once again.

By 35,000 years ago, brains like our own were allowing humanity to realize exploits far beyond the animal ken. Chimps do not forget the tricks of group hunting. Nor did we. With our delicately flaked stone tools, now far more sophisticated than they'd been two million years earlier, we were able to strip the fur from our prey (woolly mammoths were popular, in those days of ice), carve out their ribs, use the calcium struts as framework for large homes, and cover the crescent-shaped bones with fur. One pelt would not suffice to tent a house of substantial size. Our ability to use one tool to fashion another, something no bird or chimp seems to have known, allowed us to extend weaving far beyond the limits to which chimps and birds had taken it, making threads from sinews and needles from bone. With these our ice age ancestors could stitch enough hides together to roof and side their skeletal supports. They could also fashion pelts into elaborate clothes, then encrust their haute couture with beadwork made from carved, drilled and polished bits of bone. Our new skills had brought us back to the elaborate decoration of early bower birds.

Why the constant echo of the same forces, even many of the same modus operandi, among men, microorganisms, birds and other beasts? It's often said that humans differ a mere 1.6% to 3.6% in our chromosomes from chimps. But we forget that most of our genes we share with life forms from the most to the least primitive. We are all programmed by a common heritage. In later episodes I'll suggest a theory to explain why old motifs reappear in the strangest ways. Why men, for example, are compelled to act so much like quarks and leptons hungering for companionship. This theory penetrates the cosmic tapestry to a level molecules, genes and emperors must obey. But we will have to save the unveiling of this scalpel for a later time, and first see how the pentagram of complex adaptivity works its deepest mysteries.

1 Language Networks

Knitting nodes of humans like synapses was long distance trade, which first reared its head two million years ago, specializing in the swap of rare and workable stone . A crucial aid in the give and take of craft and raw material was a transmitter capable of threading whole new kinds of intricacy from one mind to another. More than the wrrs and chutters of monkeys, this was a brocade of sound that gathered tufts of meaning into tapestries. Specialists call it syntactic language: noises linked in structured chains of nouns, verbs and adjectives. Some theorists propose that the germ of sentences may have appeared two million years ago. One hypothesis suggests that speech's rise coincided with the beginning of tool making. Another says it came about as a substitute for the grooming which holds a troop of monkeys or apes together. Even the most cautious expert seems to agree that full-fledged language was in place by 30,000 years ago. Amidst the wealth of speculation, one bit of evidence stands out. Analysis of a two million year old skull from Koobi Fora in Africa indicates that Homo habilis possessed a patch of brain unknown in our previous ancestors. This new cerebral curio was Broca's area - an apparatus vital to fluid, nuanced self expression .

For many episodes, I've traced a form of socially transmissible knowledge not recognized in previous memetic schemes: the behavioral meme. Human and animal bodies pick up information from pressure gauges in the bottoms of the feet, from nerves which wrap the base of fur and body hairs, from others sensing the vibrations of bristles in the ear, from the tips of neural fibers groping molecules in the nasal cavity's air, and from light detectors in the eye. The nervous system zaps these gleanings to a jerry rig of gadgetry whose strange ways we'll soon see. And all is funneled through the emotional center of the brain - the limbic system - a leftover from reptilian and early mammalian times. There, instinct and personal memory set off signal flares such as excitement or disgust. Should a batch of input spark a meaningful ignition, the limbic system routes the arrival to the storage lockers of the mind. But not all storage lockers are the same. In fact, there are two radically different kinds.

If the entering experience is fear, elation or a body movement - leaping from the top branch of one tree to another, riding a bicycle, hammering a recalcitrant nut into giving up its meat - it is shuffled down to the amygdala and planted deep under the eaves of the cortex in a curved mesh of axons called the striatum, with excess packed away in the motor and sensory pathways, the cerebellum, and a widespread nervous system so out of our control that its very name is "autonomic." We've seen the bewildering variety of animals who can manage this imitative learning feat, catching the passed football of emotional and muscle memories. In humans implicit memes remain outside of our awareness. Yes, we know how to ride a bike. But the finest rally racer can't explain the symphony of neural cues he uses to sustain a simple thing like balance. If we focus consciously on the angle to which we must adjust each vertebra while slaloming through traffic at top speed, we are likely to lose the hang and scrape our head on asphalt.

Broca's area, the brain enhancement possessed two million years ago by the Homo habilis known as KNM-ER 1470, helped create entirely new forms of data cabinets, those which house explicit memes. Explicit memories, the kind we can recite and convey by speech, the kind that our story-telling consciousness can spin into detailed instructions or share with a high-paid shrink, take a very different route to permanent storage. They pass upward to the hippocampus, where they are distributed to the cortexes of the temporal lobes, accessible to manipulators like Broca's area and to two others which emerged in early Homo habilis - the supramarginal and angular gyri . These are some of the processors which prep data for our blathering consciousness and tongue .

Language laces spectacular new properties into the group brain. Among other things, it stitches individual minds into a quilt of mass hallucination - an intricate shared vision able to carry a tribe beyond all visible horizons or to throw the clan dramatically off course. This consensual delusion - known to us as "human culture" - has become the most intriguing network-splicer of them all. But within it lies a paradox - for language and culture spawn simultaneous opposites: conformity and diversity. The wrestling of these intimate antitheses gives the group brain of humans an agility not seen since the creative global web which first arose among cyanobacteria some 3.5 billion years ago.

However, to unravel the weave and clash of culture's phantasms, we must first expose one of the strangest ways in which conformity enforcers needle-and-thread generations and widely dispersed humans into a common drapery...the illusion of "reality."

2 What is "Reality"?

> This way, that way, I do not know
> What to do

I am of two minds.

Back to basics for a moment. Just what is "reality?" Is it an oh-so-solid thing you can pound with your hands and rivet with your eyes? Or is it, as postmodernists proclaim, a projection of the social brain? Postmodernism is often a fashionable bungle of obfuscation, but in this case the eyes and hands don't have it - the "radical constructionists" do. Reality is more a fabrication than even the trendiest postmodernists suspect.

In the late 1930s and early 1940s, logical positivists said that knowledge broke down into two parts: "sense-data, and the conceptual structures we use to clip the sense data together." One formalizer of the emerging philosophy, J.S.L. Gilmour , proclaimed that sense data are "objective and unalterable." Good guess, but no cigar! Canadian neurologist Wilder Penfield's studies are often cited by those who believe reality is a concrete thing we perceive without distortion. When Penfield touched the naked brains of neurosurgery patients with electrodes in 1933, they reported vivid, detailed memories. The conclusion many drew and continue believing to this day is that the brain warehouses fine-grained tapes of past experience. Later analysis showed this conclusion was mistaken. Many of the "memories" were confabulations. One patient , for example, recalled the time that he'd been robbed down to the minutest detail. There was only one problem - he'd never been robbed in his life. The reality of the external world registers poorly on the human mind. One eyewitness to Abraham Lincoln's assassination swore the killer had crawled away on his hands and knees, another said he'd leaped fifteen feet, a third declared that he'd stopped to deliver a line of Latin, and a fourth said emphatically that he'd shimmied down a flagpole. There was no flagpole at the scene. Even the most highly trained observers end up mixing fiction with their "facts" . Before chromosomes were discovered, scientists looked carefully at cells then drew what they had "seen" without a chromosome in sight. After chromosomes had become accepted truths, researchers suddenly peppered their "unvarnished" cellular portraits with the things. Lacking the concept of the chromosome, observers would have sworn these objects were not there. Other oddities

spindle, fold and mutilate the seeming firmness of "the real world." Turn the level of lighting up and down and the sound of a nearby buzz saw seems to rise and fall

as well. If you shine a light and play a faint tone over and over again, then turn on the light in utter silence, the mind will hear a tone that isn't there.
The image that we see is the end product of chopping, coding, long-distance transmission, neural guesswork and editable cut and paste. The slice and dice begins in the eye itself, which separates and reshapes input rather than merely taking snapshots. Some photo cells are specialized to register a fine edge. When they spot what they are looking for, they take enormous liberties. They "request" that the cells around them cease reporting what those cells "see" so the edge-experts can spotlight the contour which they're working to pick out. Yes, data-juggling begins at very the frontier where our senses meet the outer world.
Next come radical forms of transmutation. Photo cells transmogrify incoming light to a pulse of chemicals and electrons. Twisting things even further, the 125 million neurons of the eye must compress their hoard of interpretations to a code able to squeeze through a cable a mere million neurons in size. On arrival in the brain, the compacted stream stops briefly in the thalamus, where it is mixed, matched and modified with flows of input from ears, muscles, fingertips, and even sensors indicating body position.
The thrice rearranged jumble of jigsaw pieces is sent off to the visual cortex, where it is divided up again. Each portion is tucked into a separate storage belt responsible for gleaning a different type of meaning. If you're twirling in a swivel chair , one belt will reshape the blur whipped past your eyes to a picture crisp with artificial clarity. Meanwhile neurons from all over the brain sift scattered fragments, trying to contribute their own sense of them. For instance, cells which signal if an animal or human is friend or foe add their best guess to the moving batch of "sensory" ingredients.
Finally a council of representatives from the superior colliculus, the thalamus, the locus coeruleus, the hypothalamus and the occipital cortex pool their squabble of conclusions and cast a vote on what the twinges of light impinging on the retina might be. Not until they've agreed on an image do they send it to the left cerebral hemisphere, presenting it as a panorama accompli to the conscious mind. What we see is not the product of direct perception, but of a reconstruction which borders on fragile artistry.
The assembly process we call "sight" is so powerful that if you are given a set of goggles whose custom lenses turn everything you see upside down, eventually your sensory construction crew will take the topsy turvy rays of light and rebuild their image upside up.
The eyes are not the only "senses" which use a Rube Goldberg process to simplify the world. The entire human body is composed of separate systems bouncing signals back and forth, sometimes conflicting, sometimes reaching a disturbingly synthetic compromise. Dr. Michael Gazzaniga feels a center in the left cerebral hemisphere pulls together messages from the competing factions and fashions them into a policy statement of the moment. It also uses them, in Gazzaniga's opinion, to construct a theory which it calls the self and another which it calls the world. But that ever-changing theory can be terribly off base.
Often we don't have the foggiest idea of what's going on in our most immediate reality - our selves. Researchers rigged subjects to a finger-pulse stress detector, then ran their human guinea pigs through a modestly hair-raising situation. When the ordeal ended each victim was quizzed on how he or she felt. "Fine" said many, whom the stress detector indicated were very rattled indeed. "Upset," said others who, according to their physiological signals were actually quite calm. Further studies have shown that adolescents who report they are aggressive often aren't, and those who say they're not aggressive are. In one research trial, women were hooked up to a device measuring vaginal blood volume and given an erotic story to read. Many who said they were aroused weren't, and many who said they weren't were. In yet another experimental probe, subjects were wired to an electroencephalograph rigged to register sleep and were allowed to doze off. Though many fell into a solid slumber, they usually were certain they'd stayed wide awake.
As we shall see in our next episode, the internal assembly steps patching together our reality are filled with open loops demanding input from a crowd of other human beings. At a level far, far deeper than we know, even the most granite of our solidities is a chimera frozen in position by the conformity enforcers of the communal brain.

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Reality is a shared hallucination

By Howard Bloom.

History of the group brain VIII - 35,000 B.P. and Beyond.

The artificial construction of reality was to play a key role in the new form of global intelligence which would soon emerge among human beings. If the group brain's "psyche" were a beach with shifting dunes and hollows, individual perception would be that beach's grains of sand. However this image has a hidden snag - pure individual perception does not exist.

Sara Rogenhofer

> Being here is a kind of spiritual surrender. We see only what the others see, the thousands who were here in the past, those who will come in the future. We've agreed to be part of a collective perception.

Don DeLillo

A central rule of large-scale organization goes like this: the greater the spryness of a massive enterprise, the more internal communication it takes to support the teamwork of the parts. For example, in all but the simplest plants and animals only 5% of DNA is dedicated to DNA's "real job," manufacturing proteins. The remaining 95% is preoccupied with organization and administration, supervising the maintenance of bodily procedures, or even merely interpreting the corporate rule book "printed" in a string of genes.

In an effective learning machine, the connections between internal elements far outnumber windows to the outside world. Take the cerebral cortex , roughly 80% of whose nerves connect with each other, not with sensory input from the eyes or ears. No wonder in human society individuals spend most of their time communicating with each other, not exploring beasts and plants which could make an untraditional dish. This cabling for "bureaucratic maintenance" has a far greater impact on what we "see" and "hear" than most psychological researchers suspect. For it puts us in the hands of a conformity enforcer whose power and subtlety are almost beyond belief.

In our previous episode we mentioned that the brain's emotional center - the limbic system - decides which swatches of experience to "notice" and store in memory. Memory is the core of what we call reality. Think about it for a second. What do you actually hear and see right now? This article. The walls and furnishings of the room in which you sit. Perhaps some music or some background noise. Yet you know sure as you were born that there's a broader world outside those walls. You are certain that your home, if you are away from it, is still there. You can sense each room, remember where most of your things are placed. You know the building where you work - its colors, layout, and the feel of it. Then there are the companions who enrich your life - family, the folks at the office, neighbors, friends, and even people you are fond of whom you haven't talked to in a year or more - few of whom, if any, are in the room with you. You also know we sit on a planet called the earth, circling an incandescent ball of sun, buried in one of many galaxies. At this instant, reading by yourself, where do these realities reside? Inside your mind. Memory in a very real sense is reality. What the limbic system decides to "see" and store away becomes an interior universe pretending to stretch so far outside that it can brush the edges of infinity.

> We are accustomed to use our eyes only with the memory of what other people before us have thought about the object we are looking at.

Guy de Maupassant
The limbic system is more than an emotive sifter of the relevant from the inconsequent. It is an intense monitor of others , using its social fixations to retool your perceptions and your memories. In short, the limbic system makes each of us a plug-in of the crowd.
Elizabeth Loftus
, one of the world's premier memory researchers, is among the few who know how powerfully the group shapes what we think we know. In the late 1970s, Loftus performed a series of key experiments. In a typical example, she showed college students a moving picture of a traffic accident, then asked after the film, "How fast was the white sports car going when it passed the barn while traveling along the country road." Several days later when witnesses to the film were quizzed about what they'd seen, 17% were sure they'd spied a barn, though there weren't any buildings in the film at all. In a related experiment subjects were shown a collision between a bicycle and an auto driven by a brunette, then afterwards heard questions about the "blond" at the steering wheel. Not only did they remember the non-existent blond vividly, but when they were shown the sequence a second time, they had a hard time believing that it was the same incident they now recalled so graphically. One subject said, "It's really strange because I still have the blond girl's face in my mind and it doesn't correspond to her [pointing to the woman on the videotape]...It was really weird." In visual memory, Loftus concluded that hints leaked to us by fellow humans are more important than the scene whose details actually reach our eyes.

Though it got little public attention until the debates about "recovered" memories of sexual abuse in the early and mid 1990s, this avenue of research had begun at least two generations ago. It was 1956 when Solomon Asch published a classic series of experiments in which he and his colleagues showed cards with lines of different lengths to clusters of their students. Two lines were exactly the same size and two were clearly not - the mavericks stuck out like basketball players at a convention for the vertically handicapped. During a typical experimental run, the researchers asked nine volunteers to claim that two badly mismatched lines were actually the same, and that the actual twin was a total misfit. Now came the nefarious part. The researchers ushered a naive student into the room with the collaborators and gave him the impression that the crowd already there knew just as little as he did about what was going on. Then a white-coated psychologist passed the cards around. One by one he asked the pre-drilled shills to announce out loud which lines were alike. Each dutifully declared that two terribly unlike lines were perfect twins. By the time the scientist prodded the unsuspecting newcomer to pronounce judgement, he usually went along with the bogus acclamation of the crowd. Asch ran the experiment over and over again. When he quizzed his victims of peer pressure, it turned out that many had done far more than simply go along to get along. They had actually shaped their perceptions to agree, not with the reality in front of them, but with the consensus of the multitude.

To polish off the mass delusion, many of those whose perception had NOT been skewed became collaborators in the praise of the emperor's new clothes. Some did it out of self-doubt. They were convinced that the facts their eyes reported were wrong, the herd was right, and that an optical illusion had tricked them into seeing things. Still others realized with total clarity which lines were duplicates, but lacked the nerve to utter an unpopular opinion. Conformity enforcers had rearranged everything from visual processing to open speech, and had revealed a mechanism which can wrap and seal a crowd into a false belief. Another experiment

indicates just how deeply social suggestion can penetrate the neural mesh through which we think we see hard-and-solid facts. Students with normal color vision were shown blue slides. But one stooge in the room declared the slides were green. Only 32% of the students ended up going along with the vocal but misguided proponent of green vision. Later, however, the subjects were taken aside, shown blue-green slides and asked to rate them for blueness or greenness. Even the students who had refused to see green where there was none in the original experiment showed that the insistent greenies in the room had colored their perceptions. They rated the new slides more green than they would have otherwise. More to the point, when asked to describe the color of the afterimage they saw, the subjects often reported it was red-purple - the hue of an afterimage left by the color green. The words of one determined speaker had penetrated the most intimate sanctums of the eye and brain.

But this is just the iceberg's tip. Social experience literally shapes cerebral morphology. It guides the wiring of the brain through the most intensely formative years of human life, determining, among other things, which of the thinking organ's sections will be enlarged, and which will shrink.

An infant's brain is sculpted by the culture into which the child is born. Six-month olds can distinguish or produce every sound in virtually every human language. But within a mere four months, nearly two thirds of this capacity has been sliced away. The slashing of ability is accompanied by ruthless alterations in cerebral tissue. Brain cells are measured against the requirements of the physical and interpersonal environment. The 50% of neurons found useful thrive. The 50% which remain unexercised are literally forced to die. Thus thefloor plan underlying the mind is crafted on-site to fit an existing framework of community.

When barely out of the womb, babies are already riveted on a major source of social cues. Newborns to four-month-olds would rather look at faces than at almost anything else. Rensselaer Polytechnic's Linnda Caporael points out what she calls "microcoordination", in which a baby imitates its mother's facial expression, and the mother, in turn, imitates the baby's. Since psychologist Paul Ekman, as we'll see later in more detail, has demonstrated that the faces we make recast our moods, the baby is learning how to yoke its emotions to those of a social team. Emotions, as we've already seen, craft our vision of reality. There are other signs that babies synchronize their feelings to those of others around them at an astonishingly early age. Empathy - one of those things which bind us together intimately - comes to us early. Children less than a year old who see another child hurt show all the signs of undergoing the same pain.

> After all, what is reality anyway? Nothin' but a collective hunch.

Lily Tomlin

Cramming themselves further into a common perceptual mold, animal and human infants entrain themselves to see what others see. A four-month old human will swivel to look at an object his parent is staring at. A baby chimp will do the same. By their first birthday, infants have extended their input-gathering to their peers. When they notice that another child's eyes have fixated on an object, they swivel around to focus on that thing themselves. If they don't see what's so interesting, they look back to check the direction of the other child's gaze and make sure they've got it right. When one of the babies points to an item that has caught her fancy, other children look to see just what it is. One year olds

show other ways in which they soak up social pressure. Put a cup and something unfamiliar in front of them and their natural tendency will be to check out the novel object. But repeat the word "cup" and the infant will dutifully rivet its gaze on the drinking vessel. Children go along with the herd even in their tastes in food. when researchers put two-to-five-year olds at a table for several days with other kids who loved the edibles they loathed, the children with the dislike did a 180 degree turn and became zestful eaters of the item they'd formerly disdained. The preference was still going strong weeks after the peer pressure had stopped.

At six, children are obsessed with being accepted by the group and become incredibly sensitive to violations of group norms . They've been gripped by yet another conformity enforcer which structures their perceptions to coincide with those around them.

Even rhythm draws humans together in the subtlest of ways. William Condon of Pennsylvania's Western State Psychiatric Institute analyzed films of adult conversations and noticed a peculiar process at work. Unconsciously, the conversationalists began to coordinate their finger movements, eye blinks and nods. Electroencephalography showed something even more astonishing - their brain waves were moving together. Newborn babies already show this synchrony - in fact, an American infant still fresh from the womb will just as happily match its body movements to the speech of someone speaking Chinese as to someone speaking English. As time proceeds, these unnoticed synchronies draw larger and larger groups together. A student working under the direction of anthropologist Edward T. Hall hid in an abandoned car and filmed children romping in a school playground at lunch hour. Screaming, laughing, running and jumping, each seemed superficially to be doing his or her own thing. But careful analysis revealed that the group was moving to a unified rhythm. One little girl, far more active than the rest, covered the entire schoolyard in her play. Hall and his student realized that without knowing it, she was "the director" and "the orchestrator." Eventually, the researchers found a tune that fit the silent cadence. When they played it and rolled the film, it looked exactly as if each kid were dancing to the melody. But there had been no music playing in the schoolyard. Said Hall, "Without knowing it, they were all moving to a beat they generated themselves." William Condon was led to conclude that it doesn't make sense to view humans as "isolated entities." And Edward Hall took this inference a step further: "an unconscious undercurrent of synchronized movement tied the group together" into what he called a "shared organizational form."

No wonder input from the herd so strongly colors the ways in which we see our world. Students at MIT were given a bio of a guest lecturer. One group's background sheet described the speaker as cold, the other group's handout praised him for his warmth. Both groups sat together as they watched the lecturer give his presentation. But those who'd read the bio saying he was cold treated him as distant and aloof. Those who'd been tipped off that he was warm, rated him as friendly and approachable. In judging a fellow human being, students replaced external fact with input they'd been given socially.

The cues rerouting herd perception come in many forms. Sociologists Janet Lynne Enke and Donna Eder discovered that in gossip, one person opens with a negative comment on someone outside the group. How the rest of the gang goes on the issue depends entirely on the second opinion expressed. If the second prattler agrees that the outsider is disgusting, virtually everyone will chime in with a sound-alike opinion. If, on the other hand, the second commentator objects that the outsider has positive qualities, the group is far less likely to descend like a flock of harpies tearing the stranger's reputation limb from limb.

Crowds of silent voices whisper in our ears, transforming the nature of what we see and hear. The strangest come from choruses of the dead - cultural predecessors whose legacy has a dramatic effect on our vision of reality. Take the impact of gender stereotypes - notions developed over hundreds of generations, contributed to, embellished and passed on by literally billions of people during the long human march through time. In one study , parents were asked to give their impression of their brand new babies. Infant boys and girls are completely indistinguishable aside from the buds of reproductive equipment between their legs. Their size, texture, and the way in which newborns of opposite sex act are the same. Yet parents consistently described girls as softer, smaller and less attentive than boys. The crowds within us resculpt our gender verdicts over and over again. Two groups of experimental subjects were asked to grade the same paper. One was told the author was John McKay. The other was told the paper's writer was Joan McKay. Even female students evaluating the paper gave it higher marks if they thought was from a male.

The ultimate repository of herd influence is language - a device that not only condenses the influence of those with whom we share a common vocabulary, but sums up the perceptual approach of swarms who have passed on. Every word we use carries within it the experience of generation after generation of men, families, tribes, and nations, including their insights, value judgements, ignorance, and spiritual beliefs. Experiments

show that people from all cultures can see subtle differences between colors placed next to each other. But only those societies equipped with names for numerous shades can spot the difference when the two swatches of color are apart. At the turn of the century, The Chukchee had very few terms for visual hues. If you asked them to sort colored yarns, they did a poor job of it. But they had over 24 terms for patterns of reindeer hide, and could classify reindeer far better than the average European scientist, whose vocabulary didn't supply him with appropriate tools.

Physiologist/ornithologist Jared Diamond , in New Guinea, saw to his dismay that despite all his university studies of nature, the natives were far better at distinguishing bird species than he was. Diamond had a set of scientific criteria taught in the zoology classes back home. The natives possessed something better: names for each animal variety, and a set of associations describing characteristics Diamond had never been taught to differentiate - everything from a bird's peculiarities of deportment to its taste when grilled over a flame. Diamond had binoculars and state-of-the-art taxonomy. But the New Guineans laughed at his incompetence. They were equipped with a vocabulary each word of which compacted the experience of armies of bird-hunting ancestors.

Rensselaer Polytechnic Institute's Linnda Caporael points out that even when we see someone perform an action in an unusual way, we rapidly forget the unaccustomed subtleties and reshape our recalled vision so that it corresponds to the patterns dictated by language-borne conventionality. A perfect example comes from 19th century America, where sibling rivalry was present in fact, but according to theory didn't exist. The experts were blind to its presence, as shown by its utter absence from family manuals. In the expert and popular view, all that existed between brothers and sisters was love. But letters from middle class girls exposed unacknowledged cattiness and jealousy. Sibling rivalry

didn't begin to creep from the darkness of perceptual invisibility until 1893, when future Columbia University professor of political and social ethics Felix Adler hinted at the nameless notion in his manual for the Moral Instruction of Children. During the 1920s, the concept of jealousy between boys and girls finally shouldered its way robustly into the repertoire of conscious concepts, appearing in two widely quoted government publications and becoming the focus of a 1926 Child Study Association of America crusade. It was only at this point that experts finally coined the term "sibling rivalry." The formerly non-existent demon was blamed for adult misery, failing marriages, crime, homosexuality, and God knows what all else. By the 1940s, nearly every child-raising guide had extensive sections on this ex-nonentity. Parents writing to major magazines spotted the previously unseeable emotion almost everywhere.

The stored experience language carries can tweak the difference between life and death. It's been reported that one unnamed tribe used to lose starving mothers, fathers and children by the droves each time famine struck, despite the fact that a river flowed near them filled with fish. The problem: they didn't define fish as food. We could easily suffer the same fate if stranded in their wilderness, simply because our culture tells us that a rich source of nutrients is inedible too - insects.

The influence of the mob of those who've gone before and those who stand around us now can be mind-boggling. During the middle ages when universities first arose, a local barber/surgeon was called into the lecture chamber year after year to dissect a corpse for medical students gathered from the width and breadth of Europe. A scholar on a raised platform discoursed about the revelations unfolding before the students' eyes. The learned doctor would invariably describe a network of cranial blood vessels that were nowhere to be found. He'd report a shape for the liver radically different from the form of the organ sliding around on the surgeon's blood-stained hands. He'd verbally portray jaw joints which had no relation to those being displayed on the trestle below him. But he never changed his narrative to fit the actualities. Nor did the students or the surgeon ever stop to correct the book-steeped authority. Why? The scholar was reciting the "facts" as found in volumes over 1,000 years old - the works of the Roman master Galen, founder of "modern" medicine.

Alas, Galen had drawn his conclusions, not from dissecting humans, but from probing the bodies of pigs and monkeys. Pigs and monkeys do have the strange features Galen described. Humans, however, do not. But that didn't stop the medieval professors from seeing what wasn't there. For no more were they ruggedly individualistic observers than are you and I. Their sensory pathways echoed with voices gathered for a millennium, the murmurings of a mob composed of both the living and the dead. The world experts of those days and ours conjured up assemblies of mirage. Like ours, their perceptual faculties were unrecognized extensions of a collective brain.

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