
Creative Nets in the Precambrian Age
Howard Bloom 20.03.1997

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 (1)

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.

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.

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.

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. 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 (2)

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.

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.

LINKS

(1) http://www.comet.chv.va.us/quill/
(2) http://star.tau.ac.il/~eshel/

Telepolis Artikel-URL: http://www.heise.de/tp/r4/artikel/2/2114/1.html

----
Networking in Paleontology's "Dark Ages"
Howard Bloom 22.04.1997

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 previous episode (1), 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.

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.

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.

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.

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 previous article (2) 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...."

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.

SUBTEXTE (**)

bundles of information

Shannon equates information with the number of choices a sender can transmit to a receiver. Virtually every form of energy or matter is either a sender, a receiver, or both. The sensitivity of a receiver to such basic alternatives as those embodied in electron shells is enormous. Consider the contrasting responses of oxygen atoms to atoms of iron or hydrogen. One union creates water, the other rust. Clearly the interpretation of each transmission is radically different, embodying the measure of information Shannon characterizes as entropy or H.

primitive cells

Some exponents of the "RNA world" model speculate that the first cells were constructed by ribonucleic acid. Though this remains a possibility, 1995 experiments by a team under the direction of molecular biologist Charles Wilson indicate that RNA alone, in Wilson's words, was not sufficiently "competent" to pull off such a feat. (See Nature, Vol. 374, 4/27/95, Wilson et al.)

Cyclic AMP's

Prokaryotic bacteria also use cyclic AMP as a second messenger. But within eukaryotes, its job is taken to new levels. The manner in which eukaryotic protozoans employ another interior messenger, the calcium ion CA2+, illustrates how intricate are the tasks for which eukaryotic data carriers are used. CA2+ helps regulate the rhythmic rowing of cilia, plays a part in building internal envelopes to suck in food and expel wastes, and is vital to cell division.

spirochetic microtubules

The spirochetic legacy would prove vital to the elaboration of nervous system components, eventually contributing to neurons, balance sensors, and the rods and cones of eyes.

LINKS

(1) http://www.heise.de/tp/r4/artikel/2/2115/1.html
(2) http://www.heise.de/tp/r4/artikel/2/2115/1.html

Telepolis Artikel-URL: http://www.heise.de/tp/r4/artikel/2/2127/1.html

----
The Embryonic Meme
Howard Bloom 22.05.1997

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-non-conformists 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, multi-cellular animals have begun their advance toward the creation of a whole new kind of global intellect.

Telepolis Artikel-URL: http://www.heise.de/tp/r4/artikel/2/2143/1.html

----
From Social Synapses to Social Ganglions: Complex Adaptive Systems in the Jurassic Age
Howard Bloom 02.08.1997

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.

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 roost-mates 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 hunt-mates 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.

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. Conformity enforcers impose enough similarity on group members to give the social structure coherence, relative permanence, and the ability to carry out large-scale, integrated, multi-participant projects. In humans, conformity enforcers lead, among other things, to a collective perception, a socially-constructed view of reality which influences both childhood brain development and adult sensory processing, and which produces a weltanschauung displaying many of the characteristics of a shared hallucination.

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.

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.

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."

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.

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:

Bacillus colonies utilize the most basic conformity enforcer - the genome, which restricts the range of forms and of operating methods among the colony's individuals. The resulting semi-uniformity makes it possible for every member of the community to "understand" a common collection of "languages."

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.

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.

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.

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?

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.

Telepolis Artikel-URL: http://www.heise.de/tp/r4/artikel/2/2162/1.html

----

Mammals and the Further Rise of Mind
Howard Bloom 17.09.1997

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.

I. Biology, Evolution, and the Global Brain (1) II. Creative Nets in the Precambrian Age (2) III. Networking in Paleontology's "Dark Ages" (3) IV. The Embryonic Meme (4) V. From Social

Synapses to Social Ganglions: Complex Adaptive Systems in the Jurassic Age (5) VI. Mammals and the Rise of Mind (6) VII. Tools of Perception - The Construction of Reality (7) VIII. Reality is a shared Hallucination (8)

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.

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 Lego-linkage 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.

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.

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."

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.

SUBTEXTE (**)

210 million years

Prof. Burt Kotler, an expert on rodents at Ben-Gurion University's Blaustein Institute for Desert Research at Sde Boker, Israel. Quoted in Judy Siegel-Itzkovich. "The why behind the whiskers." Jerusalem Post, 10-06-1996: 5.

article

John F. Eisenberg. "Parental Behavior." In David McFarland, ed. The Oxford Companion to Animal Behavior. New York, Oxford University Press, 1982: 443-447.

insect eating mammals

Peter J. Bryant. "The Age of Mammals (Cenozoic): 65-0 m.Y.B.P."; Irvine, CA: School of Biological Sciences, University of California at Irvine, 1996. Downloaded 5/31/97 from http://mamba.bio.uci.edu/%7Epjbryant/bio65/lec02/b65lec02.htm.

Mammals

Kathleen Hunt. "Transitional Vertebrate Fossils." 1997. Downloaded 5/31/97 from http://www.talkorigins.org.

slavish timidity

David Sloan Wilson. "Reply to Joseph Soltis, Robert Boyd, and Peter J. Richerson: Can Group Functional Behaviors Evolve by Cultural Group Selection? An Empirical Test." Current Anthropology, June 1995: 489, pp. 473-494.

Squirrels

Richard G. Coss and Donald H. Owings. "Rattler Battlers." Natural History, 5/89: 31-32.

primates

Stuart A. Altmann. "The Structure of Primate Social Communication." In Social Communication

Among Primates, edited by Stuart A. Altmann: 346. Chicago: The University of Chicago Press, 1967.

K. Ronald Hall

I cannot overstress the importance of the work of K. Ronald Hall to the observation primate social networks in the wild. His careful notes and highly original insights poured forth in the '50s and early '60s, when social interaction was by no means a major focus of ethologists.

imitation

K.R.L. Hall. "Social Learning In Primates." In Primates: Studies in Adaptation and Variability, edited by Phyllis C. Jay. New York: Holt, Rinehart and Winston, 1968: 383-397.

Shirley Strum

Shirley C. Strum. Almost Human: A Journey into the World of Baboons. New York: Random House, 1987: 132

K.R.L. Hall

K.R.L. Hall. "Experiment and Quantification in the Study of Baboon Behavior in its Natural Habitat." In Primates: Studies in Adaptation and Variability, edited by Phyllis C. Jay. New York: Holt, Rinehart and Winston, 1968: 120-130.

most widely distributed

K.R.L. Hall. "Experiment and Quantification in the Study of Baboon Behavior in its Natural Habitat." In Primates: Studies in Adaptation and Variability, edited by Phyllis C. Jay. New York: Holt, Rinehart and Winston, 1968: 120.

social organization

K.R.L. Hall. "Social Organization of the Old-World Monkeys and Apes." In Primates: Studies in Adaptation and Variability, edited by Phyllis C. Jay. New York: Holt, Rinehart and Winston, 1968: 30.

heightened craving

David McFarland, ed. The Oxford Companion to Animal Behavior. New York, Oxford University Press, 1982: 251.

Hall

K.R.L. Hall. "Tool-Using Performances as Indicators of Behavioral Adaptability." In Primates: Studies in Adaptation and Variability, edited by Phyllis C. Jay. New York: Holt, Rinehart and Winston, 1968: 143.

baboons

Stolba, A. 1979. Entscheidungsfindung in Verbänden von Papio hamadryas, Ph.D. Dissertation, Universität Zürich, Zurich; Kummer, H. 1992. Weise Affen am Roten Meer: Das soziale Leben der Wüstenpaviane, Munich, Germany; Piper; summarized in Jan A.R.A.M. van Hooff, "Understanding Chimpanzee Understanding," in Chimpanzee Cultures, ed. Richard W. Wrangham, W.C. McGrew, Frans B.M. de Waal, and Paul G. Heltne with assistance from Linda A. Marquardt. Cambridge, MA: Harvard University Press, 1994: 279, 267-284.

Christopher Boehm

Christopher Boehm. "Four Mechanical Routes To Altruism." March, 1996, unpublished manuscript: 23. Hans Kummer. Primate Societies: Group Techniques of Ecological Adaptation. Chicago: Aldine Press, 1971; Christopher Boehm. "Rational Preselection from Hamadryas to Homo sapiens: The Place of Decisions in Adaptive Process." American Anthropologist, June 1978: 265-296.

Pumphouse gang

Shirley C. Strum. Almost Human: A Journey Into The World of Baboons. New York: Random House, 1987: 203-259.

Hall

K.R.L. Hall. "Experiment and Quantification in the Study of Baboon Behavior in its Natural Habitat." In Primates: Studies in Adaptation and Variability, edited by Phyllis C. Jay. New York: Holt, Rinehart and Winston, 1968:122

Elephants

I. Douglas-Hamilton and O. Douglas-Hamilton. Among the Elephants. New York: Viking Press, 1975; summarized in John Tyler Bonner. The Evolution of Culture in Animals. Princeton, NJ: Princeton University Press, 1983: 177.

Robin Dunbar

Robin Dunbar. Grooming, Gossip and the Evolution of Language. Boston: Faber and Faber, 1996: 65.

Robert Seyfarth and Dorothy Cheney

Dorothy L. Cheney, Robert M. Seyfarth. "The representation of social relations by monkeys." Cognition, 37 (1990): 167-196. Dorothy L. Cheney and Robert M. Seyfarth. How Monkeys See The World: Inside the Mind of Another Species. Chicago: University of Chicago Press, 1992. Dorothy L. Cheney, Robert M. Seyfarth. "The Evolution of Social Cognition in Primates." In Behavioral Mechanisms in Evolutionary Ecology, edited by Leslie A. Real. Chicago: University of Chicago Press, 1994: 371-389. Robert M. Seyfarth and Dorothy L. Cheney. "Some general features of vocal development in nonhuman primates." In Social Influences on Vocal Development, edited by Charles T. Snowdon & Martine Hausberger. Cambridge: Cambridge University Press, 1996: 249-273.

LINKS

(1) http://www.heise.de/tp/r4/artikel/2/2102/1.html
(2) http://www.heise.de/tp/r4/artikel/2/2114/1.html
(3) http://www.heise.de/tp/r4/artikel/2/2127/1.html
(4) http://www.heise.de/tp/r4/artikel/2/2143/1.html
(5) http://www.heise.de/tp/r4/artikel/2/2162/1.html
(6) http://www.heise.de/tp/r4/artikel/2/2192/1.html
(7) http://www.heise.de/tp/r4/artikel/2/2073/1.html
(8) http://www.heise.de/tp/r4/artikel/2/2227/1.html

Telepolis Artikel-URL: http://www.heise.de/tp/r4/artikel/2/2192/1.html