The Embryonic Meme

By Howard Bloom.

History of the Global Brain Part IV

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Numbers are critical to the execution of this process.

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

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

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

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

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

Published on 1997-05-22 00:00:00 in Telepolis
http://www.heise.de/tp/artikel/2/2143/1.html.