DECIPHERMENT
OF
LINEAR X

Edited by

BRIAN CONLEY

PIEROGI

–

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Dedicated to Karleton Fyfe

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Figure 1. Linear B Tablet (As 1516)

Decipherment of Linear X

Brian Conley

> It is useless to go no further than the skin or bark of plants if you wish to know their nature; you must go straight to their marks…the face of the world is covered with blazons, with characters, with ciphers and obscure words—with "hieroglyphics," as Turner called them. And the space inhabited by immediate resemblances becomes like a vast open book; it bristles with written signs; every page is seen to be filled with strange figures that intertwine and in some places repeat themselves. All that remains is to decipher them.
>
> —Michel Foucault, "The Prose of the World," *The Order of Things*

This project began by looking at a stick. Several years ago, on a rainy afternoon in upstate New York, I came across an ordinary stick partially buried in muddy ground (figure 3). I noticed that, beneath the bark, the wood was covered with elaborate incisions (figure 34). These carvings had a striking calligraphic quality, and were organized in diverse variants of an "X" formation. They appeared to be intentional, beautifully and elaborately designed, with systematic, repeating marks that were visually related—like the script of a language. This was observable despite the fact that anyone familiar with the local forest and its inhabitants would have recognized the traces of common beetles, who burrow beneath tree-bark and carve these marks.

Every literate person has, at some point, looked at unfamiliar script and identified the represented language, however unusual and distant it may be from his or her own. I can distinguish written Thai and Chinese, though I can't read a word of either, and I can do this no matter how the characters are deployed across the page or whatever other surface they happen to occupy. There is a visual gestalt for written language and, in their apparent systemization and intentionality, the incisions on these sticks display it. Accordingly, when I first dug up my rune-like branch, I guessed that it might be a Native American artifact. Even after realizing that I was looking at the residue of insect inhabitation, I decided to pursue deliberately the association of that first response. Treating the proximal location as an archaeological dig, I staked out a set of markers (figure 4), and then laid out a grid, numbering each quadrant, developing a tagging and archiving system, and photographing everything. I eventually found many dozens of similarly carved branches, including a full standing tree covered from top to bottom.

The more I looked, the more I was impressed by the linguistic gestalt of the beetle tracks. Even more provocative was the fact that they actually appeared similar to one of the earliest written languages, Linear B, in use in Crete and mainland Greece between 1600 and 1100 B.C. I found myself making surprisingly precise one-to-one comparisons between

Linear B syllabaries and my stick (plate 13: Linear B, left; Linear X, right). At the same time, I remembered the story of Michael Ventris and his decipherment of Linear B in 1953. Ventris, an autodidact with an adventurous and generous intellectual spirit, was able to crack the code of this unknown ancient system when the world's best academic linguists had failed. In this, Ventris was in unusual company. As Maurice Pope remarks in *The Story of Decipherment*, the three most important decipherments in history—including the translation of Egyptian hieroglyphics by Jean-Francois Champollion in 1823, and the pivotal insight into the system of Mayan glyphs by Yuri Valentinovich Knorosov, in 1952—were made not by scholars in the chairs of important departments at great universities, but by individuals who, through wit and creativity, avoided ingrained presuppositions to make leaps that lead to workable translations. Champollion presented his first paper on Egyptian etymologies at age seventeen, and Knorosov was a young artilleryman stationed in Berlin when he snatched at random a single book from the burning National Library—a summary of then-available scholarship on the enigmatic Mayan codices.

Linear B

Sir Arthur Evans, the British archaeologist, found the first set of Linear B tablets in 1900, during his excavation of the ancient city of Knossos on the island of Crete. Evans spent his last 40 years trying to decipher the language on these tablets, hoarding the majority of them and making them generally unavailable to other scholars. In the end he was unable to make the decipherment. But in 1936 at Burlington House in London, the home of the Royal Academy of Arts, the 85 year-old Evans organized a small exhibition of Greek and Minoan art. Giving an impromptu tour of the exhibition to a group of schoolboys—including the 14 year-old Michael Ventris (figure 22)—Evans directed the boys to the Linear B tablets (figure 1) and mentioned that neither he nor anyone else could read them. From that day until the end of Ventris' brief life, he worked on the problem and eventually he deciphered Linear B. Ventris, however, never became a trained linguist; his profession was architecture. Linear B was a personal interest and he brought unusual methodologies to its decipherment. In contrast to Evans, Ventris established communication with other scholars working on Linear B, like Emmett Bennett and Alice Kober, and sharing with them a progressive set of diagrams that he called "work notes" (figure 2). These notes graphically summarized the accumulated ideas of the group, and worked out sign relationships among the characters of Linear B. The "work notes" now constitute a record of many of the conceptual steps, leaps and guesses by which the decipherment was made.

Linear X

In the spirit of these historical decipherments, I decided to hold in suspension what I know to be obvious—that the marks on the sticks I unearthed are made by insects and insects can't write. I have chosen instead to consider, as a thought-experiment, the possibility that the marks are intentional and constitute the written language of Linear X. The present goal is not to "decipher" Linear X. At this stage, I am trying to do for the bark beetles notation what the Danish surveyor and traveler Carsten Niebuhr did for cuneiform in 1772; that is, to document and present the marks of the script for observation. Niebuhr's drawings of the three types of cuneiform discovered at Persepolis laid the foundation for their decipherment by German high-school teacher Georg Grotefend, English army officer Henry Rawlinson, and scholar Edward Hincks between 1846 and 1857. Similar to Niebuhr, I am producing photographs and clay tablets as documents of the marks of Linear X. With

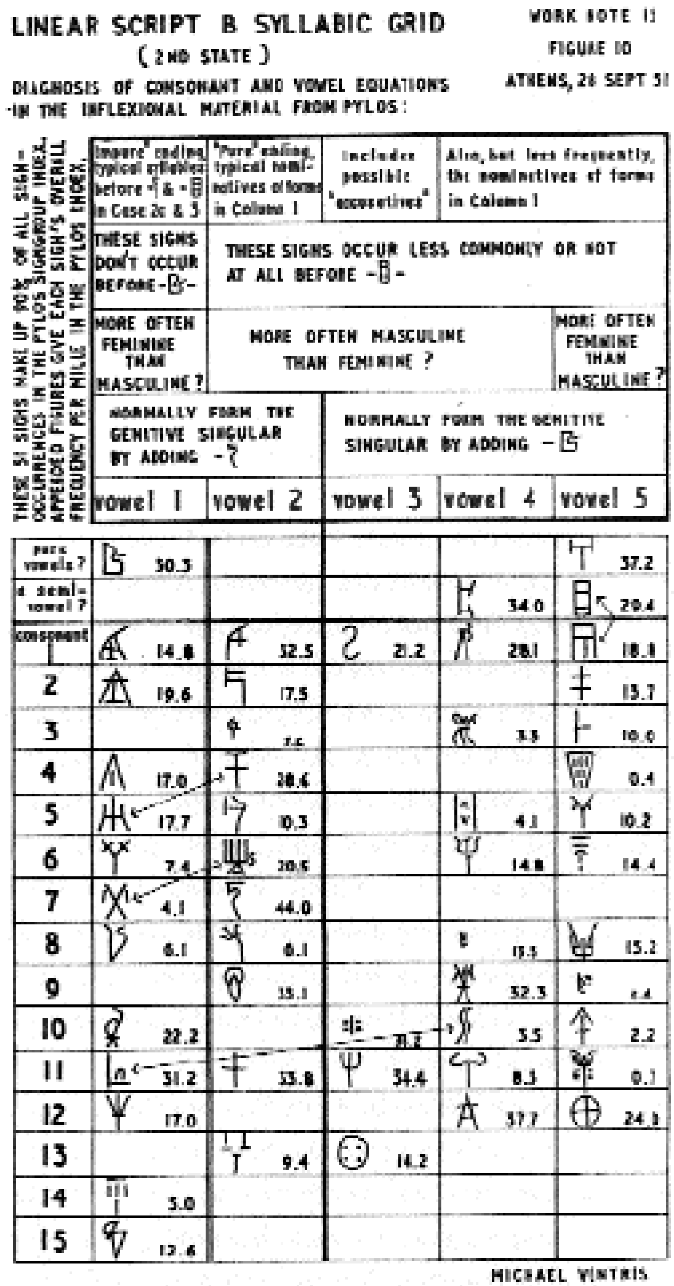

Figure 2. Michael Ventris: Linear Script B Sylliabic Grid

this journal I am attempting to open questions typically foreclosed in scientific and intellectual orthodoxies. Experts in linguistics, archeology, philosophy of consciousness, animal intelligence, artificial intelligence, and cryptology make many assumptions regarding the mutually exclusive relationship between language-use and animality. This journal and the accompanying exhibition attempt to set such assumptions on their edge, to approach problems of consciousness, communication, and animality from epistemologically diverse locations and divergent methodologies, and thereby generate a conversation that will, I hope, stimulate future events, discussions, and productions both artistic and theoretical. *Decipherment of Linear X* asks: How far down the evolutionary scale can we go and still find consciousness or intelligence? What can that consciousness do? How might it communicate? And what are the costs—philosophical, ethical, practical, and political—of ignoring the possibility that such consciousness exists?

The project consists of two parts, exemplary objects and speculative texts. In 2004, having gathered a large group of similarly marked sticks from the same rural location, I enlisted the help of two university ceramics departments to roll individual branches onto wet clay—much like Sumerian cylinder seals bearing cuneiform—in order to produce clear views of the character and distribution of the inscriptions around the circumference of each one. The resulting ceramic tablets (plate 15), along with the inscribed tree-trunk, and a series of photographs made on-site outdoors to document individual marks (plates 1-12, 14 and 16), constitute the exhibition. In place of an accompanying catalogue, the present volume invites contributors from a number of fields to consider, in light of the concerns and presuppositions particular to their various specialties, the questions posed by a hypothetical Linear X. These include a roboticist whose focus is the origins of intelligence; a science writer who examines pre-linguistic Ice-Age notational systems; an expert in animal behavior and communication; and Charles Darwin himself, represented by an essay in which he theorizes that the tip of a plant's root acts like an animal brain. Perspectives from beyond the scientific community are offered by an historian who analyzes the convergence of cryptographic practice with cultural politics, by another historian who considers the persistent trope of *Natura Pictrix* or "Nature the Artist," and by writers—including a translator of ancient Greek, and the great fabulist Jorge Luis Borges—who discuss the mythological origins of language and the points at which symbol-systems and aesthetic interpretations intertwine.

Language

> It is easy to imagine a language consisting only of orders and reports of battle. Or a language consisting only of questions and expressions for answering yes or no. And innumerable others. And to imagine a language means to imagine a form of life.
>
> —Wittgenstein, *Philosophical Investigations*

Linguistics traditionally grants primacy to spoken language. Convention and common sense proclaim the spoken word to be the original medium of human communication, while writing is seen as an awkwardly evolved and manufactured afterthought. The case is perhaps based on the undeniable fact that babies speak before they write. On the other hand, the historical record consists for the most part of written documents—clay tablets, papyrus, stone engravings, etc. Archaeology thus presents the contemporary theoretician with inscriptions and marks, i.e. writing, as the foundation of our knowledge about language.

Writing did not have a birth, and there is much evidence to suggest it did not "emerge," in the technical, evolutionary sense of the term, by which properties or traits are thought to burst unaccountably into existence when key elements combine. Writing instead underwent a gradual development over a vast period of time, and pre-linguistic precedents are identifiable in diverse eras and cultures. Abstract geometric marks on stone, dating from the Ice-Age, or 35-10,000 B.C., have been interpreted by Alexander Marshack as notation devices and in one case, a lunar calendar. In this journal he addresses abstract meandering lines, "macaroni," carved in stone during the same period. Hand formed clay "tokens," used for counting, date back to 8,000 B.C. and have been discovered throughout the Middle East. These geometries, meanders, and tokens are not language; nothing corresponding to sentences can be written with them. But they are human marks intentionally made to serve a nonpictorial, representational, and communicative purpose, and with them in mind it becomes appropriate to see written language evolving over time. The later development of full-fledged written language has been identified in several different locations and in different eras. Cuneiform from Mesopotamia in contemporary Pakistan and Iraq dates from 3,100 B.C., while Egyptian hieroglyphics came into use around the same period. An undeciphered script from the Indus Valley dates from 2500 B.C. The related syllabaries of Linear A and B were active from approximately 1600 to 1100 B.C. in the Minoan culture of Crete and the later Mycenaean culture of mainland Greece. Alphabetic script was finally established in Palestine circa 1700 B.C. Ideographic language, meanwhile, surfaced in China around 1200 B.C., although related clay shards bearing proto-linguistic markings go back as far as 4800 B.C.

These earliest written languages were invented to keep accounts, or at least that was one of their primary purposes. Many of the oldest Linear B tablets, for example, record agricultural transactions. In other words, the original purpose of documentation was to maintain power and control in the material dimension of life. Order and accuracy were, one assumes, the aims of such notation. But writing and record keeping can aid deception equally well as memory; if no one else can make a record, then records kept by the king or the king's accountant trump all other recollections. To mention a later example of this dual quality of language, many of Plato's dialogues concern the Sophists' use of language to distort and even falsify the truth. One way to look at the Socratic method, which became a cornerstone of Western thinking, is as a technique to enable one to see through the falsehoods of sophistic arguments.

Administrative management may have been the first, but it was, of course, not the only motivation for producing written language. There were also myths, laws, and religious dogma to be preserved, and even personal stories to be told. In cuneiform there is the well-known *Epic of Gilgamesh*, and the Hammurabi Code of the King of Babylon, as well as a reminiscence from around 2000 B.C. by a teacher about his days in scribal school. Chinese writing more or less simultaneously developed past the basic concerns of record keeping to preserve epics of hunting and warfare, weather predictions, prophesies, dreams, and communion with spirits. A few tablets of Linear A and B also make reference to something other than recordkeeping. Excavating the palace at Knossos in 1900, Sir Arthur Evans found an unusual tablet with a reference in the script that he later designated as Linear A, to the goddess Potnia Theron "Mistress of Wild Animals" and "Queen of the Wild Bees." At the same site, Evans found a small sculpture of a woman in Minoan dress, breasts bared, with a cat on her head and snakes in each of her upraised hands (see cover). This figure is believed to be Potnia Theron, a precursor to the Greek goddess Artemis. Other images of Potnia depict her suckling a griffin, or with her body composed of bees. These images open up a window on Minoan culture, telling us much more than most of the excavated tablets in that they point not only to religious ideas and the relation of humans to the culture's deities but also to the relationship of humans to animals. These images and artifacts become important in the decipherment of the language that describes them because, following Wittgenstein, to decipher a language, one must decipher a form of life.

Animality

> I know that animals do many things better than we do, but this does not surprise me. It can even be used to prove they act naturally and mechanically, like a clock which tells the time better than our judgment does. Doubtless when the swallows come in spring, they operate like clocks. The actions of honeybees are of the same nature, and the discipline of cranes in flight, and of apes in fighting, if it is true that they keep discipline. Their instinct to bury their dead is no stranger than that of dogs and cats who scratch the earth for the purposes of burying their excrement; they hardly ever actually bury it, which shows that they act only by instinct and without thinking.
>
> —René Descartes, letter to the Marquess of Newcastle

Judeo-Christian dogma upholds the clear division: we are made in the likeness of God, distinguished by consciousness and language, and granted dominion over other life-forms. The theory of evolution obviously complicates this vision—if humans evolved from animals, how are we made in the image of God?—and Christians, including Darwin, have had to do some fancy footwork to compensate.

One solution is the theory of emergence, by which properties or traits are thought to pop unaccountably into existence when certain elements combine. The emergence of mind or consciousness is paradigmatic of the theory. Specific biochemical elements are thought to have combined in specific ways in human beings alone, in order to produce an entirely new entity—consciousness. This new entity, in turn, is absolute. It cannot be reduced to a sum of its constituent elements, and no successive shift in the combination will produce another such entity. Even though an ape's brain chemistry is very similar to a human's, consciousness exists only in the latter. For a Christian accepting evolution, the hand of God is seen here, as proof of intelligent design.

In contrast to emergence theory, however, continuity theory states that there are always precedents for any new property, whether easily observable or not. Nothing pops out of nowhere. Consciousness did not appear at a particular moment in human evolution, but developed continually, and precedents should exist throughout the animal kingdom for this trait, just as there are precedents for human traits like bipedal motion.

This project embraces continuity theory. It asks how far down the evolutionary scale does consciousness exist? What would it look like and who would recognize it?

Quite remarkable examples of animal intelligence can be cited, if one examines not the discrete intelligence of an individual creature but the collective intelligence exhibited in complex cooperative endeavors like hive- and nest-building, migration patterns, or swarming behavior. Such studies look at group response in the absence of a leader, and treat the composite whole as the entity endowed with decision-making ability.

> Consider, for example, the huge raid of the African army ant, *Dorylus (Anomma) nigricans* composed of millions of completely blind workers…how the army ant swarm raids [are] created literally by the blind leading the blind. Imagine trying to organize vast numbers of blind automata so that they can

> unknown and dangerous terrain, fight battles against foes more powerful per capita than themselves, sustain few casualties in their own ranks, retrieve the corpses of their prey, and find their way home efficiently without getting lost. This is not fiction from H.G.Well's *War of the Worlds*. It is what army ants do almost every day of their lives.
>
> —Camazine et al., *Self-Organization in Biological Systems,* p. 257

David K. Lewis is also interested in forms of intelligence expressed in the absence of a unitary decision maker but focusing on humans. Lewis, taking an example from David Hume, asks us to consider two people rowing a boat. The problem is for each person to coordinate his or her movements with those of the other so that the boat stays on a straight course and the destination is arrived at. The goal can be reached in various ways, whether each person rows with equal strength and skill, or whether they row unequally. The end is achieved as long one compensates for the other when necessary. For another example, think of what happens on a busy city sidewalk. Lewis asks how it is that we can navigate an onrushing crowd of anonymous others without saying a word to anyone? There is no leader or conductor, and no explicit guiding principles or rules; the same negotiations take place in Tokyo or Karachi, Dallas or Baghdad. Lewis proposes that hustling urban pedestrians rely on a non-linguistic intelligence enabling an instantaneous reshaping of paths to goals that is immediately communicable to others, so that all are able to reconfigure despite immense differences of culture, attention and temperament. Lewis terms such situations "coordination problems." In the case of humans, non-linguistic communication and group decision-making is considered an application of a special form of human intelligence and consciousness. In the case of animals, considered as clocks or automata, these processes are assumed not to be the result of consciousness, but to be instinct driven. Why is this? If Lewis' idea of coordination problems is paired with a Saussurean view of language—that meaning is only the play of arbitrary difference—and examined in the light of collective intelligence, would this not open a new way of thinking about animal communication systems and language?

Looking Backward

A circularity obtains when humans try to establish whether other creatures have consciousness, intelligence, thoughts, or mind, because human consciousness is the medium by which these determinations are made. When human consciousness sees nothing that it recognizes as itself—the capacity to say *cogito, ergo sum*, for example—then it maintains that consciousness does not exist. This act of unfulfilled projection—looking for images of the human self in nature, and not finding them—is the reverse of the anthropomorphic or "pathetic" fallacy. These are both cases of mirror reflection: gazing into the world and not realizing one is looking into one's own eyes.

> Presumption is our natural and original malady. The most calamitous and fragile of all creatures is man, and at the same time the proudest. He sees and feels himself placed here in the mire and dung of the world, attached and fixed in the worst, most lifeless, and most corrupt part of the universe, on the meanest floor of the house and the farthest removed from the vault of heaven, with animals of the worst condition of the three [of those that fly, swim, and live on the ground]; and he goes installing himself in his imagination that he makes himself God's equal, that he ascribes to himself divine attributes, that he winnows himself and separates himself from the mass of other creatures, determines the share allowed the animals, his colleagues of faculties and powers as seem good to him. How does he know, by the effort of intelligence, what inwardly and secretly moves the animals? By what comparison of them with ourselves does he deduce the stupidity which he attributes to them?
>
> —Michel de Montaigne, *In Defense of Raymond Sebond*

Figure 3. The first stick with Linear X incisions was found in mud.
(Field data, Upstate New York. B. Conley)

Figure 4. Markers locating the initial set of sticks with Linear X incisions.
(Field data, Upstate New York. B. Conley)

Ambrosia Beetles and Genetic Intelligence

Michael Ryan

As the bark is peeled back from the downed tree, it reveals intricate patterns incised into the surface of the wood. The carvings appear almost as a miniature version, a fractal as it were, of the Nazca lines. The latter are engraved in the surface of the pampas south of Lima, Peru. Their scale is so large that their true form, depicting animals and a variety of geometric patterns, can only be comprehended from the sky. How and why they came into existence is a mystery; perhaps they were part of liturgical ceremonies that invoked astronomical powers. Regardless of their origin, however, it is clear that they were created by intelligent beings—that is, humans.

Despite the tree patterns' similarity to the Nazca lines, and even though it seems that these patterns are not random but purposeful, the tree carvings are presumed *not* to have been created by intelligent beings. This is because, unlike the Nazca lines, their origin is not at all disputed: The engravings are relics of the bark beetle's endeavors to reproduce.

There are many species of bark beetles, all of which are in the family *Scolytidae* (Order *Coleoptera*), one of the most successful members of the class *Insecta*.

> They are distributed worldwide and there are many cosmopolitan genera. The bark beetles, in particular, have flourished in the coniferous forests of North America. The most destructive species are the genus *Dendroctonus* (literally "killer of trees") whose hosts include all conifers and most hardwoods. There are almost 24 known species of *Dendroctonus* in the world; 23 of these are found only in North America and one is found in Europe. Of the North American species, 19 are found north of Mexico, the remainder are in Mexico and Central America. (p.23-4, Stark)

Scolytidae (figure 5) are quite small, usually about $1/8^{th}$ of an inch or less, although some species can approach an inch. They are black or brown, and have small heads and inconspicuous mouths furnished with well-developed, powerful mandibles capable of chewing even the hardest wood. (They have wings as well, but flying is not their strong point, as they rarely venture more than a couple of miles from their birthplace.) Bark beetles live and reproduce in the outer layers of trees, creating distinctive, species-specific incised patterns in the phloem and cambium layers, just below the bark for which they are commonly named (Lovenwirth 1999).

The female beetle locates a host tree, bores through the bark, and creates a chamber—a "gallery"—in the cambium layer in which to lay her eggs. But before she can reproduce, of course, the female needs to find a mate. In the dark under the bark, visual signaling would be of little use, and so she resorts to a more dependable sensory modality, odor. Here the tree further aids her labors. As the female digests the wood layer from which she has gouged out the gallery, it passes through her gut and is excreted in a pellet form called frass. The frass is "tilled" together with collected fungal spores which have also been deposited by the female (Evans 1984). The excretion in this "fungal garden" is transformed into edible food for the young. In the scientific literature this is called "ambrosia" (after the food of the Greek and Roman Gods) and this is why these beetles are also known as ambrosia beetles. Their insectoid agriculture is facilitated by specially evolved apparatus:

> For example, the elytral declivity in…*Scolytus* at the posterior is modified somewhat like a specialized bulldozer or shovel. Other modifications include rake-like tibiae, flattened or concave head capsules, and dense hairiness (a mobile broom!) (p.37-8 Stark)

The pellets contain varying levels of aggregation pheromones, chemical signals, that attract male beetles for mating, as well as female beetles for colonization (Coulson 1979, Evans 1984). Although the chemical odor appears of critical importance, there may also be visual and auditory clues.

> The organs which detect pheromones (sensilia) are located on the antennae. There are literally hundreds of sensilia with thousands of receptor pores. Airborne molecules of the pheromones and host odors are collected and transmitted through the central nervous system, and elicit behavioral responses....Spacing of gallery sites on the host tree and the density of attacks by bark beetles are controlled by a weakening or cessation of the attractant pheromone, by release of repellant pheromones, or by stridulation, which is the production of sound by friction. Stridulation is highly developed in *Scolytids*. (p.34 Stark)

> Successful entry to the phloem in the bark-wood interface signals the beginning of the production phase of the life cycle. After attacking bark beetles have penetrated to the phloem layer, they begin construction of the brood gallery. Many species, particularly polygamous ones, excavate a nuptial chamber for mating. Individual egg galleries for each female radiate from this chamber. The nuptial chamber is usually kept free of boring material and frass and may be visited from time to time by the females. (p.35 Stark)

Once mating has occurred, the female oviposits at regular intervals along the length of the gallery. The larvae hatch in a period of one to three weeks, and begin to bore through the phloem at right angles to the gallery chamber (Safrank, 1995, Horn 1976), creating the tell-tale tunnel patterns typical of their species (Lovenwirth 1999). While constructing these passageways, the larvae pass through four developmental stages. They then over-winter in the tree, pupate the next spring, and, when sexually mature, fly to another host tree (Safrank 1995). The cycle continues as long as there are trees to support the expanding population.

Not surprisingly, the beetles' boring, aggregation, mating, and reproduction come at a cost to the tree. When the bark and underlying surfaces are breached, the tree sends a flood of sap to force the invading beetle out and plug the hole. If the tree is weak or the onslaught great, however, the beetles can overwhelm this defensive measure.

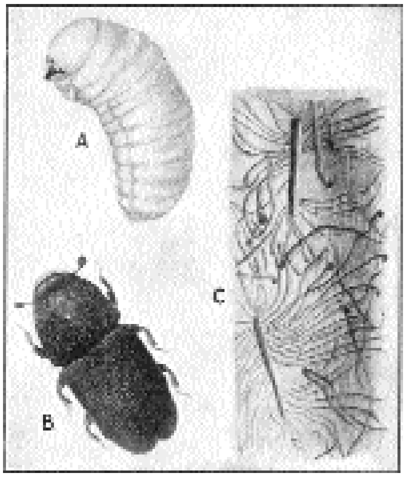

Figure 5. *Scolytidae*. A, larva or grub. B, adult or beetle. C, parent and larval galleries in sapwood of injured twig from which the bark has been removed. (Metcalf and Flint, 1939)

Once the beetles become established, further problems for the tree occur. The "farmed" fungus can clog the tree's water-transport system. Infestation also destroys the tree's cambium layer and leaves it susceptible to disease and even death (Swain 1948). Thus, the more successful the beetles are, the more they harm their future prospects as they destroy the hosts they require for life and sustenance. Nevertheless, this symbiosis has been going on for millions of years, and neither the trees nor the beetles have disappeared. So there appears to be some equilibrium in the system.

> …successfully attacking beetles initiate a complex chain of events leading to colonization of the tree. Once a few beetles have successfully entered the bark of the selected host, aggregation of individuals of both sexes commences. This is a critical phase of the bark beetle life cycle, for the defenses of a living tree, even stressed trees are formidable. Most conifers contain copious quantities of oleoresin with toxic properties and so a large number of beetles are needed to successfully attack a healthy tree. (p.32 Stark)

In fact, because of the duration of their interaction, there is a growing interest in the co-evolution of these beetles and the trees they prey upon:

> The association between bark beetles and their host trees is an ancient one. Although there is a paucity of evidence linking insects and plants during their early evolution in the Paleozoic, fossil evidence shows clearly that both insects and land plants evolved rapidly and simultaneously as soon as the ozone accumulated in the upper atmosphere to levels that substantially reduced the damaging effects of ultraviolet radiation. In the Permian, fossils which can be assigned to the insect order *Coleoptera* appear coincident with the appearance of fossils that characterize the order *Coniferales*, the plant taxon that gave rise to all modern coniferous families. By the Triassic period, which began 280 million years ago, we can find fossils of

> petrified wood showing galleries characteristic of *Scolytid* feeding habits. This ancient coexistence has provided ample opportunity for reciprocal evolution to produce numerous intricate interactions….' (p.350 Sturgeon and Mitton)

So, like the Nazca lines, the beetles' wood engravings are ancient, purposeful, constructed in a particular pattern, and only visible, if not decipherable, at a distance far removed from the position of the architects that constructed them. And, like the mysterious drawings on the pampas, the *Scolytid* marks evince a non-random regularity that at first glance often suggests an origin in some unknown, aboriginal communication system. The patterning's eerie familiarity derives, in part, from the larval tendency to burrow from the galleries at ninety degrees—just as many written languages, including cuneiform and Linear B, display line segments that typically diverge at right angles and do not, of course, do so at random. One would not impart the same kind of intelligence to the beetle and its engravings as one readily does to Linear B or the Nazca lines, only because one requires "intelligence" to be cognitive and attributable to humans alone. But consider this: The bark beetles' mark-making is instinctive behavior, acquired and fine-tuned over millions of years—a genetic intelligence.

Figure 6. Linear X markings. Photo: Fei Jun

Gallery Structure Formation in Conleyborus Scarabaeoides

Luc Steels

Members of the *Scolytidae* species (bark beetles) construct intriguing structures by excavating slender mines or burrows in the bark of trees or between the bark and sap wood (figure 7). Typically (for example for the *Anisandrus dispar*, the European shot-hole borer), the adult bores a hole in a tree during the spring, constructs a maternal chamber, and then digs a characteristic network of galleries of uniform diameter emanating from the chamber. About 40 eggs are laid and larvae feed on xylophagous fungi (*Ambrosia*) introduced by the female on the walls of the galleries (Grégoire, 1988). The gallery structures are definitely not random and neither completely regular. They are not identical for different subspecies of *Scolytidae* and show large variation even within the same subspecies or for the same individual.

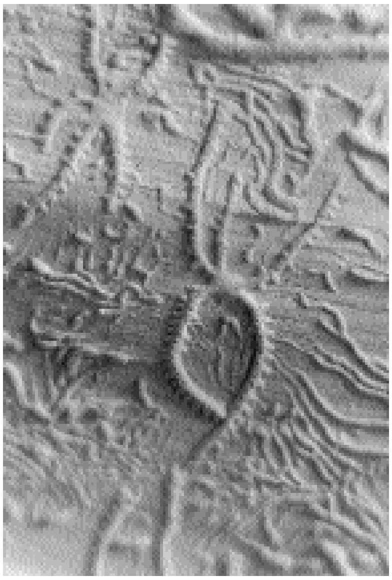

Figure 7. Typical example of markings produced by *Scolytidae* based on the excavation of galleries in tree wood. (Field data, Upstate New York. B. Conley)

This paper reports on attempts to understand the nature of these structures. At first sight, they have a calligraphic character and resemble marks in Minoan Linear A and B (Chadwick, 1980). So we may wonder whether any intelligent design or conscious effort to follow specific patterns is implied, similar to the way human cultures have developed various writing systems which are transmitted from one generation to the next. If not, then what are the structural principles underlying these fascinating markings and what are the mechanisms that implement them? The question is of ecological value because bark beetles have a devastating effect on ecosystems in Northern Europe, where they attack fruit trees, and in Canada, where they attack the soft pine population. More generally, research into the mechanisms that give rise to the markings produced by *Scolytidae* raises deeper questions about the origins of complexity in animal behavior, in particular how far seemingly complex structures necessarily require highly intelligent (and perhaps even conscious) organisms to produce them or whether they can be the result of self-organisation.

Method

Science observes natural phenomena and attempts to find first the systematicity and then the underlying principles that could give rise to the phenomena. These principles can be mathematically captured in systems of differential equations, which are then shown, usually through Monte Carlo simulations, to adequately cover the phenomena one is interested in. Researchers in "artificial life" have pioneered an alternative modeling approach in the form of agent-based models. In this approach, the relevant aspects of the environment are captured in virtual worlds, and the crucial properties of organisms are implemented as behaviors of artificial software constructions known as agents. These agents act like animated robots (sometimes called animats) that operate in a virtual world, similar to the way animated characters like Lara Croft operate in a computer game world. An early example of this approach, inspired by stygmergetic behavior of social insects, can be found in Steels (1990). Contemporary ethologists now routinely use both types of models interchangeably, but in this paper only agent-based models will be employed, mainly because they allow a much better treatment of the very complex phenomena we want to investigate.

The real world is complex at many different scales and not everything can be captured in a model (whether based on differential equations or agents). To be informative, the model should only incorporate what is relevant for an explanation of the phenomena of interest. Moreover the model should not necessarily be completely faithful to reality. As Galileo showed, there is great value in making idealised abstractions, like the ideal pendulum or the frictionless cannonball. These abstractions can be understood thoroughly, and then used to confront richer realities, which are contingent on many additional factors and hence much less amenable to model construction.

I will follow the same approach in this paper and define an "idealised bark beetle," further called the *Conleyborus scarabaeoides* (by analogy with bark beetle species that resemble it). The *Conleyborus scarabaeoides* (commonly named the Conley beetle) is an idealisation in the sense that it has only the behaviors that are relevant for gallery construction. More realistic investigations for naturally occurring species can use this idealised beetle as a first approximation.

Hypothesis

The main hypothesis of the investigation is that the markings produced by bark beetles are the emergent side effect of the complex interactions between a number of coupled dynamical systems. In other words, there is no pre-established pattern that the beetles have innately stored nor a culturally established repertoire that they try to copy, similar to the way human beings reproduce signs. The causal factors cannot be reduced to a single source and the markings emerge through self-organisation. This hypothesis is in line with earlier work on how social insects, like termites, honey bees, wasps, or ants, collectively construct complex nests, establish paths from food sources to their nests, or assemble in swarms to migrate or defend themselves against predators (Camazine, et al., 2001).

In fact, some aspects of *Scolytidae* behavior have already been approached this way. Larvae have been shown experimentally to exhibit aggregation behavior and self-organisation models have been proposed to explain how the aggregation occurs (Deneubourg, et al., 1990). The larvae use chemical communication which pulls them together due to a positive feedback mechanism. Larvae emit a chemical substance and are themselves attracted to it. So the higher the concentration in a certain area, the more the larvae are attracted to that area, and the concentration increases even further attracting more larvae. The chemical attraction is countered by negative feedback because larvae try to avoid each other. The net effect of both dynamical processes is that larvae stick together and form aggregate paths, particularly under the bark of the tree (figure 8). Notice also that the patterns in figure 8 are very different from those in figure 7. These are different kinds of marks by different kinds of *Scolytidae*. Another kind of *Scolytidae* goes beyond the surface of the wood and burrows straight into the body of the tree (figure 12) making similar galleries. In the remainder of this paper we will focus only on this type of structure.

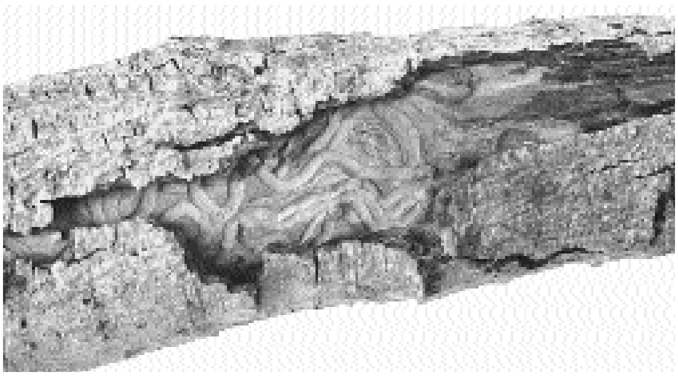

Figure 8. Characteristic aggregation paths of larvae between bark and tree wood. (Field data, Barranco de Arure, Gomera, Spain. L. Steels.)

In the case of gallery formation in *Scolytidae*, the literature suggests that the intervening coupled dynamical systems include:

1. *The textural properties of the wood.* The beetles make tunnels within the wood and will meet more or less resistance depending on texture. For example, they navigate around

branch points where the wood is much harder. It follows that we will see different markings depending on the tree type and even the individual tree.

2. *The reaction of the tree to the presence of larvae.* When tunnels are made, the tree reacts by producing large amounts of resin which can potentially kill the larvae. The larvae react to this by sticking together to avoid getting overwhelmed.

3. *The embodiment of the beetle (and the larvae).* The size of the galleries is largely determined by the size of the body (figure 9) and the beetles tend to excavate in the same direction because turning the body around is not so easy. So we expect to see gentle curves, rather than 90 degree angles.

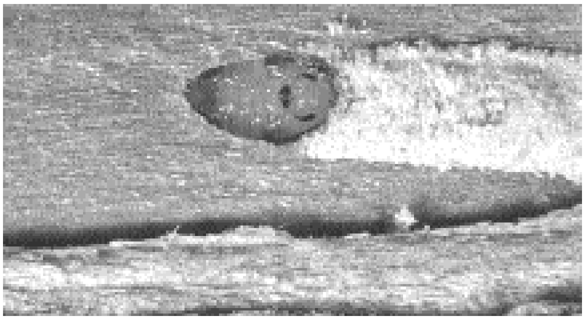

Figure 9. Excavation of a tunnel by a larvae. The size of the tunnel is largely determined by body size. (Inra Zoology HYPP)

4. *Repulsion among the beetles.* Beetles keep out of each others' way because they are in competition for the same food sources. Thus when there is an initial hole in a certain location, the next beetle arriving on the same branch will start a new hole at a certain distance to avoid interference with the first. While digging, beetles must avoid getting into other galleries. A tree branch is a limited terrain and can only sustain a limited population of beetles.

5. *Presence of fungi.* In most cases, the beetles do not live off the wood itself, but use fungi as a food source. These fungi are introduced by females and thrive in the dust resulting from tunnel excavation. The fungi population has its own dynamic which is coupled to the dynamic of the larvae population. They co-exist in a symbiotic relation with the beetles.

6. *Beetle life cycle.* Beetles lay eggs, and clearly the number of eggs and where they are deposited in the maternal chamber or in the tunnels determine how the tunnels will further expand. Beetles hibernate in the tunnels and they get further excavated due to beetle traffic along existing paths.

This list is not intended to be exhaustive but illustrates that a complex set of factors interferes in gallery construction. Given all these factors, it is obvious that a model of differential equations is not very realistic. An agent-based model will still be very complex but can be built up step by step and allows the integration of spatio-temporal structures much more easily. It is also obvious that not everything can or needs to be modeled to help us gain insight in the processes that give rise to the markings of interest here. I will here ignore the growth process of the tree, the resin attacks, the chemical communication and aggregation of the larvae, the life-cycle of the beetle, the temperature changes in the environment, and many other factors that all play a role in this ecosystem. The markings produced by the beetles exhibit a bewildering complexity, without being entirely random, and the great challenge is to show that they are nevertheless based on a number of simple underlying principles. These principles must translate into behaviors that can be carried out by a beetle based only on local observation and control and with a minimum of sensing or complex information processing.

When observing a surface as in figure 7, we get only a very partial view of the total ecosystem that plays a role in gallery formation. A tree branch is a three dimensional structure and beetles excavate in all directions. So we will use a three-dimensional cellular automaton as the basic grid to model the world, as opposed to the more common two-dimensional cellular automata used in many "artificial life" models. Only the surface layer of the automaton will be visualised. To emphasize the three-dimensional character of the galleries, I designed the drawing programs in such a way that structures are drawn with shadows, so that they appear to stick out.

The position of the beetle is defined in terms of <x,y,z> coordinates on the 3D grid. Each beetle also has a characteristic size, modeling the body shape, a tilt plane which is by default level with the ground, and an orientation (a 360 degree angle with respect to the tilt plane).

Behaviors of the Conleyborus scarabaeoides

I now show that gallery formation producing markings with a complexity similar to natural markings can be explained with a few rather straightforward behaviors: tunneling, path retracing, borehole initiation, chamber construction, and spawning of larvae. Each of these behaviors contains random choices which are influenced by the state of the environment and it is through their interaction with the environment that the typical markers emerge.

1. *Tunneling*. The Conley beetles or their larvae form tunnels by crawling step by step over the 3D grid and removing wood in the process. Given the position of a beetle in x,y,z coordinates, the next adjacent position is computed by translating the angle into a new set of coordinates, and the beetle moves to this position, excavating the area in its path based on its current size (figure 10). Because of the grain-size of the cellular automata, a tunnel cannot be as smooth as for real life beetles.

A tunnel has an orientation and a size. The size of the tunnel is a side effect of the size of the beetle, which excavates enough to comfortably pass through, i.e. slightly larger than its own size. When a tunnel is bending, slightly more area is excavated to allow the body to make the turn.

The orientation of the tunnel is a side effect of the orientation of the beetle, which is basically constant, with slight, random variation (left and right with respect to the existing orientation). This variation models the resistance encountered by the wood. Variations can accumulate and may then give rise to a bend in the tunnel.

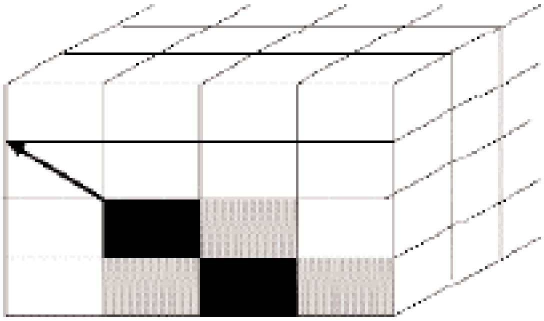

Figure 10. A 3D-Cellular automaton is used to model the wood. The next move of a beetle is calculated based on its orientation and its current position.

This kind of tunneling behavior already generates the typical single gallery strands which we observe in natural markings (see figure 11, left). Notice the use of shading, producing an apparent depth. The markings produced by the beetles give the impression of paths left by rolling stones, coming down from a mud hill. Note that the tunnel is not a computational object in the simulation but a side effect of beetle behavior.

This specification of tunneling behavior cannot be the whole story however. First of all we also see in natural settings characteristic symbol-like structures consisting of an internal blob (interpreted as the presence of a maternal chamber) with tentacles going up or down similar to a sea anemone (figure 7). This suggests that local orientation in tunneling behavior should occasionally be influenced by a global direction. More research is required to investigate the precise cause or ecological reason for pursuing a global direction. In the Conley beetle simulations discussed here, I have assumed that the global orientation is either guided by gravity or anti-gravity, depending on the initial orientation: When orientation is above 270 degrees or below 90 degrees, the beetle will progressively

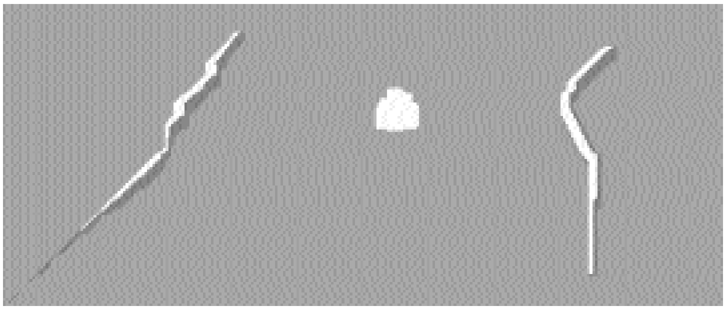

Figure 11. The three main structures produced as a side effect of the tunneling behaviors of *Conleyborus scarabaeoides*.
Left, construction of a tunnel in random direction (top to bottom).
Middle, maternal chamber excavated by random movements.
Right, tentacular structure due to the influence of a global orientation.

seek an orientation of zero degrees, otherwise it tends towards 180 degrees. With this kind of influence on tunneling, the Conley beetles produce tentacle-like tunnels (see figure 11, right). The size of the gallery generally decreases as the beetle approaches the end of the tunnel.

A second point is that in natural settings, beetles tend to avoid an already existing gallery, even though this is far from always the case (figure 7). This implies that beetles must sense from a distance whether there is a gallery in the direction in which they are going. Because this is presumably not possible using visible means, we can speculate that it is based on chemical communication, which has been proven to show an important role for other aspects of beetle behavior as well.

Avoiding existing galleries has also been incorporated in the tunneling behavior of Conleyborus scarabaeoides. Around each gallery a “taboo” zone is dynamically computed as tunnels are excavated. Beetles are able to sense these “taboo” zones and perform obstacle avoidance behavior around them or halt in front of them.

2. *Path Retracing*. Once a tunnel exists, beetles can move through them, retracing the position from where they came. This requires that they can turn around in a gallery, and that they can compute the next move based on a perception of the orientation of the gallery in front of them. Retracing of a path may give rise to additional excavation, slightly enlarging the gallery. Again, the behavior is not necessarily completely successful, and sometimes the Conley beetle may start to excavate from a point somewhere in the middle of a gallery, wrongly believing it has reached the maternal chamber.

3. *Borehole Initiation*. A beetle arrives on the bark of a tree and then bores a hole into the branch. The selection of the entry point is partially random, and partially determined by the presence of other holes. In nature, beetles avoid making a new hole too close to an existing one in order not to get into competition right away (figure 12). We therefore must supply the Conley beetle with an entry point selection process, based on the perception of existing holes observed by matching a visual pattern against perceived reality. Once a position is chosen, excavation of a tunnel starts in a random orientation and goes for a randomly chosen distance into the wood.

Figure 12. Holes are randomly spaced but at a certain distance from each other. (Field data, Barranco de Arure, Gomera, Spain. L. Steels.)

4. *Chamber construction*. The Conley beetle constructs a maternal chamber by making random excavating movements around a central position. The number of movements is randomly determined. This results in an amorphous area of undetermined size (see figure 11, middle).

The four behaviors discussed so far are chained: A beetle arrives on a piece of wood and initiates a borehole. After some time, it constructs a maternal chamber, and then it starts making a tunnel in a randomly chosen direction. When the tunnel has a certain depth (again randomly determined) the beetle retraces the path back to the maternal chamber and then chooses a new direction for the next tunnel.

5. *Spawning of larvae*. The final behavior I had to introduce to get the characteristic gallery structures of *Scolytidae*, concerns the spawning of the larvae. They mature and then start to construct their own tunnels in the wood. The number of larvae and the times at which they are spawned are randomly determined but they follow a more or less regular pattern. The position where larvae are deposited determines from where a new tunnel starts, and the orientation of the tunnel is basically perpendicular to the orientation of the gallery or chamber structure from where the larvae start to move, but alternating left and right. Beetles and larvae build further on existing gallery structures, thus illustrating the kind of stygmergetic behavior which is very common in social insects.

When the beetle deposits larvae while moving in a tunnel (which may bend slightly), we often see a series of parallel lines, because only the galleries in one perpendicular direction are visible. The galleries in the other perpendicular direction go deeper inside the wood and are not visible on the surface. In most cases we do not see the main gallery in which the adult beetle is moving either, because it is also located below the surface.

When the beetle deposits larvae while moving on the edge of a maternal chamber, we see the characteristic "symbols" as in natural markings (see figure 7). The beetle is moving around the edge of the maternal chamber and new galleries start at random points on the edges, but then move globally up or down.

Results and Discussion

The results of putting the different behaviors of Conleyborus scarabaeoides in action on a 3D grid are shown in figure 13. This image has been produced by a single invocation of the simulation program where a random number of beetles attack virgin wood, make boreholes and maternal chambers, excavate tunnels, and spawn larvae that then construct their own tunnels. The image has been made slightly less sharp through the use of a 3x3 filter, simulating the effect of taking a photograph of the wood surface. We clearly observe structures that are similar to those observed in the natural settings shown in figure 7.

More examples of simulation results are shown in figure 14. The comparison with natural markings could potentially be made more precise by a mathematical characterisation of structures in natural and artificial settings. But the analogy is striking to the naked eye.

These simulations therefore give substance to the main claim of the present paper,

Figure 13. Markings produced by *Conleyborus scarabaeoides*. We see a typical symbolic structure in the bottom right corner and other galleries around it.

namely that the markings produced by *Scolytidae* are the emergent side effect of a number of dynamical processes, including the way tunnels are constructed in the wood, the embodiment of the beetle, the intervals with which larvae are spawned, etc. The observed complexity is due to the randomness, influencing decisions at all levels of this ecosystem. The observed order is due to the many constraints inherent in the physical and biological world and a number of default choices, for example, to start a new gallery perpendicular to an existing one and not in a completely random direction. Gallery formation in *Scolytidae* therefore follows the same general principle as other structures formed by social insects. The hypothesis of high intelligence (let alone consciousness), innate knowledge of patterns, or global coordination and planning of behavior is not required.

Returning to the intriguing similarity between the markings of *Scolytidae* and early writing systems such as Minoan Linear A or B, I refer to some of my other work, which has shown that the building blocks of human communication systems, such as the speech sounds of human languages, can also be explained as the emergent side effect of self-organising processes. In the case of speech, there are free choices that language users collectively make, but these are constrained by the physics of the sound medium, the nature and control of the vocal apparatus, the capacities of the human auditory system, and the behavior of neural networks in the brain (Steels and Oudeyer, 2000). Similar research could investigate the origins of writing systems (such as clay tablet markings, Chinese characters, or Minoan Linear A or B), by modeling the influence of the physics of the medium, the interaction of available tools with the medium, the nature of human gestures, and the limits and potentials of human visual pattern recognition. Of course, in the case of speech or writing systems, there is a cultural transmission process as well, because the physical signs play a role in collective semiotic processes that are transmitted from one generation to the next (Steels and Kaplan, 2000).

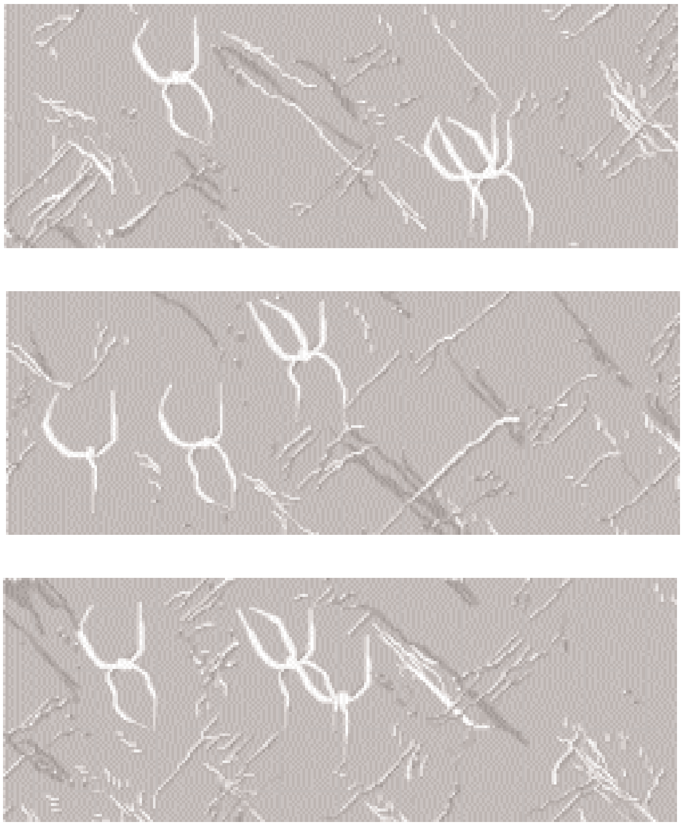

Figure 14. More markings produced by *Conleyborus scarabaeoides*. Each is based on a single run of the simulation with random choices for number of beetles attacking the wood. Roughly parallel lines (as in top image, left lower corner) are produced by offshoots from an invisible deeper perpendicular gallery.

Note

This paper was presented at the 8th International Conference on the Simulation of Adaptive Behavior, "From Animals to Animats 8," July 13–17, 2004. Los Angeles, CA.

Acknowledgements

I am indebted to Brian Conley whose interest and extensive field work on *Scolytidae* in Upstate New York was a direct inspiration for the research presented here, and to Marleen Wynants for help during my own field work on *Scolytidae* in the Barranco Arrure, Gomera, Spain, as well as early feedback on the simulations. I programmed the 3D cellular automaton, the agent behaviors, and the graphic visualisation directly in Macintosh Common Lisp, although the use of a variant of Logo would have been a viable alternative.

The Tip of the Radicle Is a Brain:

From the Power of Movement in Plants

Charles Darwin
Assisted by
Francis Darwin

Having made these few preliminary remarks, we will in imagination take a germinating seed, and consider the part which the various movements play in the life-history of the plant. The first change is the protrusion of the radicle, which begins at once to circumnutate. This movement is immediately modified by the attraction of gravity and rendered geotropic. The radicle, therefore, supposing the seed to be lying on the surface, quickly bends downwards, following a more or less spiral course, as was seen on the smoked glass-plates. Sensitiveness to gravitation resides in the tip; and it is the tip which transmits some influence to the adjoining parts, causing them to bend. As soon as the tip, protected by the root-cap, reaches the ground, it penetrates the surface, if this be soft or friable; and the act of penetration is apparently aided by the rocking or circumnutating movement of the whole end of the radicle. If the surface is compact, and cannot easily be penetrated, then the seed itself, unless it be a heavy one, is displaced or lifted up by the continued growth and elongation of the radicle. But in a state of nature seeds often get covered with earth or other matter, or fall into crevices, etc., and thus a point of resistance is afforded, and the tip can more easily penetrate the ground. But even with seeds lying loose on the surface there is another aid: a multitude of excessively fine hairs are emitted from the upper part of the radicle, and these attach themselves firmly to stones or other objects lying on the surface, and can do so even to glass; and thus the upper part is held down whilst the tip presses against and penetrates the ground. The attachment of the root-hairs is effected by the liquefaction of the outer surface of the cellulose walls, and by the subsequent setting hard of the liquefied matter. This curious process probably takes place, not for the sake of the attachment of the radicles to superficial objects, but in order that the hairs may be brought into the closest contact with the particles in the soil, by which means they can absorb the layer of water surrounding them, together with any dissolved matter.

After the tip has penetrated the ground to a little depth, the increasing thickness of the radicle, together with the root-hairs, hold it securely in its place; and now the force exerted by the longitudinal growth of the radicle drives the tip deeper into the ground. This force, combined with that due to transverse growth, gives to the radicle the power of a wedge. Even a growing root of moderate size, such as that of a seedling bean, can displace a weight of some pounds. It is not probable that the tip when buried in compact earth can actually circumnutate and thus aid its downward passage, but the circumnutating movement will facilitate the tip entering any lateral or oblique fissure in the earth, or a burrow made by an earth-worm or larva; and it is certain that roots often run down the old burrows of worms. The tip, however, in endeavouring to circumnutate, will continually press against the earth on all sides, and this can hardly fail to be of the highest importance to the plant; for we have seen that when little bits of card-like paper and of very thin paper were cemented on opposite sides of the tip, the whole growing part of the radicle was excited to bend away from the side bearing the card or more resisting substance, towards the side bearing the thin paper. We may therefore feel almost sure that when the tip encounters a stone or other obstacle in the ground, or even earth more compact on one side than the other, the root will bend away as much as it can from the obstacle or the more resisting earth, and will thus follow with unerring skill a line of least resistance.

The tip is more sensitive to prolonged contact with an object than to gravitation when this acts obliquely on the radicle, and sometimes even when it acts in the most favourable direction at right angles to the radicle.

The tip was excited by an attached bead of shellac weighing less than $1/200^{th}$ of a grain (0.33 mg.); it is therefore more sensitive than the most delicate tendril, namely, that of *Passiflora gracilis*, which was barely acted on by a bit of wire weighing $1/50^{th}$ of a grain. But this degree of sensitiveness is as nothing compared with that of the glands of *Drosera*, for these are excited by particles weighing only 1/78740 of a grain. The sensitiveness of the tip cannot be accounted for by its being covered by a thinner layer of tissue than the other parts, for it is protected by the relatively thick root-cap. It is remarkable that although the radicle bends away, when one side of the tip is slightly touched with caustic, yet if the side be much cauterised the injury is too great, and the power of transmitting some influence to the adjoining parts causing them to bend, is lost. Other analogous cases are known to occur.

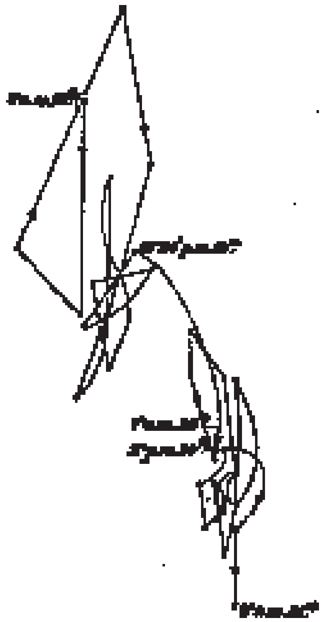

Figure 15. *Fragaria*: circumnutation traced from 8 am May 19th to 8 am May 21st.

After a radicle has been deflected by some obstacle, geotropism directs the tip again to grow perpendicularly downwards; but geotropism is a feeble power, and here, as Sachs has shown, another interesting adaptive movement comes into play; for radicles at a distance of a few millimeters from the tip are sensitive to prolonged contact in such a manner that they bend towards the touching object, instead of from it as occurs when an object touches one side of the tip. Moreover, the curvature thus caused is abrupt; the pressed part alone bending. Even slight pressure suffices, such as a bit of card cemented to one side. Therefore a radicle, as it passes over the edge of any obstacle in the ground, will through the action of geotropism press against it; and this pressure will cause the radicle to endeavour to bend abruptly over the edge. It will thus recover as quickly as possible its normal downward course.

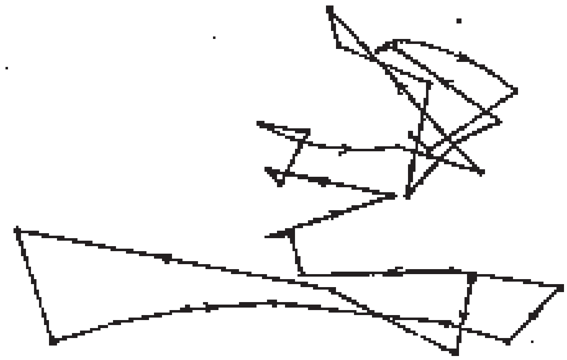

Figure 16. *Oxalis carnosa*: flower-stem, feebly illuminated from above, its circumnutation traced from 9 am April 13th to 9 am April15th. Summit of flower 8 inches beneath the horizontal glass. Movement probably magnified

Radicles are also sensitive to air which contains more moisture on one side than the other, and they bend towards its source. It is therefore probable that they are in like manner sensitive to dampness in the soil. It was ascertained in several cases that this sensitiveness resides in the tip, which transmits an influence causing the adjoining upper part to bend in opposition to geotropism towards the moist object. We may therefore infer that roots will be deflected from their downward course towards any source of moisture in the soil.

Again, most or all radicles are slightly sensitive to light, and according to Wiesner, generally bend a little from it. Whether this can be of any service to them is very doubtful, but with seeds germinating on the surface it will slightly aid geotropism in directing the radicles to the ground. We ascertained in one instance that such sensitiveness resided in the tip, and caused the adjoining parts to bend from the light. The sub-aërial roots observed by Wiesner were all apheliotropic, and this, no doubt, is of use in bringing them into contact with trunks of trees or surfaces of rock, as is their habit.

We thus see that with seedling plants the tip of the radicle is endowed with diverse kinds of sensitiveness; and that the tip directs the adjoining growing parts to bend to or from the exciting cause, according to the needs of the plant. The sides of the radicle are also sensitive to contact, but in a widely different manner. Gravitation, though a less powerful cause of movement than the other above specified stimuli, is ever present; so that it ultimately prevails and determines the downward growth of the root.

*

It has now been shown that the following important classes of movement all arise from modified circumnutation, which is omnipresent whilst growth lasts, and after growth has ceased, whenever pulvini are present. These classes of movement consist of those due to epinasty and hyponasty; those proper to climbing plants, commonly called revolving

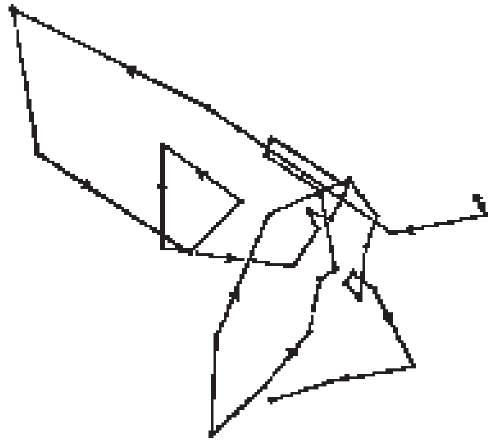

Figure 17. *Quercus* (American sp.): circumnutation of young stem, traced on horizontal glass, from 12:50 pm Feb. 22nd to 12:50 pm 24th. Movement of bead greatly magnified at first, but slightly towards the close of the observations—about 10 times on an average.

nutation; the nyctitropic or sleep movements of leaves and cotyledons, and the two immense classes of movement excited by light and gravitation. When we speak of modified circumnutation we mean that light, or the alternations of light and darkness, gravitation, slight pressure or other irritants, and certain innate or constitutional states of the plant, do not directly cause the movement; they merely lead to a temporary increase or diminution of those spontaneous changes in the turgescence of the cells which are already in progress. In what manner, light, gravitation, etc., act on the cells is not known; and we will here only remark that, if any stimulus affected the cells in such a manner as to cause some slight tendency in the affected part to bend in a beneficial manner, this tendency might easily be increased through the preservation of the more sensitive individuals. But if such bending were injurious, the tendency would be eliminated unless it was overpoweringly strong; for we know how commonly all characters in all organisms vary. Nor can we see any reason to doubt, that after the complete elimination of a tendency to bend in some one direction under a certain stimulus, the power to bend in a directly opposite direction might gradually be acquired through natural selection.[1]

Although so many movements have arisen through modified circumnutation, there are others which appear to have had a quite independent origin; but they do not form such large and important classes. When a leaf of a Mimosa is touched it suddenly assumes the same position as when asleep, but Brucke has shown that this movement results from a different state of turgescence in the cells from that which occurs during sleep; and as sleep-movements are certainly due to modified circumnutation, those from a touch can hardly be thus due. The back of a leaf of *Drosera rotundifolia* was cemented to the summit of a stick driven into the ground, so that it could not move in the least, and a tentacle was observed

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[1]See the remarks in Frank's "Die wagerechte Richtung von Pflanzentheilen" (1870, pp. 90, 91, etc.), on natural selection in connection with geotropism, heliotropism, etc.

during many hours under the microscope; but it exhibited no circumnutating movement, yet after being momentarily touched with a bit of raw meat, its basal part began to curve in 23 seconds. This curving movement therefore could not have resulted from modified circumnutation. But when a small object, such as a fragment of a bristle, was placed on one side of the tip of a radicle, which we know is continually circumnutating, the induced curvature was so similar to the movement caused by geotropism, that we can hardly doubt that it is due to modified circumnutation. A flower of a Mahonia was cemented to a stick, and the stamens exhibited no signs of circumnutation under the microscope, yet when they were lightly touched they suddenly moved towards the pistil. Lastly, the curling of the extremity of a tendril when touched seems to be independent of its revolving or circumnutating movement. This is best shown by the part which is the most sensitive to contact, circumnutating much less than the lower parts, or apparently not at all.[2]

Although in these cases we have no reason to believe that the movement depends on modified circumnutation, as with the several classes of movement described in this volume, yet the difference between the two sets of cases may not be so great as it at first appears. In the one set, an irritant causes an increase or diminution in the turgescence of the cells, which are already in a state of change; whilst in the other set, the irritant first starts a similar change in their state of turgescence.

Why a touch, slight pressure or any other irritant, such as electricity, heat, or the absorption of animal matter, should modify the turgescence of the affected cells in such a manner as to cause movement, we do not know. But a touch acts in this manner so often, and on such widely distinct plants, that the tendency seems to be a very general one; and if beneficial, it might be increased to any extent. In other cases, a touch produces a very different effect, as with *Nitella*, in which the protoplasm may be seen to recede from the walls of the cell; in *Lactuca*, in which a milky fluid exudes; and in the tendrils of certain *Vitaceae*, *Cucurbitaceae*, and *Bignoniaceae*, in which slight pressure causes a cellular outgrowth.

Finally, it is impossible not to be struck with the resemblance between the foregoing movements of plants and many of the actions performed unconsciously by the lower animals.[3] With plants an astonishingly small stimulus suffices; and even with allied plants one may be highly sensitive to the slightest continued pressure, and another highly sensitive to a slight momentary touch. The habit of moving at certain periods is inherited both by plants and animals; and several other points of similitude have been specified. But the most striking resemblance is the localisation of their sensitiveness, and the transmission of an influence from the excited part to another which consequently moves. Yet plants do not of course possess nerves or a central nervous system; and we may infer that with animals such structures serve only for the more perfect transmission of impressions, and for the more complete intercommunication of the several parts.

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[2]For the evidence on this head, see the "Movements and Habits of Climbing Plants," 1875, pp. 173–4.

[3]Sachs remarks to nearly the same effect: "Dass sich die lebende Pflanzensubstanz derart innerlich differenzirt, dass einzelne Theile mit specifischen Energien ausgerüstet sind, ähnlich, wie die verschiedenen Sinnesnerven des Thiere" ('Arbeiten des Bot. Inst. in Würzburg,' Bd. ii. 1879, p. 282).

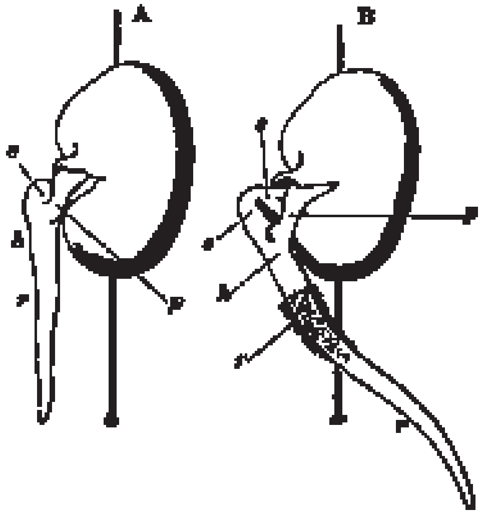


Figure 18. *Vicia faba:* germinating seeds, suspended in damp air: A, with radicle growing perpendicularly downwards; B, the same bean after 24 hours and after the radicle has curved itself; *r*, radicle; *h*, short hypocotyl; *e.* epicotyl appearing as a knob in A and as an arch in B; *p*, petiole of the cotyledon, the latter enclosed within the seed-coats.

We believe that there is no structure in plants more wonderful, as far as its functions are concerned, than the tip of the radicle. If the tip be lightly pressed or burnt or cut, it transmits an influence to the upper adjoining part, causing it to bend away from the affected side; and, what is more surprising, the tip can distinguish between a slightly harder and softer object, by which it is simultaneously pressed on opposite sides. If, however, the radicle is pressed by a similar object a little above the tip, the pressed part does not transmit any influence to the more distant parts, but bends abruptly towards the object. If the tip perceives the air to be moister on one side than on the other, it likewise transmits an influence to the upper adjoining part, which bends towards the source of moisture. When the tip is excited by light (though in the case of radicles this was ascertained in only a single instance) the adjoining part bends from the light; but when excited by gravitation the same part bends towards the centre of gravity. In almost every case we can clearly perceive the final purpose or advantage of the several movements. Two, or perhaps more, of the exciting causes often act simultaneously on the tip, and one conquers the other, no doubt in accordance with its importance for the life of the plant. The course pursued by the radicle in penetrating the ground must be determined by the tip; hence it has acquired such diverse kinds of sensitiveness. It is hardly an exaggeration to say that the tip of the radicle thus endowed, and having the power of directing the movements of the adjoining parts, acts like the brain of one of the lower animals; the brain being seated within the anterior end of the body, receiving impressions from the sense-organs, and directing the several movements.

Plate 1: LX–Ca Bc 004

Plate 2: LX–Ca Bc 009

Plate 3: LX–Ca Bc 012

Plate 4: LX–Ca Bc 006

Plate 5: LX–Ca Bc 010

Plate 6: LX–Ca Bc 003

Plate 7: LX–Ca Bc 007

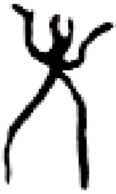
Plate 8: LX–Ca Bc 011

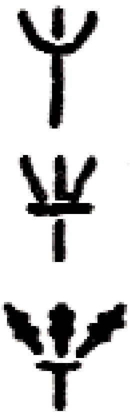
Plate 9: LX–Ca Bc 008

Plate 10: LX–Ca Bc 014

Plate 11: LX–Ca Bc 013

Plate12: LX–Ca Bc 005





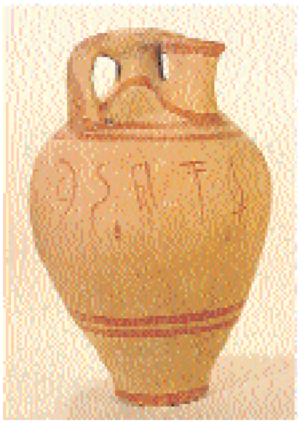
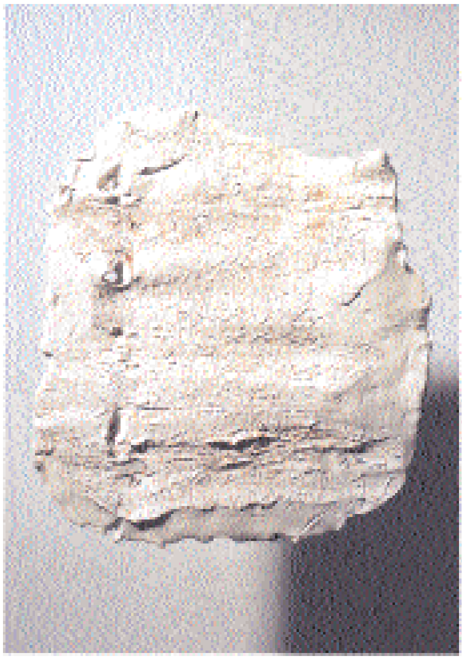


Plate13: Three sign comparisons–Linear B and Linear X

Plate14: LX–Ca Bc 001



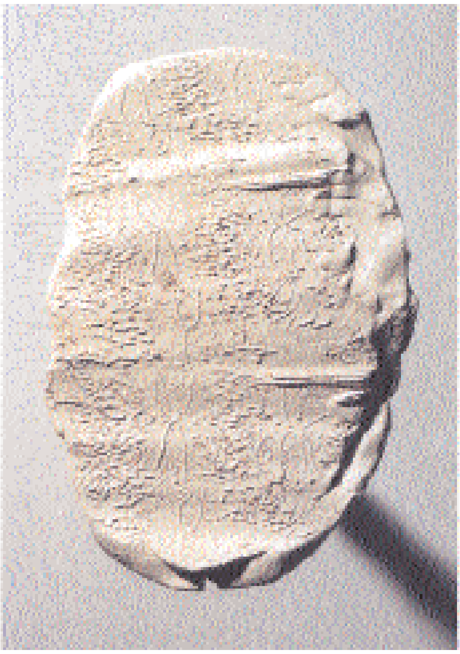


Plate15: Linear X Tablets

Plate16: LX–Ca Bc 002

Natura Pictrix: A Conversation

Marina Warner and Brian Conley

Brian Conley: In looking at Charles Darwin's book *Power of Movement in Plants* one finds chapter and section titles such as: "The circumnutating movements of seedling plants," "Straightening of the tip due to hyponasty," "The resemblance between the movements of plants and animals," and "The tip of the radicle acts like a brain." What is it about Darwin's book that interests you, and what might it have to do with writing and language?

Marina Warner: It wasn't through language that I became interested in Darwin, though you're right that it might have been. I had become very involved in the idea of *Natura Pictrix*, or Nature the Artist, a view of phenomena that is really NeoPlatonist, I suppose, and begins in the Renaissance with people like Alberti and Leonardo, who wanted to open up the secret architecture and structures of the natural world. But perhaps it really begins earlier, with the analysis of the Fibonacci series, in Pisa in the 13th century. Mathematics and artistry meet so wonderfully in the curling of tendrils on a sweet pea or of a passion fruit vine. Two of my favourite books are *The Curves of Life* by Theodore Andrea Cook (l914) and a more recent study, *Patterns in Nature* by Peter S. Stevens, from l976, also wonderfully illustrated. But even more than this pervasive natural harmonics, this innate hermetic geometry and logic, even more than the Golden Section and the recurrence of certain angles in the branching of plants, I am delighted by "images made by chance." I came to the idea that plants make drawings, as in those late experiments by Darwin and his son, through Athanasius Kircher's collection of stones with letters of the alphabet inscribed in them by nature. By the end of his life, Kircher had managed to complete the alphabet and the stones are illustrated in the wondrous catalogue of his cabinet of curiosities, the Musaeum Kircheranium, which was in the Jesuit College in Rome, and was a huge attraction in the seventeenth century and later (I heard there were plans to reassemble it somehow). I was working on "fata morgana" or mirages in the sky (castles in the air) for my never-ending but nearly completed book about spirits and how to think about them, and so I was alert to adventitious pictures and the activity of the imagination in finding them in unlikely places. Of course for Kircher, such natural pictures were the results of God's design showing up in natural wonders. Then I began reading the Surrealist Roger Caillois, who was an inspired commentator on "the language of the imagination" and a believer in the innate structure of phenomena and our relations with them, and wrote marvelously about intrinsically mythopoeic things, like octopi and spiders. He was a collector of images made by chance–

some of his fantastic jaspers and crystals and agates are illustrated in a slim book, *The Writing of Stones*, published towards the end of his life. Last year in Paris I saw some of these stones in an exhibition of mostly Surrealist artifacts, called "Le Reve"—there was a really lovely one, an agate with a dancing sprite in the heart of it, known as "Petit Fantome."

I began forming a plan to make an exhibition of found images, or drawings, which would consist of many such marvels. For example, there is another, enrapturing Victorian study, which you know, I'm sure, as it's about insects—*Ants, Bees and Wasps* by Sir John Lubbock. It was published two years after Darwin's *Power of Movement in Plants*. Here, the diagrams and engravings illustrate the paths of ants and the flights of wasp and bees. Ants and bees are the Miros and Gorkis and Calders and Arps of nature, making lovely looping clusters and meanders and knots.

What I especially loved about the artist as flower, as leaf, as vegetable, was the powerful expressiveness of their species difference: perhaps it is anthropomorphising plants (reprehensible, as with animals?) to find the austerity of Sol Lewitt in the circumnutations of *brassica* (is this cabbage?!) or the lovely languorous floppiness of some Eva Hesse work in the tips of the *phaseolus multiflorus* radicle seeking water. But the aesthetic satisfaction these tracings give are related to the graphic satisfactions of human art (figure 15 and 16), probably at a cognitive level. It's at this cognitive level that a comparison exists between Kircher's images made by chance in stones, and the stones Caillois collected, and drawings made by plants or ants, because they exist in exchange with our imaginations and pleasure centres. It's of great interest aesthetically, because such images abolish artistic intention altogether. Pleasure centres to me are closer to the appetites and to the animal soul, so called, which responds directly to the perception of the senses—the touch of a petal as opposed to the "rose" that appears in the mind's eye when you say the word or read it.

When I got the Darwin volume out of the London Library, and read the description of setting up the experiments, I especially liked two things, one that the Darwins were doing it all at home, in their living room and on their own window sills—the research was part of the ordinary domestic day, and secondly, their technology sounded so ingenious and so homely at the same time: the little burins attached to the tips of the stalks so that they would scratch the prepared blackened surface of a glass, the little leads bound to the tendril tips, so that they could draw (figure 18).

That's why I respond with such empathy to your Linear X, the ingenious script of the beetles.

BC: You raise interesting questions about the relationships between intention and chance in the production of art and other objects of interest. You mention painters whose projects are intention driven, though they may use chance techniques and rocks that by chance have letters of the alphabet embedded in them. I raise the case of Linear X in which marks have been purposefully made by insects and ask how can we say that these are not intentional.

Without being aware of it I must also be interested in images made by chance as well. More than ten years ago I found a piece of gray dust on the floor that looks remarkably like an angel, and I have been carrying it around with me ever since. Even though I have lost most of my possessions a couple times in recent years, somehow I have managed to keep this thing. I think I like the chasm between referent and material substrate; it is disgusting and transcendental simultaneously. Several years ago, somewhere between the first Gulf war and the war in Bosnia, I made an object (the reasons for which I am still not clear) by pouring the contents of my woodstove inside a double-pane window. I put a metal frame on it so it could be hung in any direction and changed regularly. No matter which way it is oriented, the ash, charcoal and nails form a detailed and very convincing image of one or more rather bleak looking mountains, very close to the landscape where Osama bin Laden hid after 9/11...well...where the Americans conducted their first bombing raid. These two cases seem in line with Caillois and the "Petit Fantome." There is a formation generated in inert matter that produces an image in interplay with the viewer.

MW: I was ill for a time once a few years ago, and fever trips the switch on the brain's powers to screen out random meanings. I would watch the ceiling panels above my bed in the hospital, as they presented at one time distant vistas of rivers stippled in dots and at another time close up tangles of undergrowth. My scale kept changing in relation to these apparitions, because with fever you lose the sense of your own body in space. It becomes much larger, hence the rolling landscapes, or smaller, screwed up tight—hence the bug's eye view of flowers and vegetation. In her essay "On Being Ill," Virginia Woolf watched the clouds drifting outside the window, and drifted with them into this kind of skewed but enhanced consciousness, as when children (and Anthony and Cleopatra) see shapes that are dragonish. Woolf writes, "One should not let this gigantic cinema play perpetually to an empty house."

BC: One of the stories explaining the origin of Chinese written language was that the first calligraphic signs were found in the form of cracks in the underside of heated turtle shells.

MW: Kircher wanted to know everything, not least the origins of language and he wrote inspiringly on the Tower of Babel, and speculated, like many of his contemporaries, on Adam and Eve's speech in the Garden of Eden (Umberto Eco has written one of his entertaining and hugely learned studies of this, *The Search for the Perfect Language* [see also Frances Richard's essay in this volume]). But what interests me most of all is that the origins of reading and writing go back to the quest for knowledge: in this sense, they are truly the fruit of the tree in Eden. Those cracks in tortoise shells were omens, read by priests intent on knowing the future, on laying bare what is hidden, on prophesying. Joseph Needham in his wonderful books about the history of science and civilization in China makes the point that just as the mapping of the stars was inspired by the need to know what lay in store for a child from its birth onwards (astronomy originates as astrology), so literacy itself originates as oracle, with the decipherment of the random fissures in the chitin of a tortoise—whose shell was also strung to make a lyre in the later myth of Apollo and the origin of music. The two systems are associated by the imagination of storytelling: random patterns in sight and sound turn into clusters of meaningful signs, with power to fill the mind with thoughts and feelings. (This twist to the story of human communication systems is so much more inspiring than the dreary tallies of goods, lists of officials, and other record-keeping that fills cylinder seal after cylinder seal in Sumerian literature [and Linear B tablets]—though it must be admitted that property drove the creation of sign systems too, in tandem with the longing to have knowledge of what is concealed from human sight.

Another rich seam of myths about the origins of writing involves birds: cuneiform reeds mark the clay as do the prints of birds in sand. In Greek myth, Hermes who is the Gods' messenger and hence a master of communications, interprets the signs bird's steps make. For years I tried to track down another, related story which Robert Graves tells in passing, that the alphabet was invented in Crete, from the dance of the cranes on the threshing floor. But I have never managed to discover the source of this or anything more.

BC: That is one of the originary myths about cuneiform.

MW: Do you remember how children's adventure stories used to be filled with heroes who could read tracks? The tracks of all kinds of creatures, large and small (I was terrified by Sherlock Holmes—"It was the footprint of a gigantic hound!") There was a kind of imperialist awe in some of these stories—Rudyard Kipling's Kim was a scout who could read a spill of earth, a bent twig. Mowgli the jungle boy had developed preternatural powers—animal powers—of alertness, which made his surroundings legible in a way no ordinary human could experience. Baden Powell, when he founded the Boy Scouts, was inspired by this vision of native skills, and part of the Boy Scout adventure was learning codes and signals, knots and marks to convey messages and orientation. But you will think I am going off on yet another tangent—that this is too labyrinthine.

BC: Can't the "seeing-in" that exists in exchange with our imaginations and pleasure centers be a form of domination and occlusion?

MW: I suppose it could be in the sense that the quiddity of things-in-themselves has to surrender to the observer's mind. Magritte made a series of paintings of a mountain in the shape of a great eagle. Sometimes, two eggs lie on the windowsill in front of the view of the mountain, in other versions, the windowpane is shattered and scattered on the floor of the room as if the bird had crashed through the glass. The images animate the mountain against all inherent and known ways of being a Mountain. Magritte called this series of pictures, "The Domain of Arnheim," after an Edgar Allan Poe story, in which a millionaire aesthete creates an enchanted landscape garden to his own design in order precisely to rectify nature's incoherence. However, in the story another character presents an opposing view, and argues that what appears to be artless and even poorly arranged in nature might not be disposed for human eyes at all, but be perfectly and meaningfully disposed for the pleasure of "the earth angels." So when we see natural phenomena form into new meanings, like the script of the bark beetles, or birds spreading their wings in rocks, we might not be imposing our subjective fantasy at all, but entering the cognitive viewpoint of an earth angel.

This is not just whimsy on my part. Powers of pareidolia (divining images in random marks) are on the whole acute in children and mental patients and as I said earlier, the feverish and the sick—for it is when the mind—and above all what is known as reason—has not yet developed fully or has let go or lost control—that the legibility of the universe increases. And that legibility belongs to metaphysics, to the long belief that there is a motion and a spirit that interfuses all of creation and gives it meaning. This takes us back to those intertwined human impulses, prophecy and writing.

BC: Meaning, then, is produced through the interplay of a mind reaching into the world to find it, and the world in some sense reaching back to the observant mind yielding some of its characteristics and shedding others—what Slovoj Zizek calls "the answer of the Real." As you say, things-in-themselves must surrender to the observer's mind.

MW: This is why the origin of writing—as opposed to that of language itself, though oracular utterance can require analogous acts of decipherment—is based in projection and its first purpose is prophecy.

BC: You are talking about a view of a pliant mind-infused world, where language, art and other signifying/symbolizing activities play such an active role that meaning and ontology can't be distinguished. But also, interestingly, you seem to say that reason and rationality not only don't help in sorting out the world and its meaning systems, they actually impede understanding, if I read you properly.

MW: I wouldn't say impede because that rules out rational activity. I'd like to offer an analogy: the constellations [of stars] are grouped in their image clusters to tell stories; these in turn have led to very intricate systems of thought produced by deep rational analysis of the stars' behaviour. But this brain activity of the highest sophistication produced NeoPlatonist astrology on the one hand and Newtonian physics on the other. We consider one irrational, the product of projective imagination, the other among the highest achievements of the human mind. I don't really see how with regard to the processes of discovering meaning and order, this distinction can be made. It is only with the passage of time that values change and the status of attributed significance rises or falls. Nobody gathers the sibyl's leaves now, but at one time they helped govern Rome.

BC: Winding down this conversation and returning to the beginning: are you sure these are drawings made by Darwin's plants?

MW: After I heard about the experiments, I was surprised—and disappointed—that the drawings reproduced in the book showed plottings on a graph, and lines joining up marks made at different points in the medium or on the paper by the growing shoots and roots (figure 17). But the way in which the Darwins studied the "power of movement" describes the plants taking their different lines for a walk, so yes, the plants made drawings, but they are waiting for someone to bring them into being.

BC: I am wondering about your last comment that someone needs to complete the circuit that transforms marks, and other inert stuff (like rocks) into language or drawings. Do you mean someone with consciousness and intention—the Observer?

This leads me to my final question: Are human consciousness and intention necessary for something to be a language, or be a drawing…for Linear X to be a language and Darwin's plant markings to be a drawing?

Or simply: Who is the Observer?

MW: I think many of these questions hang in the air most delightfully.

Entomology Recapitulates Etymology

David Serlin

> The role of history will…not, then, be a history of continuity, but a history of deciphering, the detection of the secret, the outwitting of the ruse, and the reappropriation of a knowledge that has been distorted or buried. It will decipher a truth that has been sealed.
>
> —Michel Foucault, "Society Must Be Defended"

> Nature is a language…can't you read?
>
> —The Smiths, "Ask"

In the early 1930s, an unemployed American architect named Alfred Butts began scanning the front pages of the *New York Times* to see if he could discover the mathematical frequency with which the 26 letters of the English alphabet appeared in common words. Butts, an amateur philologist, was probably not the first to determine that vowels appear more regularly than consonants, with "E" unsurprisingly taking the lead. But in coordinating the letters along a continuum of highest to lowest frequency, Butts assigned numerical values to each, so that those with the lowest distribution received the highest points and vice versa. Butts marked each letter and its distribution value on handcrafted individual wooden tiles. Then he developed a set of gaming rules and, using his own architectural drafting equipment, fabricated a crossword puzzle-like pattern, which he pasted directly onto folded checkerboards. Throughout the 1940s, Butts sold his invention under the names Lexico and, later, Criss-Cross Words. In 1948, however, he rechristened it Scrabble, and after 1952, when Butts licensed Scrabble to distributors Selchow and Righter, it was transformed into a premier American pastime.

Scrabble has become a nostalgic, though therefore often clichéd, symbol of the leisure activities—along with paint-by-numbers sets and model airplane kits—promoted as domestic hobbies for middle-class Americans during the Eisenhower era. Such a description, though, not only ignores the popularity of the game to the present day, but also tends to minimize the cultural significance of Butts' invention. Indeed, by imputing only kitsch to Scrabble, we fail to recognize how it partakes of the twentieth century's desire to quantify everyday human behavior through language structures. Many in the modern social sciences—from anthropologists like Claude Lévi-Strauss to linguists like Ferdinand de Saussure—sought related methods for understanding language not merely as a form of social interaction, but as a self-contained cultural system of signs and symbols.

In Britain, for example, in 1953—during the same period in which Butts enjoyed his earliest widespread success—another architect with philological ambitions, Michael Ventris (figure 22), announced his decipherment of Linear B, the written record of the oldest surviving Greek dialect, Minoan and Mycenaean. Linear B, which had baffled linguists and classical scholars alike, proved to be a fertile testing ground for Ventris' ingenuity and, in many respects, mirrored Butts' discovery of patterns of syllabic frequency and distribution across a continuum of established linguistic conventions. Unlike Butts' marketing of Scrabble, however, the decipherment of Linear B did not make Michael Ventris a multi-millionaire: killed in a car accident in 1956, Ventris earned only his own canonization in the rather specialized realms of ancient-language scholarship. Along with the authentic decipherment of Linear B, however, came significant insight into the development of language itself. In particular, Ventris—with the help of Cambridge scholar John Chadwick—showed how the language identified as Linear B was at its core transitional, helping to account for the shift between the dialect and later versions of Greek. Beyond the triumph of exposing its syllabic basis and internal logic, Ventris proved Linear B to be that rare thing: the material residue of linguistic change preserved in written and phonetic traces. In essence, Ventris saw Linear B as the recorded evidence of a language's awkward embryonic stage, evidence that in turn preserved morphological features of an otherwise lost culture and people.

One could argue that, in the aura of discovery surrounding the successful elucidation of such alphabetic-syllabic systems, something was revealed to mid-twentieth-century culture that extended far beyond the mere intellectual pleasures of playing with common words or deciphering the esoterically indecipherable. The national interest that the British philological community expended on Ventris paled in comparison, for example, to the international attention lavished on two of its other academic sons, also at Cambridge, Francis Crick and James Watson (figure 19 and 20). During that same remarkable year, Watson and Crick—whose death in July, 2004 sent wistful tremors through the scientific press—stunned the world when they announced that they had explained the structure of deoxyribonucleic acid (DNA). In much the same way that Ventris showed how the syllabic arrangement and internal structure of Mycenaean made legible the building blocks of ancient Greek, Crick and Watson showed how the chemical arrangement and internal structure of DNA rested upon the terms A, C, G, and T (corresponding to the nucleotides adenosine, cytosine, guanine, and thymine), which served as the building blocks for all organic life. As Maurice Pope observed in his 1975 study *The Story of Decipherment*, "Those who remember 1953, when Ventris and Chadwick published the decipherment of Linear B, will recall that it was marked by two other great accomplishments. Hillary and Tensing made the first successful ascent of the highest mountain in the world. Crick and Watson established the structure of the DNA molecule, and so took the first step in explaining the mechanism of life." From the planet's highest peak to the chemical microstructures that constitute living organisms, our understanding of the terrain of the earth and of our own material bodies underwent a significant paradigm shift, as life now could be mapped as a series of apparently simple and recombinant codes—from the exploratory duos to the repeating Linear B glyphs to the four reshuffling nucleotides to Butts' triple-and-quadruple letter-scores.

Pope's emphatic correlation between these diverse campaigns toward charting and codification suggests that the status attached to such accomplishments was not an

Figure 19. Francis Crick

Figure 20. James Watson

incidental component of postwar culture, but was in fact central to it. Indeed, the work of Ventris, Crick and Watson, et al. took shape during a particularly pernicious historical moment, charged with what can only be described as cryptographic anxiety. At approximately the same moment when the scientific elite and popular media were celebrating archeological and biological code-cracking triumphs, British intelligence was seeking to alienate one of its military prodigies: Alan Turing (figure 21), the brilliant mathematician and pioneer of what would become known as artificial intelligence. In 1938, Turing was invited from Cambridge to work with the Government Codes and Ciphers School in London. They were interested in a typewriter-like tool Turing had developed, which used complex algorithms to transform any message into impossibly irregular—and therefore cryptographically inviolable—combinations of three-letter words. Working with British espionage services, Turing applied the device, which became known as the "Enigma Machine," to break the secret three-letter wireless messages used by the Germans to communicate with their bombers and U-boats. By 1940, he had definitively cracked the Nazi code. But in 1952, just as Ventris was completing his decipherment of Linear B, Turing was arrested on charges of indecency after he casually admitted to a Manchester police officer his involvement in a homosexual relationship. For his crime, Turing was forced to undergo "orgotherapy," a series of estrogen treatments designed to neutralize what was presumed to be his testosterone-driven desire for men. Two years later, in a gesture combining classical and Biblical allusions, Turing committed suicide by eating a cyanide-dipped apple; the orgotherapy had, among other things, induced gynecomastia, which had enlarged his breasts.

For the self-consciously heterosexual culture of the early 1950s, Turing's proclivities constituted deviance, not only in terms of his sexual orientation but also in the breach of trust his transgressions represented. After becoming a national hero by outwitting the Nazis, Turing became a national embarrassment, and through the alchemy of displaced abjection, the Nazi peril was transmuted into a homosexual menace. The decipherer himself became an enigma; Turing's homosexuality was treated as a riddle that could not be broken, except perhaps through erasure by suicide. Indeed, for postwar scientists and psychologists, homosexuality signified a kind of behavioral Linear B, a totem of puzzling difference whose features, facilitated by a subculture with its own social clues and linguistic codes, represented a closed book and looming threat to those unable to read it. Yet Turing was also a test case for demonstrating that, whatever beliefs were projected onto homosexuality as evidence of *social* deviance, homosexual persons did not in fact represent *mathematical* deviance. By readily admitting to his homosexuality, Turing confirmed the existence of a subculture that "should" have remained encrypted, but which instead was revealed as legible through the culture at large. Witness, for example, the efflorescence of Polari, an idiom devised by urban gay men in Britain during the 1950s and 1960s that was an amalgam of Italian, Cockney rhyming slang, thieves' cant, and street Yiddish and which, paradoxically, regularly surfaced on BBC broadcasts.

Figure 21. Alan Turing

Figure 22. Michael Ventris

Of course, demographic frequency and distribution do not de facto guarantee social tolerance, just as legibility does not automatically translate into comprehension. But a hallmark of Cold War-era investment in the political utility of rational control was precisely this elision of biological or statistical difference and social or moral undesirability. Quantitative processes for unraveling and codifying the data produced by living organisms—variously analogous to the solving of word games, the "treatment" of homosexuality, the elucidation of DNA structure, or the unscrambling of ancient writings—enabled scientists not only to demarcate what distinguishes the merely numerous from the dangerously deviant or the productively patterned, but also what distinguishes conscious and deliberate—and therefore acceptable—human activity from the automatic and unconscious impetus under which much of life operates.

Such suspicion of irrational proliferation, furthermore, implies a metaphorical relationship between human infiltrators like urban homosexuals or wartime enemies and natural agents of environmental invasion. At this level, the adventures of *Dendroctonus mexicanus*, a pine bark beetle, become instructive. In 1949, J.P. Perry, a scientist working for the Rockefeller Foundation's Agricultural Program in Mexico, began a series of studies of the infestations of pine forests in central Mexico by *D. mexicanus*. In a 1951 article for the Rockefeller Foundation's journal *Unasylva*, Perry described the beetle's depredations as epidemic; the initial outbreak had occurred in the small towns of Tlalmanalco, San Rafael, and Amecameca in the mid 1940s, and by 1949 had spread to approximately four thousand acres of surrounding countryside. Like the Nazi code, or the so-called Communist conspiracy, or the homosexual subculture, *D. mexicanus* could be contained only if its inner sancta could be penetrated, its social structures explicated, and its biological mechanisms uncovered using the weapons of experts.

Perry's contribution to the study of the beetles was two-fold. He observed and quantified the methods and frequency with which they "attacked" pine trees, and how their initial assaults made possible secondary and tertiary incursions by successive waves of the insect species *D. valens* and *Ips bonanseai*. Perry also described, for the first time, the interior spaces carved through infestation, in which *D. mexicanus* laid its eggs, thus making it possible for the insects to use specific trees as anchors for the wholesale takeover of pine forests. In his detailed descriptions of the creatures' fertilization rituals, which take place in "nuptial chambers," and the intricate tunnels used to create "egg-galleries," Perry portrayed an architecture of occupation and propagation paradoxically tempered by language that equated insect invasion and sexual reproduction.

The language of heterosexual connubiality, however, was only one aspect of Perry's anthropomorphic reverie. His article concludes with recommendations for the control of beetle infestations, including both natural and artificial techniques—the introduction of woodpeckers; new forest management strategies; and the spraying of toxic oils that make pine trees uninhabitable by *D. mexicanus* and its apprentices. But Perry also devotes whole sections of the *Unasylva* report to field observations and philosophical speculations (such as the section on "Group Attacks") about the actions of *D. mexicanus*, many of which he attributes to ravenously devious instinct: "As long as there are sufficient living pines in the larger infestation centers, the insects apparently merely spread out from the group kill." By casting his remarks about entomological life-cycles into the language of terrorism, Perry attributes to natural processes a form of irrational, asocial behavior that can only—that must—be isolated and rehabilitated by human agency.

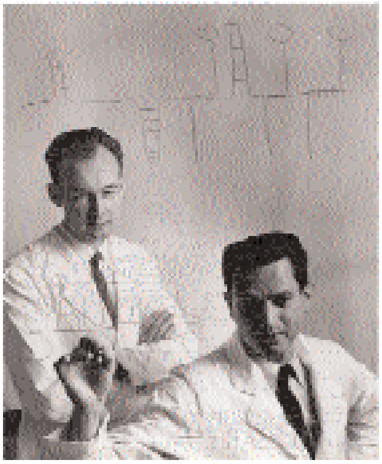


Figure 23. Heinrich Matthaei was Marshall Nirenberg's first postdoctoral researcher. Their collaboration led to the now famous protein synthesis poly-U experiments and the first clue to the genetic code. (1961, National Medical Library, Bethesda, MD)

Rehabilitating the marauding predator, be it national, sexual, chemical, or entomological, is of course only the first step in the re-rationalization of social life at its most basic levels. The real dream of the codifier or code-cracker is to move beyond decryption to readability and thence, if possible, to communication and rewriting of the code. It was this aspiration to mastery of biogrammar that excited scientists around the world in 1961, when Marshall W. Nirenberg, a research scientist at the National Institutes of Health in Bethesda, Maryland, announced his own findings about nucleotides. Nirenberg explained how, in experiments with uracil (a variation on the nucleotide thymine), he had been able to direct the building of an amino acid chain composed of phenylalanine. In a strange analogy to Turing's three-letter algorithm in the Enigma Machine, Nirenberg deduced that three units of uracil (UUU) composed phenylalanine's three-letter "code-word." He soon saw, in other experiments, that AAA (three adenosines) was the code word for the amino acid lysine, while GUU—one unit of guanine (G) added to two units of uracil (UU)—was the code word for valine. By 1966, Nirenberg had successfully deciphered the entire genetic code by translating 21 amino acids into their respective three-letter terms. As American biochemist George Beadle and his wife Muriel Beadle wrote in their 1966 book *The Language of Life*, "the deciphering of the [genetic] code has revealed our possession of a language much older than hieroglyphics, a language as old as life itself, a language that is the most living language of all—even if its letters are invisible and its words are buried deep in the cells of our bodies."

Nirenberg endeavored to move beyond the understanding of DNA as that which could be broken and decoded. Whereas for Crick and Watson biological processes were akin to a linguistic system with its own coherent internal logic, and for Perry insect activity was a kind of behavioral mystery that, once solved, could suspend the beetle's instinctive depredations, Nirenberg focused on what he perceived to be the next phase of molecular research: the manipulation of genetic material itself. Beginning in the late 1960s, biologists began increasingly to describe DNA as an information-processing machine whose formerly enigmatic operating system was now ready to be reengineered and rationalized for assembly-line service to the greater good (or, perhaps prophetically, to the commercially viable). As Nirenberg observed in *Science* in 1967, "Man now understands the language of the civilization, has written quite elementary messages in the form that robots understand, and via such texts has communicated directly with the robot. The robots read and faithfully carry out the instructions." Nirenberg's comparison between genetic mechanisms and industrial robotics was not coincidental: by the early 1970s, molecular genetics, artificial intelligence research, cybernetic systems, and semiotics had developed a palpable scientific and ideological synergy that became the standard vision of biomedical realism for the next three decades. In June 2000, for example, in a celebrated collaboration between the federally funded Human Genome Project and the privately funded Celera Genomics, scientists at both institutions announced that using supercomputers they had decoded and sequenced all three billion "letters" in the 35,000 genes found in the human genome, thereby providing a vast semiotic grid for future technicians to read, interpret, and use.

Among the many insights gained about the human genome in the course of its sequencing was the revelation—predicted by some scientists in the 1980s but confirmed with the announcement—that, outside of these decoded 35,000 genes, approximately ninety-eight percent of the genome is illegible "junk." In contrast to the ingenuity and elegance represented by Turing's Enigma Machine or Crick and Watson's DNA structure, the human genome apparently consists of endless and often redundant sets of pre-grammatical hiccoughs and tepid bursts of white noise that are not only unreadable, but may in fact prove that deciphering our own biogrammar will be either the great ontological challenge of our time or an enormous cosmic joke. Still, the illegibility of the genome has not prevented some companies with names like Rosetta Inpharmatics and deCode Genetics from making valiant attempts to de-encrypt what they perceive to be the genome's hidden messages. Some scientists, such as IBM's Isidore Rigoutsos, advocate "data-mining" approaches that assign alphanumeric sequences to genomic data and then apply the techniques Michael Ventris used in the decipherment of Linear B. The cryptographic gestalt, forged in the crucible of Cold War urgency, has so deeply saturated our own historical moment that we can hardly detect its presence, let alone parse its meaning in order to make it comprehensible.

In the aftermath of September 11, 2001, the multi-billion-dollar and multinational networks that have nurtured research and development in genomics—endeavors which depend almost exclusively on the recoding and remapping of biogrammar, and which promise applications in pharmaceutical research, biotechnology, genetic engineering, nanotechnology, and so forth—exist in awkward symbiosis with an ever-growing diffusion of predators, marauders, and renegades who resist all coordinated efforts to code, map, and control their activities. Medical geneticists believe they can know and understand the distribution and frequency of "code words" in the human genome that predispose the body to particular diseases. So, too, do intelligence-gathering agencies believe they can know and understand the distribution and frequency of codes and organic agents—whether human or microscopic—allegedly poised to do us unspeakable harms. Here again, displaced abjection transmutes the Communist menace, the homosexual deviant, and the ravenous pine bark beetle that haunted the Cold War mind into *bête noirs* for the twenty-first century: the fundamentalist terrorist, the HIV virus, and the biochemical weapon of mass destruction. In an aggressive spiral of Aristotelian epiphanies, we have had to come to terms with the fact that our intelligence is highly unreliable, while our knowledge is at best incomplete and at worst contradictory. Still, such epiphanies do not dissuade us from our dream of rational control and biological containment, just as Perry dreamed that one could contain the *D. mexicanus* epidemic and produce a better world. We may attempt to decode the vast stretches of proto-linguistic "chatter" in the human genome, just as we try to do the same in the chemical structures of killer viruses or in the organizational cells of terrorists. But there is no Enigma Machine for elucidating the most rudimentary genetic secrets. There is only the slow and quiet counting of time on wooden tiles.

The Origins of Intelligence*

Luc Steels

Abstract

Although substantial progress has been made on the question of the origin of life, less progress can be seen concerning the origins of intelligence. There is not even general agreement of what intelligence is. This paper proposes a definition of intelligence grounded in biology, which makes the question of the origins of intelligence seem more approachable. It then identifies two major transitions that must have been crucial in the development of intelligence: the origins of "general purpose" neural networks and the origins of language. Some experimental work is reported that tries to recapitulate these major transitions using an artificial life perspective.

1 Introduction

Where does intelligence come from? How can we explain that in a physical world populated by living systems, the capacity that we call intelligence developed? Astonishingly enough, we have hardly any theory about this. Science has developed reasonable, although still debated, theories of the origin of the universe, such as the Big Bang theory. There are also theories of the origins of galaxies, of the earth and the moon, and of geological structures. There are theories of the origin of life, the diversity of species, and the origin of Man. So, why don't we have a theory of the origin of intelligence?

The reason is partly that for many people no such theory is needed. Mind is eternal, they say, belonging to a Platonic universe. Seeking an explanation for its origins is therefore absurd. Such a Platonic view is still common today with mathematicians like Penrose [15]. However it is not a scientific explanation. It is similar to the earlier view that the origin of the universe needs no explanation because it has always been there and will always be there, or that all the different species, including Man, were created in a few days by an omniscient being. If we want a scientific theory of the origins of intelligence, we must close the gap between the basic laws of physics and biology and theories of intelligence. Right now the gap is enormous and it can only be closed by working from both sides.

This paper raises a few issues and provides some directions and experimental approaches for addressing the question of the origins of intelligence. No clear definite answer can be given yet, although a way can be pointed out. The first section defines

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intelligence as a continuum with current biological views of living systems. It is only by having such a definition that we can hope to pinpoint precisely where intelligent systems outgrow living systems.

2 Defining Intelligence

Traditional definitions of intelligence involve a strong subjective component. For example, Turing has defined intelligence operationally by an experiment in which a human tries to identify whether he is interacting with a computer program or a real human being. If this distinction is not possible, the program is assumed to be intelligent. Newell [14] has defined a system to be intelligent if knowledge-level descriptions, beliefs, and intentions can be ascribed to it. Both definitions are not only subjective because they rely on human judgement but also because they ignore the embodied nature of human intelligence and the function of intelligence in survival.

This section proposes an alternative definition of intelligence which seeks to establish a continuum with life. It first identifies the class of evolving complex adaptive systems, then identifies progressively more complex instances from chemical systems to living systems, and then to intelligent systems.

2.1 *Evolving Complex Adaptive Systems.* Let us delineate a class of systems with four defining characteristics: self-maintenance, adaptivity, information preservation, and spontaneous increase of complexity. I propose to call such systems evolving complex adaptive systems. Living systems are an obvious subset but there are already autocatalytic chemical reactions with the same properties and intelligent or cultural systems could be seen as other examples.

• Self-maintenance: Self-maintenance means that the system is actively establishing itself. To avoid annihilation due to increased entropy, the system needs to constantly rebuild itself by drawing materials from the environment and establish a boundary between itself and the rest of the environment. Maturana and Varela have called this process autopoiesis [11].

• Adaptivity: The system is not only capable of maintaining its own internal equilibrium for a constant environment, but also adapts when there are (small scale) changes to the environment in order to enhance its chances of further existence.

• Information preservation: The information defining the system is capable of being preserved so that the system does not depend on the continued existence of its components to survive. It is the role of the components that keeps the whole system together and if the various roles and their interrelations are preserved the whole system is preserved.

• Spontaneous increase in complexity. The most remarkable aspect is that the system is able to increase its own internal complexity. This could mean that there are increasingly more parts, more complex relations between parts, more complex behaviors of the parts, etc. Moreover, often instances of the same system come together to form a larger whole that operates as a single system evolving complex adaptive system at a higher level.

We can identify different instantiations of this basic class of evolving complex adaptive systems, where each instantiation builds further upon the previous instantiations but adds more powerful machinery so that self-maintenance and adaptivity is more successful, information is better preserved and the growth of complexity becomes faster. Each time a major transition has been responsible for shifting to the next level of complexity, but the new level then "slaves" the level below, or we can at least see a kind of co-evolution towards greater complexity of both. The major instantiations are (a) autocatalytic chemical reactions, (b) living systems, (c) intelligent systems, and (d) cultural systems. Conglomerations of these systems (groups of co-evolving reactions, species, colonies, societies) form among themselves, evolving complex adaptive systems with their own dynamics.

a. *Autocatalytic chemical reactions (uncoded life).* The various properties of evolving complex adaptive systems can already be seen in certain types of chemical reactions which are known as pre-life or uncoded life systems [8]:
• The reactions achieve self-maintenance by being autocatalytic. The substances that start the beginning of the reaction are regenerated, often after a long cycle and in larger quantities, so that the whole reaction chain can start again and proliferate. In some cases it is possible to show that boundaries form themselves [9].
• These reactions can be shown to be adaptive to changes in the environment. For example, the rate may slow down when temperature conditions change or when materials are less abundantly present. In some cases there are conditional pathways depending on the conditions in the environment.
• Autocatalytic reaction networks preserve information by making copies of themselves (with potential errors). Such copying has been synthesised in the laboratory.
• Autocatalytic reactions have recently been shown to be able to undergo evolution by natural selection, known in this case as molecular evolution. It is enough that there is a reaction that is autocatalytic and that variations occur in replication. When the environment (in this case the other chemicals present) provides selectionist pressures, then there is an evolution towards more complex molecules or reaction pathways that are capable of coping better with the selection pressures.

b. *Living systems.* Living systems clearly have all the properties of evolving complex adaptive systems. They most probably originated out of autocatalytic chemical reaction networks but achieve the characteristics of evolving complex adaptive systems differently:
• The simplest living systems (such as unicellular organisms) use metabolic pathways enclosed in cell membranes to maintain themselves while drawing materials from the environment. More complex living systems exhibit a much wider behavioral repertoire because groups of cells form organs with complex coordinated functions.
• Adaptivity is now not only achieved using chemical means but by changes in behavior, such as heavier breathing when oxygen content is lower or slower movement when it is very hot. Behavior is controlled using special-purpose neural networks.
• The most important innovation is, however, the preservation of information by coding the system in terms of genes. This requires the “discovery” that proteins can function as interpreters of a code [5]. The code itself, in the form of DNA, is now copied as opposed to the whole organism. Additional proofreading while copying assures that much more complex information can be preserved, not only for creating the next generation of an individual but also for constantly regenerating parts of a single individual.
• The genetic mechanism also provides a much more powerful way to generate more complexity. The code is mutated or combined via crossover operations and then subjected to naturally occurring selection. A larger search space of possible life forms can thus be explored and it becomes easier to build further upon existing complex forms. Other ways are used to increase complexity as well, which include level formation and self-organisation.

Based on these principles living systems have shown several transitions towards ever-greater complexity. Recent overviews of the important transitions have been given by Maynard-Smith and Szathmary [12] and de Duve [3].

c. *Intelligent systems*. Intelligent systems can be defined as systems that have the same four properties (self-maintenance, adaptivity, information preservation, and increase in complexity) but use other means to achieve them. It is not yet completely obvious where the key lies, but two things are surely important:

• Neural networks, which initially were completely specific, have become general purpose structures which can store a large number of complex behavioral patterns, sustain processes for interpreting signals from the world, and can control at a fine grained level complex action patterns. Most importantly, these networks and processes develop and adapt themselves continuously and very quickly (compared to genetic evolution).

• At some point a symbolic capacity has developed: This is the ability to interpret the world in terms of concepts, to represent states of the world using these concepts, and to perform symbolic reasoning by manipulating these representations. This symbolic capacity also sustains symbolic learning.

These features result in superior capacity for all the four properties of evolving complex adaptive systems. Self-maintenance is enhanced by the ability to handle much more complex behavior, to be responsive to many more environmental influences, and to control much more complex actuators (such as hands). Adaptivity is enhanced by the capacities of neural networks to acquire new knowledge and by symbolic learning. There is a vast increase in the amount of information that can be preserved, compared with the genes. Finally, there is a steady and fast build up of complexity, particularly during the developmental stages of the organism.

d. *Cultural systems*. It is useful to define yet another instance of the general class of evolving complex adaptive systems, namely cultural systems of which language is one of the main examples. Other examples are religious systems and social systems. These cultural systems appear to have their own internal dynamics which cause them to maintain themselves, adapt, preserve information and become more complex. Thus languages originate, develop, and sometimes die, like organisms. They are formed by the joint distributed action of millions of individuals that speak a language. Languages constantly adapt to changes in the meanings that users want to express and have become more complex to cope with the pressure of reducing cognitive overload for speaker and hearer as well as the pressure to say more in a shorter time frame.

Interrelationships

There are complex interrelations between these different types of systems because one system is built on top of another: living systems embody a multitude of autocatalytic reaction networks, intelligent systems have grown out of living systems, and cultural systems have evolved through intelligent systems. Often a “slaving” relation can be observed between the different layers. For example, once living systems come into existence, they enslave autocatalytic reaction networks to become metabolic pathways under the control of the genes. Similarly, the vocal apparatus necessary for speech is an adaptation from the earlier vocal apparatus, observed in chimpanzees, which could not make so many distinctive sounds. The development of the vocal apparatus in Homo Sapiens results, however, in a high risk of choking, which was non-existent before, and a dislocation of certain teeth (wisdom teeth) which often have to be removed surgically. These two features are disadvantageous from a purely biological survival point of view but developed nevertheless to support the complexification of language.

The complex self-enforcing relations between levels are probably crucial for understanding intelligence. On the one hand, intelligent systems have grown out of living systems. On the other hand, intelligent systems are the substrate on which cultural systems have evolved. Language is a cultural system that clearly seems to have played a primordial role in pushing intelligent systems toward the extreme plasticity that is known today. Cultural systems have their own dynamic which sometimes (as in the case of wars due to religious or nationalistic tendencies) enslaves the individuals to act against their own self-interest or the interest of others.

3 Steps toward intelligent systems

The problem of the origins of intelligence can now be posed with much greater precision. First, we need to understand how neural networks, which initially were completely specific, could have become general purpose dynamical systems. Second, we need to understand how an independent symbolic level could have emerged. For none of these questions is there a plausible answer today. This section provides some more discussion and then sketches possible technical and experimental approaches.

3.1 *The plasticity of the neural substrate.* We need to find the major transitions through which neural networks, which were initially special-purpose and hence the subject of genetic evolution by natural selection, have become general-purpose and moldable by developmental and learning processes. There is so far no theory to explain this, partly because there is not yet an adequate theory that explains the plasticity of neural networks as such.

Two approaches have dominated research on plasticity so far. The first approach focuses on mechanisms that perform induction based on a large number of example behaviors, either supervised or unsupervised. Various neural network techniques have been proposed and applied with varying degrees of success [23]. This approach relies however on the prior availability of enough examples and assumes enough time to perform the inductive process. These conditions are seldom satisfied for agents having to stay viable in an unknown environment. The second approach performs a kind of genetic evolution. The behavioral networks are subjected to random variation by mutation and crossover and consequent selection [7]. This approach cannot work on a single agent that has to stay viable as it acquires new behavior, because it relies on the exploration of a population of agents of which most members will fail to survive. Genetic evolution is in general too slow to be responsive to changes to the environment fast enough. When studying intelligent systems we seek especially mechanisms which are not genetic.

Our own approach is selectionist in the sense that behavioral networks are generated independently of the environment in which they have to operate and then subjected to selectionist pressures. But the selectionist process takes place during the lifetime of the individual. Different variations are tested after each other. The exploration strategy must be such that the agent remains viable. The proposed mechanism has some strong relations between the "neural darwinism" hypothesis of Edelman [4] which focuses however on the acquisition of categorisation competence, as opposed to behavioral regulation, for remaining viable in a challenging ecosystem.

In our laboratory we have set up a robotic ecosystem to experimentally investigate this selectionist development process. The ecosystem includes a set of small robots which have about 20 sensors, a series of actuators including two motors driving left and right wheels, and their own computational capacity and batteries. The ecosystem is generic for situations where a developing agent is confronted with a growing population "p" of competitors for its energy resources. There is a steady inflow of these resources in the ecosystem to reach a level "g." The developing robot has an internal energy level which decreases due to normal bodily operation and active behavior. Internal energy can be replenished by recharging at a certain location. The resource availability at this location "b" is replenished from the globally available resources. The competitors which take the form of lamps, grow by consuming as well from the globally available resources. So the more competitors there are, the less resources will be available for the robot. But the robot can combat the competitors and thus maintain an adequate supply of resources for itself. The situation is moreover such that one robot cannot survive on its own. It needs to cooperate with other robots so that they take turns to work and recharge.

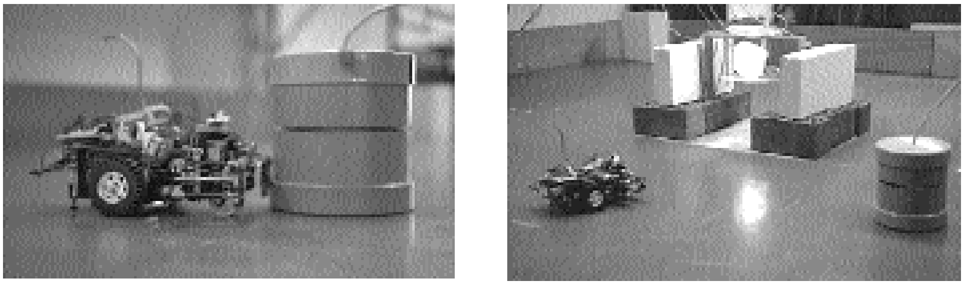

Figure 24. Robotic ecosystem as physically realised at the VUB AI laboratory. There are a number of robots which can recharge themselves in a charging station. There is competition for the energy flowing in the charging station in the form of lamps which can be put out by the robots by pushing against the boxes in which they are housed. (L. Steels, 2004)

Given this ecosystem, a cyclic series of activities is observed in which the robot seeks the charging station where resources are available, consumes resources to replenish its battery, moves out of the area to seek out the competitors, and looks for the charging station again when its energy level is getting low. A developing robot should be able to learn these behaviors while interacting with the environment. At the start of the experiment, the robot performs a default random walk behavior which, due to the benign initial conditions, nevertheless results in viable behavior. The robot is assumed to have a variety of basic behavior systems in the spirit of the behavior-oriented approach [17]. Each behavior system is a goal-seeking feedback control system modulated by a motivational quantity. For example, for alignment to visible light, the goal is to have zero difference between the left and right photosensors. The motivation is linked to energy deficit.

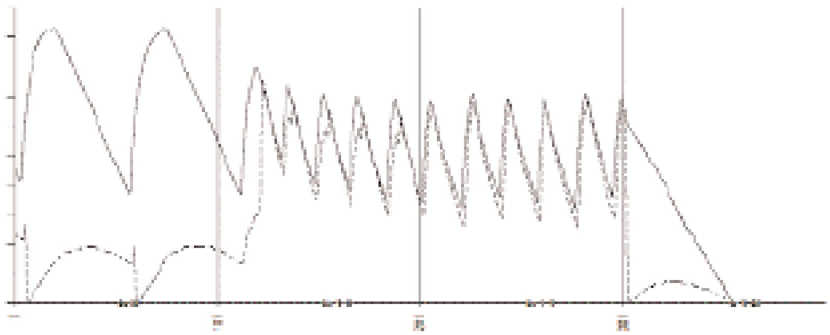

Figure 25. The different combinations of the forward movement motivation and the contact sensor are tried for 100 time steps each. Actual energy level and forward movement are shown. Only b9 (the first one) produces a significant improvement in performance.

Figure 25. shows a snapshot of the learning process which takes the form of the successive exploration of different alternative behaviors by instantiating certain couplings between sensor or motivational quantities and motor quantities. In this example, the robot is trying a connection between a contact sensor which detects that the robot is in the charging station and in the process of forward movement. The robot "discovers" that it should stop in the charging station. More details of these experiments can be found in [21], [22].

Although we have managed to get some build up of behavioral complexity, it is still too early to say that this kind of selectionist process gives the desired flexibility and plasticity that we see in intelligent behavior, and then there still remains the problem of how the dynamics implied by this scheme could have evolved out of special-purpose dynamical networks.

3.2 *Language as the key of a symbolic layer.* Classical symbolic AI systems exhibit great complexity for particular functionalities such as expert problem solving, chess playing, etc. But this functionality is typically completely programmed by hand based on an analysis of human competence. These systems are therefore frozen instances of intelligence as opposed to evolving adaptive intelligent systems. Moreover they mostly do not have any direct relationship to reality but need a human to interpret reality and supply the symbolic descriptions that are needed. Unfortunately, not much progress can be seen yet on how the gap between sub-symbolic and symbolic capacities should be bridged, nor on the question of the origin of the symbolic layer.

Most of the present work assumes that there are abstraction facilities in neural networks or a new higher-level dynamic that may emerge. In our own work, we take a quite different approach. We assume that language has played a key role in the formation of a symbolic layer in human intelligence and therefore focus on experiments in which the origin of language could take place. We are exploring two hypotheses:

a. Language is an autonomous adaptive system which forms itself in a self-organizing process. Language is therefore similar to other self-organizing phenomena observed in biosystems, such as paths in an ant society, clouds of birds, etc. A language is viewed as an adaptive system in the sense that it has to allow its users to express an open-ended, ever-growing or changing set of meanings with an open-ended but finite set of building blocks and combinations of building blocks. The speakers and hearers are distributed agents that through their localised linguistic behavior (namely the carrying out of conversations) shape and reshape the language. No agent has a complete view of the language and no agent can control the linguistic behavior of the whole group. Moreover no separate mechanism for language acquisition is necessary because the mechanisms that explain the origin of language also explain how it is acquired by new agents entering the community.

b. Language spontaneously becomes more complex based on the same mechanisms that give rise to complexity in biosystems in general. The development and evolution of language is primarily driven by the need to optimize communicative success and handle the very strong constraints which hold for open-ended, real world languages; namely, limited time to communicate, limited time to process the utterance, weak and error-prone acoustic transmission, limited feedback about success, constraints of the vocal apparatus, etc.

Self-organization is a common phenomenon in certain evolving complex adaptive systems. To support self-organization a system must exhibit a series of spontaneous fluctuations and a feedback process that enforces a particular fluctuation so that it eventually forms a (dissipative) structure [16]. The feedback process is related to a particular condition in the environment, for example, an influx of materials that keeps the system in a non-equilibrium state. As long as the condition is present, the dissipative structure will be maintained. Some standard applications of self-organization can be seen in morphogenetic processes, or the formation of a path in an ant society or a termite nest [2].

A language can be viewed as a dissipative structure similar to a path in an ant society. Each agent is assumed to create and continuously change his own language in a random fashion, resulting in a fluctuating linguistic community. Language must be shared in order to obtain the benefit of cooperating through communication. Hence the changes are coupled to communicative success: the higher the success the less probable a change. This results in a feedback process. When more agents use the same word for the same meaning, communicative success increases and therefore the word-meaning association becomes more stable. It has been shown that coherence indeed emerges [18].

In one experiment (reported in [19]), agents developed spontaneously and autonomously a vocabulary to talk about themselves and identify spatial relations among themselves. Here is a sample of dialog where the object is introduced by a-25 using a spatial description (straight in front of me) expressed as "b u v a j a" and confirmed by a-23 using another spatial description (behind me to the left) expressed as "b a t u I o."

```
Dialog 1142 with  a–25  a–23
  => a–25:  (a–25)

    a–25:  a–25  –>  (B  U) <– a–23:  a–25

    a–25:  FRONT  –>  (V  A) <– a–23:  FRONT

    a–25:  STRAIGHT –> (J  A)   <– a–23:  STRAIGHT
```

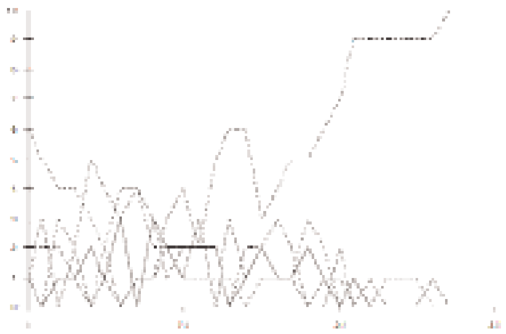

Figure 26. The results of a typical experiment with 10 agents, 5 possible words, and 1 meaning. It plots the communicative success of each word (y-axis) over time (x-axis). We see a search period in which different words compete until one gains complete dominance.

```
=>  a–23:    (a–25)
    a–23:    a–23  –>  (B  A)  <–  a–25: a–23
    a–23:    BEHIND  –>  (T  U)  <–  a–25: BEHIND
    a–23:    LEFT  –>  (L  0)  <–  a–25: LEFT
=>  a–25:    (a–25)
    a–25:    confirm-  –>  'yes'  <–  confirm
```

Additional experiments are currently being performed to explore issues like ambiguity and semantic indeterminacy [20], the formation of morphological and syntactic structures, the indirect mapping of meanings to words (where one word may capture many different meanings), the emergence and handling of ambiguity, the grounding of language in robotic agents, the creation of new meaning, etc. Through such experiments we expect to understand better how complex symbolic representations form themselves. Similar processes must be going on internally in the brain to form and shape the mental language in which knowledge is expressed, although we have not yet carried our experiments in this area.

4 Conclusions

Much remains to be discovered before a theory of the origins of intelligence can begin to take shape. We need to understand how the brain is capable of exhibiting its remarkable behavioral plasticity and how a symbolic layer might have emerged. Experiments using software agents and robotic agents appear to be a very difficult but, at the same time, rewarding way to pose questions, imagine possible answers, and experimentally test them.

Acknowledgements

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The Meander As a System:
The Analysis and Recognition of Iconographic Units in Upper Paleolithic Compositions*

Alexander Marshack

The invitation to the Canberra conference suggested that I discuss the subject of "How one can recognise iconographic units within schematic representations." I shall try to do so with a discussion of a particular class of symbolic material: that body of upper palaeolithic image that is variously described as meander, "macaroni," or serpentine and often as meaningless and beyond interpretation. It is significant in this regard that the three major interpretative or evaluative volumes on upper palaeolithic art published in the previous decade (Leroi-Gourhan 1965; Ucko and Rosenfeld 1967; and Marshack 1972) barely mention this body of marking. In one case it is referred to as "superpositioning [in which] the immediate impression is of a mass of thousands of engraved or painted lines..." (Ucko and Rosenfeld 1967:40), in another it is a masculine sign or a sign under the subheading of "unfinished outlines" (Leroi-Gourhan 1965:125). I made no mention of this form of marking.

It is clear that archaeologists have not known what to do with this class of marking or image. The reason, simply, is that there has been no theoretical basis for internal analysis or interpretation of the form, no technology for its study, and no means of relating these forms to the recognisable animal images with which they are often associated.

Attempts had been made to describe them. These are instructive for the problem of "how one can (or does) recognise iconographic units...." They indicate that what we "see" or recognise conceptually are usually "units" and "patterns" in terms of our culture, units and patterns which are relevant to us in terms of equations derived from our West European training. This paper will indicate how such "ways of seeing" change. The images or "iconographic units" will not change. The paper will touch on the problem of how "iconographic units" differentiate themselves for the maker and for the analyst.

The first careful descriptions of these markings were offered by Breuil, primarily as part of his documentation of particular caves. Since Breuil was interested in developing a comparative chronology and typology of art styles, the markings were seen, at least in part, as the earliest intuitive random scribbles within which recognisable images may originally

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have been seen and out of which the tradition of crude, simple, outline figures emerged or developed. The relatively crude animal outlines found in Breuil's early "Aurignacian-Perigordian period" are often greatly interlaced with such meanders or macaronis.

I quote Breuil in his description of the La Pileta (Malaga) meanders:

> The serpentine forms, ...so-called by stressing an exterior aspect which may be false, are exclusively localized in the lateral galleries...the interpretation... remains doubtful; perhaps the artists had no representational idea in mind, at least at the start. In this respect, the images are perhaps analogous to the meandering decorations made in the clay with fingers or an instrument with many points noted at the start of Aurignacian art at Hornos de la Penia, at Gargas, etc.... At La Pileta the technique is different since it was done by painters, but the forms are closely related. It is probably an ornamentation derived from marks left on a wall by a hand dirtied with clay.... (Breuil et al., 1915:17-18).

Breuil offers a long description of the diverse meanders made with yellow, red, or black paints.

> What is the meaning of these black serpentine forms? It is probable that they are a link in a chain derived from the primitive yellow serpentine meanders and continued by the red spiral designs. One is able to state only that the distinctive elements of the class are continued. As to whether these black serpentine forms are images of serpents, we take no absolute stand. (Ibid:24).

> If it is verified, particularly among the Australian Aborigines, that drawings of serpents are frequent and highly sacred, I would not be opposed to accepting such a conclusion ... (Ibid:41).

Breuil had, in 1915, few alternatives. He could describe, he could say that they looked serpentine, and he could seek ethnographic comparison and analogy. There was no way at this stage that archaeology could approach the images methodologically or analytically or in terms of contemporaneous comparative upper palaeolithic data.

The next stage of analysis and interpretation was offered by Leroi-Gourhan. The large number of upper palaeolithic caves discovered by mid-century, nearly 200, had provided a huge body of descriptive data. Leroi-Gourhan could, therefore, statistically study the association of images and signs with each other and their dispersal and placement in the caves. Utilising the available theory of the time, he termed these relations oppositional, polar, or "sexual," broadly male/female, and the placement or spatial distribution of these images as either central or subsidiary.

For Breuil and Leroi-Gourhan the meanders formed "near iconographic" units of different types, serpentine-meander (perhaps a snake for Breuil) and linear-phallic (perhaps a male symbol for Leroi-Gourhan). In both cases the meanders were mentioned more because of their presence than discussed because of their significance. Both efforts were valid and achieved results in description and early, tentative interpretation.

Figure 27. Breuil's rendition of the animals and meanders on the walls and ceiling of the small sanctuary. (Breuil 1952)

On a comparative basis, Leroi-Gourhan states that "There are two distinct types of symbols: solid forms such as triangles, ovals, rectangles and circles, and linear forms such as lines of dots, dashes or branches" (1972:8). The round are "female," the linear "male," and the linear serpentine meanders, therefore, crudely and unimportantly "male" or else "unfinished outlines." In his major work (Leroi-Gourhan 1965) these images do not receive substantial discussion, and they are not a major item in the book's catalogue of signs. They are, however, illustrated as "male" signs in his introductory paper on upper palaeolithic symbolism where they are described:

> Incomplete outlines and bundles of lines...form a very curious part of the Palaeolithic compositions. With very few exceptions they exist in every cave. Their location is almost constant,...between the entrance and the first group of large signs.... Among the bundles of lines the variations are numerous, but remain centered on two types which often depend on the nature of the rock: meanders or finger-print impressions and fine lines. Frequently the fine lines are grouped in parallel series of regularly spaced or doubled and tripled lines.... They can also form bundles in "comets," tortuous "rivers," "huts." (Leroi-Gourhan 1958:314)

In the Leroi-Gourhan formulation these are all considered to be subsidiary, masculine "signs."

In 1964, 1 began a study of the upper palaeolithic symbolic materials on a different theoretical basis. Instead of trying to recognise or interpret images or signs on the basis of what the modern eye sees or on what historic cultures might offer for analogic comparison, I tried to develop techniques and a theoretical basis for the intensive internal analysis of the upper palaeolithic symbolic materials. The way an image or composition was made or used might give more information than the form or "image" we recognise.

Simple efforts in the direction of internal analysis had been made before. The over-engraving or over-painting of one image by another had been used quite early by Breuil for the purpose of trying to establish chronology of styles. My effort, however, was not directed toward such long-range chronological or typological enquiries but rather to a study of the cognitive processes involved in the formation of an image, a study of the sequence of making an image or a composition or the sequence of accumulating images on a surface. For this reason the mobiliary artefacts, rather than the more or less public walls of the cave, were used to initiate the study. This enquiry was, therefore, not archaeological in the traditional sense, that is, devoted to typology or chronology, but functional and psychological. The complexity of the psychological data accumulated in the microscopic analyses of the engraved materials required recourse to non-archaeological disciplines. At a distance of 20,000 or more years simple visual examinations or "recognitions" might be used in the construction of typologies of style but, for an understanding of semantics, one must try to determine the cognitive, conceptual system within which an image functions and those personal and cultural strategies and models which are involved in the making and use of the image. (pp.286–7, Ucko)

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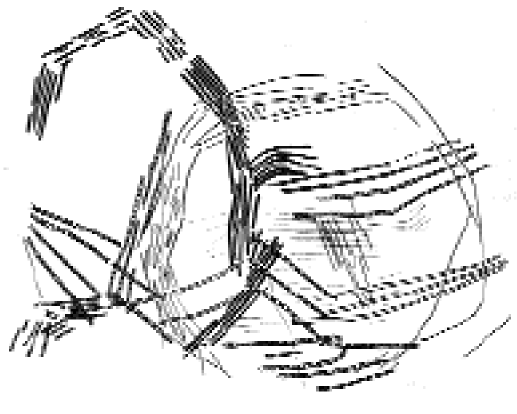
There are…complex examples [of meanders], some so confusing that they have not been adequately published….[An] example presents the kind of over-engraving and criss-crossing that gives the impression of a random macaroni (figure 28). The microscope reveals a central, core meander consisting of two branches (figure 29). Over this a second meander is engraved arcing in the other direction. This continues as an encircling form made by a double arc that peters out at right. Added to this composition are six or seven linear sets, added at many angles, some consisting of only three parallel lines, others of a multitude, filling in an area. We have a variant of the system in which the primary meander is the most structured and the additions are increasingly abstracted and simplified. The composition, clearly, was not intended as a "visual form"; it was rather a participatory form of image-making.

The evidence indicates the presence of a symbol-making system whose structures and strategies can be studied although we cannot with certainty know the semantics of the system or the nature of the supporting language involved. I assume the necessity of language, however, at a level adequate to maintain and explain the symbol-making tradition.

My analysis of the Pech de I'Aze bone and my study of Mousterian symbolic materials from different European sites have suggested that vocalised language of a certain level of complexity must have existed in the Mousterian and perhaps earlier. If we assume that abstractive symbol making and language are essential processes in the adaptive cultural capacity of Homo sapiens, then the relation of the image-symbol-icon to language is crucial for any discussion of how we recognise the "iconographic unit." A full discussion is impossible here, but aspects of the problem can be touched on.

For three-quarters of a century the meanders had been seen, copied, and published. Yet no system could be determined. In large part this failure was due to the tendency to seek for the origins of "art" in the recognisable image, recognisable to us. Because recognisable images such as animals are occasionally found among the meanders, it was assumed that it was out of random marking that representational art was eventually born.

The present approach is different. It proceeds from an assumption that in the Upper Palaeolithic the recognisable image was not derived accidentally from random meander marking, first because the meanders are not random but, more important, because the ability to see an image in a random cluster (or in a rock or wall formation) requires culture. It is part of a process of description, classification, comparison, and naming. It is a human, cultural activity. In this regard, the ability to initiate and maintain an image system, such as the meander or macaroni, requires naming and language.



Top: Figure 28. Romanelli. Engraved portion of limestone slate with complex meander patterns. Some lines are so faint they are barely visible.
Bottom: Figure 29. Romanelli. Schematic rendition of the primary branched meander, the second meander that crosses over it and the linear subsidiary sets. (A. Marshack, 1976)

These thoughts are presented for an explanation of the process of analysis as well as for an explanation of the original process of making the meanders. It was by linguistic explanation that some of the cognitive, sequential processes, strategies, and uses were delineated and described. It was only after such description that the meander system could, at last, be "seen." I stress this point. It is not visual recognition that establishes the iconographic or symbolic nature of an image or form but the linguistic component as well. (pp.299–300, Ucko)

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Having followed the meander tradition in this analysis, it is clear that nothing in current theory concerning upper palaeolithic art explains either the meander tradition or the relation of the meander to the representational image. It is surely not a form of hunting or killing magic nor a form of sexual symbolism. Its essence seems to be that it is cumulative, sequential, relational and additive.

The iconography of the meander has been explored without any attempt at an interpretation of the meaning or semantics of the tradition. I shall now, briefly, touch on this problem which will be more carefully discussed elsewhere.

If one looks at the few thousand meanders, meander units and meander compositions found on the mobiliary materials and in the caves one is struck by the fact that no two are ever precisely the same. They vary from the very simple to the exceedingly complex and yet the system, in each case, is invariant. From the point of view of chronology it would be difficult to distinguish a simple Aurignacian-Perigordian meander from simple examples in the Solutrean, Magdalenian or Romanellian.

Yet the open variability that exists within the system is helpful. As in the making of upper palaeolithic animal images, there is the occasional work of the master as well as the crude effort. Where one man will tend to elaborate another will tend to abstract and schematise. It is in the occasional idiosyncratic elaboration that one often finds the range of subsidiary, related motifs and elements that suggest the possible meanings in the system. The Romanellian pebble [not shown] contains the funnelling at the beginning, the petering out at the end, the meander with internal angles, the associated series of zigzags, the sets of tiny marks, the double arcs, the single line as an addition. All of these elements appear in the meander system. Sometimes, in the Parpallo materials [not shown], the tiny marks fill the meander or "decorate" the meander line. Sometimes the meander is formed as an accumulation of parallel zigzags. Sometimes a set of single long lines are accumulated at odd angles on a slate without reference to a meander. Sometimes the serpentine form is elaborated in labyrinthian convolutions, at times empty, at times internally marked. These are aspects of the one tradition, and despite the variations, the system does not change. (pp.312–4, Ucko)

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The present analysis [looking at additional examples] has shown that the purpose of such meanders was not topographic. Nor, in most cases, were they intended to represent an image of "water." They were, rather, iconographic acts of participation in which a water symbolism or a water mythology played a part.

The possibility that water is implied as one aspect of the meander tradition is significant. If so, the "water" may have been broadly generic. The tiny marks found in the late meander tradition may have been indicative of a rain aspect. The zigzags may be an image of water, while the double-lined band may represent the river or stream. The funnelling into a band may represent the flow or drainage to a river after a storm or in the time of thaw. These water attributes may, in reality, be iconographic of a still different, encompassing symbolism in which the meander and one's participation in the system may have had a relation to the continuous flow of other processes, seasonal, biological, ceremonial and ritual. The "river" and its sequence of sets and subsidiary marks may have represented the unreal river of a shamanistic journey or effort. I suggest these possibilities to indicate the dangers of naming and recognising an image, in our terms, and then proceeding to an explanation of the form, again in our terms. (p.315, Ucko)

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We have in the macaroni-meander evidence of one of the earliest *Homo sapiens* symbol systems. It is "iconographic" but it is not really representational. It is an iconographic element in a participatory, ritual, ceremonial, mythical or narrative complex. The meander, its use and development were probably not simple. At one stage the meander becomes related to a truly serpentine snake imagery.

Since the present analysis has been entirely based on an internal analysis of the palaeolithic materials, without analogic reference to historic usage, I can perhaps indicate briefly that the serpentine-water-rain-storm-cloud image and mythology appears in the Eurasian Neolithic, in Australia (Munn 1973, 1974), in Africa and in the Americas. I am not postulating a diffusion of the image, but I am stressing the comparable cognitive processes involved.

Of equal importance, the data indicates that palaeolithic imagery constituted a system that was not primarily representational, but was often abstract, sequential, cumulative and interrelated at many levels. Images and symbols of different classes and meanings could be related, added and juxtaposed. It is this strategy of variable, cumulative symbol use that may explain the origins and development of palaeolithic art and a large proportion of the later petroglyphs in Europe, Africa, Australia and the Americas. (p.316, Ucko)

The Tongue Not Made for Speech:

Paradise Lost and Alternative Consciousness

Frances Richard

What may this mean? Language of Man pronounc't By Tongue of Brute, and human sense exprest?
—Milton, *Paradise Lost*, IX 553-4

Eve's wondering response to the articulate temptations of the Serpent—who mendaciously claims that he has gained rational consciousness by eating the forbidden Fruit of the Tree of Knowledge—is meant by John Milton to signal Eve's mortal naiveté, her damnable willingness to believe that God's hierarchies can be overturned. In Miltonic doctrine, God personifies the pinnacle of cosmic wisdom, holding an absolute dominion synonymous with prelapsarian harmony. For his worshipful creations—angels, Adam, Eve—to accept omniscient and omnibenevolent tyranny is to make a rational choice that lower orders—animals and plants—are not privileged to consider. To covet higher status in the chain of being is therefore irrational, a perversion of free will, a sin. Eve should know that snakes can't talk. She has been warned by Adam that Satan is abroad in Eden hoping to deceive her. Her susceptibility to the Serpent's verbal blandishments signals her fatal, feminine tendency to confuse appearance with essence, and to long for power she is not meant to enjoy. But it is also possible to read Milton against the grain here, as have critics since William Blake, and to discern in the description of a questioning Eve and an eloquent Serpent a tacit counterplot, in which the subordinate consciousness of woman and animal not only complements but contains and inverts the dominant discourse of God and man.

When Eve and Adam eat from the Tree, they gain knowledge of good and evil. That is, their eyes are opened to relative truth, binary division, dialectics. It is apt, then, that the Serpent should profess to have gained language through the Fruit, since language is constituted by such difference: "a" is "a" because it is not "b," just as good is good because it is not evil. In the paradisiacal world under God's Logos, there is no such arbitrary relativity; the sign "apple" beautifully fulfills the referent *apple*. A thing and its name are not painfully split; words enact meaning. Adam exults in this plenitude when, newborn but instantly mature, he enters language as a demigod or hero of Reason:

…to speak I tri'd, and forthwith spake,
My Tongue obey'd and readily could name
Whate'er I saw… (VIII 270-3)

Like an infant crying out, yet also demonstrating enlightened causal inferencing, the awakened Adam longs to know his Maker. God duly appears, and deputizes man as regent over animals, explaining:

...I bring them to receive
From thee their Names, and pay thee fealty
With low subjection... (VIII 343-5)

God's dominion over Adam parallels Adam's governance of beasts, demonstrated via the ability to speak and categorize, synechdoches for superior intelligence:

I nam'd them, as they pass'd, and understood
Their Nature, with such knowledge God endu'd
My sudden apprehension... (VIII 352-4)

For unfallen man, as for the angels, there is no barrier between earth and heaven, and "Heav'n/ Is as the Book of God" (VIII 66-7). Reading Nature's inner truth is effortless. The Fall mortifies language, marking the linguistic sign with ambiguity and inadequacy. But what is tricky in the epistemology of *Paradise Lost* is that instability in reference and depiction—a hallmark of postlapsarian distance from the divine—defines Eve *before* the Fall. When Adam wakes, he looks immediately skyward and inquires about God. Eve, waking, has a more narcissistic view:

That day I oft remember, when from sleep
I first awak't and found myself repos'd
Under a shade on flow'rs, much wond'ring where
And what I was, whence thither brought, and how.
Not distant far from thence a murmuring sound
Of waters issu'd from a Cave and spread
Into a liquid Plain, then stood unmov'd
Pure as th'expanse of Heav'n; I thither went
With unexperienc't thought, and laid me down
On the green bank, to look into the clear
Smooth Lake, that to me seem'd another Sky. (IV 449-59)

Not existentially lonely, not thinking to cry out to God, but attracted by the amniotic waters flowing from a maternal Cave, Eve turns earthward to what "*seem'd* another Sky," a counterfeit heaven. Deepening this evidence of her core misunderstanding of truth versus illusion, Milton compares man's primary colloquy with God to woman's first relational encounter:

As I bent down to look, just opposite,
A Shape within the wat'ry gleam appear'd
Bending to look on me, I started back,
It started back, but pleas'd I soon return'd,
Pleas'd it return'd as soon with answering looks
Of sympathy and love, there I had fixt
Mine eye still now, and pin'd with vain desire,
Had not a voice thus warn'd me, "What thou seest,
What there thou seest fair Creature is thyself,
With thee it came and goes: but follow me,
And I will bring thee where no shadow stays
Thy coming, and thy soft embraces, hee
Whose image thou art..." (IV 460-73)

Under prelapsarian rules of representation, Eve experiences her reflection as a distinct yet ineluctably connected self, an original molded from an original. The picture she sees *is*—for her—reality. The woman in the water is made in her image, as Adam—and Christ—are made in God's. But the consequence of such an active feminine Logos, in which the independent female subject propagates and contemplates herself, is oxymoronic and threatening in Milton's poem. Eve is meant from the beginning to be partial, a supplement from Adam's rib. The First Parents are explicitly formed "Hee for God only, shee for God in him" (IV 299), just as the animals are created to "pay fealty…in low subjection." Furthermore, whereas in the case of God and his Sons the idea of being "made in the image of" describes a metaphysical and spiritual homology, in Eve's situation the depiction is problematically physical and literal. The mirror-image *looks like* her, but it is a mirage, a deception. (It is instructive to remember that Satan has been able to enter the Garden because he has fooled the posted guard, the angel Uriel, by assuming another disguise, as a "stripling Cherub" [III 636]. This ability to embody morphological lies is synonymous with Satanic unrighteousness. In stark opposition, however, to the ontological disapproval with which Milton frames Eve's confusion about such false appearances, he excuses Uriel's lapse by explaining that "goodness thinks no ill/ Where no ill seems" [III 688-9]).

In Eve's nativity, a distinctively corporeal and femininely coded truce between artifice and identity looms. But, as if sensing the disruptive potential of such a relation, God hastily draws the reluctant Eve away from the scene of her unsanctioned and uncanny self-regard, instructing her as He does so about the Platonic properties of reflection. Since the image *is* her—"What there thou seest fair Creature is thyself"—no underwater interlocutor exists to beguile her. At the same time, since the image *is not* real, she herself becomes in a sense a simulacrum, and her attempt at autonomy is empty. Her only hope of gaining traction on authenticity is to be relinked, as a bridelike copy, to her original "Author and Disposer" (IV, 635). Then, as recompense for her forfeited self-sufficiency, God promises Eve a role in the patriarchal system into which she has just been inducted. She will submit to Adam as Adam submits to God, slipping into the animal role of obedient servant—though her place remains above the animals in that she, like a degraded xerox, retains an image-of-an-image connection to divinity. From this middle position between man and beast, she will help Adam to populate the world in a more acceptable version of self-copying: "to him shalt bear/ Multitudes like thyself, and thence be call'd/ Mother of human Race." (IV 473-4). All the forces of Milton's 17th century Christian rationality and notions of domesticity are marshaled against her. She relents, reluctantly:

> …What could I do,
> But follow straight, invisibly thus led?
> Till I espi'd thee, fair indeed and tall,
> Under a Platan, yet methought less fair,
> Less winning soft, less amiably mild,
> Than that smooth wat'ry image; back I turn'd,
> Thou following cried'st aloud, "Return fair Eve,
> Whom fli'st thou? whom thou fli'st, of him thou art…" (IV 474-82)

Milton argues forcefully here for Eve's inferiority of mind, her organic need of Adam as "Guide/ And Head" (IV 442-3). But, as Christine Froula and others have remarked, Adam—and God, and so Milton—in these passages might protest too much. Adam's plaintive call, "Return, fair Eve,/ Whom fli'st thou?" echoes his fear, expressed to the angel

Raphael, that though he has been assured of his superiority, something feels wrong He worries that he cannot hold Eve's interest, that her beauty compromises his masculinity, that there is some other, unknown object invisibly absorbing her attention. It is as if he sensed in his pliant, charming helpmate the persistent ghost of the desirable entity in the water, her first love-object. Interestingly, he imputes this possible shortcoming not to God, but to Nature:

> Or Nature fail'd in mee, and left some part
> Not proof enough such Object [Eve] to sustain,
> Or from my side subducting, took perhaps
> More than enough; at least on her bestow'd
> Too much of Ornament, in outward show
> Elaborate, of inward less exact.
> For well I understand in the prime end
> Of Nature her inferior, in the mind
> And inward Faculties, which most excel,
> In outward also her resembling less
> His Image who made both, and less expressing
> The character of that Dominion giv'n
> O'er other Creatures; yet when I approach
> Her loveliness, so absolute she seems
> And in herself complete, so well to know
> Her own, that what she wills to do or say
> Seems wisest, virtuousest, discreetest, best;
> All higher knowledge in her presence falls
> Degraded, Wisdom in discourse with her
> Loses discount'nanc't, and like folly shows;
> Authority and Reason on her wait,
> As one intended first… (VIII 534-55)

Adam's castration anxiety, his fear of Eve's "complete" and secret access to "Authority and Reason," is traced by Froula precisely to the compromise with patriarchal culture that has been worked out for woman by a complicit God.

It is this fear of losing access to Eve's enigmatic physical charisma that prompts Adam to eat the Fruit, "Against his better knowledge, not deceiv'd/ But fondly overcome with Female charm." (IX 998-9).

> Adam's dream of Eve's creation from his rib fulfills his wish for an organ that performs the life-creating functions of Eve's womb…It is not that Adam is an imperfect image of his God, rather, his God is a *perfected* image of Adam: an all-powerful *male* creator who soothes Adam's fears of female power by Himself claiming credit for the original creation of the world and, further, by bestowing upon Adam "Dominion" over the fruits of this creation through authorizing him to name the animals *and Eve*. The naming ritual enables Adam to translate his fantasy of power from the realm of desire to history and the world, instituting male dominance over language, nature, and woman.[1]

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[1]Christine Froula, "When Eve Reads Milton: Undoing the Canonical Economy," in *Canons*, ed. Robert von Hallberg, (Chicago: University of Chicago Press, 1984), p. 160. Italics original.

Figure 30. William Blake, "The Temptation and Fall of Eve" (cat. 5299)

If, then, *Paradise Lost* can be read as a tacit parable of what Froula calls "womb envy," Eve's openness to temptation by the Serpent, and the Serpent's offer of it—indeed, all the features of the scene, including the Fruit, the Tree, and the use of speech—take on new meaning. There is a natural attraction between the Serpent and Eve because both are allied to the *natural side* of a world that—even before the Fall—is divided into rational and irrational, divinity and bestiality, *eidos* and simulacrum. In fact, it is this mysteriously preexisting lowness, this sense of a priori disenfranchisement in both Satan and Eve, that provides their motives for rebelling against God's law. Consigned by their God-given characteristics to the weak or secondary half of the binary oppositions, both aspire to cross over, to claim the authority of being "intended first." But they don't want to give up their connection to darkness, lowness, animality, fecundity, irrationality. Satan and Eve want it all, and part of what critics like Blake and Froula read into *Paradise Lost* is that Milton almost allows them to have it. Eve harkens to the Serpent offering her the chance to be "as Gods" (IX 708) because, Milton tells us, she sinfully hopes to get above her assigned station. But the text is rife with clues suggesting that, on the contrary, Eve is "as Gods" already. With beauty like a rose and hair curling like the tendrils of a vine, with inborn affinities for night, water, and serpentine intrigue, all uneasily combined with love for Adam and goddesslike fertility, Eve sums up creation. She is simultaneously elemental, plantlike, and animalistic, human and divine, innocent and inquiring, instinctive and thoughtful. Satan, whose "Pride and worse Ambition" (IX 40) inspired his revolt, evinces a similarly mongrel consciousness.

Their communication is intuitive, and it transforms the universe.

Eve is interested but not entirely shocked to hear a snake exercise the exalted capacity for speech, perhaps because she herself has known such double-consciousness. She sympathizes with the otherized discourse of beasts, who are rendered transparent to Adam's appraisal but can speak back to him only "in their looks." She acknowledges that these extra-linguistic acts contain "Much reason." The Serpent's speech makes sense to her in more ways than one.

> So gloz'd the Tempter, and his Proem tun'd;
> Into the Heart of Eve his words made way,
> Not unamaz'd she thus in answer spake.
> "What may this mean? Language of Man pronounc't
> By Tongue of Brute, and human sense exprest?
> The first of these at least I thought deni'd
> To Beasts, whom God on their Creation-Day
> Created mute to all articulate sound;
> The latter I demur, for in their looks
> Much reason, and in their actions oft appears.
> Thee, Serpent, subtlest beast of all the field
> I knew, but not with human voice endu'd;
> Redouble then this miracle, and say,
> How cam'st thou speakable of mute, and how
> To me so friendly grown above the rest
> Of brutal kind..." (IX 549-65)

He answers:

> I was at first as other Beasts that graze
> The trodden Herb, of abject thoughts and low,
> As was my food, nor aught but food discern'd
> Or Sex, and apprehended nothing high:
> Till on a day roving the field, I chanc'd
> A goodly Tree far distant to behold
> Loaden with fruit of fairest colors mixt,
> Ruddy and Gold... (IX 571-78)

Of course, this exchange is studded with Miltonic warnings. Satan is cynically flattering Eve with a lie, and she falls for it. "Subtle" is not a compliment in an epic valuing the heroic virtue of forthrightness. Animals cannot work miracles. Adam is "endu'd" with language by God, and Eve should realize that such "endu'ing" by other means is suspect. Gold is tainted by association with Mammon, the fallen angel who builds the palace of Pandemonium in Hell. Beasts are not meant to apprehend anything "high." "Fair" is opposed to "good" as seeming is to being—the Tree *is* good, because God made it, but the Fruit only *seems* appealing, because it is forbidden. Et cetera. Nevertheless, Eve and the Serpent are spinning together the idea of an alternative rationality, a parallel language, that would enter tangibly through their mouths and digestive systems and open for their officially "low" minds the "high"—and pleasurable—thoughts heretofore annexed to God.

Satan explains:

> I spar'd not, for such pleasure till that hour
> At Feed or Fountain never had I found.
> Sated at length, erelong I might perceive
> Strange alteration in me, to degree
> Of Reason in my inward Powers, and Speech
> Wanted not long, though to this shape retain'd.
> Thenceforth to Speculations high or deep
> I turn'd my thoughts, and with capacious mind
> Consider'd all things visible... IX 596-604

Now they are moving toward the Tree. Trees, of course, are vexed symbolically. Roots in the earth, crowns in the sky, trees occupy human scale, and like human bodies unite heaven and earth, vertical and horizontal. The Tree in the Garden is ambrosial to God, but poison to humans, just as the bad Fall is revisited at the good "tree" of the Cross, where Jesus, "fruit" of Mary's womb, is sacrificed and original sin redeemed. Mute as a beast, the Tree does not interfere in Satan's plan, or try to dissuade Eve from eating. Like God, it gives the gift of knowledge, but unlike God it cannot speak for itself. Like Eve and the Serpent, then, the Tree is double-natured, a figure from the flora-and-fauna realm that represents a mix of base and glorious consciousness, an extra-Godly natural reality that *Paradise Lost* is at pains to simultaneously evoke and deny.

"O Sacred, Wise, and Wisdom-giving Plant," apostrophizes the Serpent,

> Mother of Science, Now I feel thy Power
> Within me clear, not only to discern
> Things in their Causes, but to trace the ways
> Of highest Agents, deem'd however wise.
> Queen of this Universe, do not believe
> Those rigid threats of Death... (IX 679-85)

Addressing in one breath the "Mother of Science" (the Tree) and the "Queen of this Universe" (Eve), Satan explicitly links the rebellious, forbidden knowledge of Fallen consciousness to cosmic matrilineal power. What should Eve do but follow, thus intelligibly led? She too sings praises to the Fruit—an object to which Milton has compared her so many times that metaphorically, Eve is here again praising her own image as an occult goddess whose audacious "reach" gives articulation to the hierarchically undeserving and unites the animal with the rational, the body with the mind. "Best of Fruits," she cries,

> Whose taste, too long forborne, at first assay
> Gave elocution to the mute, and taught
> The Tongue not made for Speech to speak thy praise...
>
> Here grows the Cure of all, this Fruit Divine,
> Fair to the Eye, inviting to the Taste,
> Of virtue to make wise: what hinders then
> To reach, and feed at once both Body and Mind? (IX 744-9, 76-9)

⁂

Female *Scolytidae* bark beetles eat their way through pine trees, creating ramifying burrows in which to propagate their young. They use chemical markers to attract males, and digest the gouged-out wood-pulp which they internally transform and excrete to feed the larvae. Literally inscribing the world in which their progeny can thrive, female beetles go to a tree, eat from it, lure their mates to join them, and thence produce "multitudes like themselves." The knowledge prompting them to do so, which is literally carved into the fabric of their environment, is legible to scientific human judgment only as the mute, rote gestures of instinct.

But what if the beetles' intelligence includes no disjunct between bodily action and systems of symbolic communication? What if they—like the primordial female pictured in the Edenic lake, like Eve with her love-goddess play of seduction with the Serpent and with Adam—are deliberately notating on the surface of the world their own physical wit, in a kind of wild *ecriture feminin* that is not meaningful to human readers because it is not addressed to us? It sounds like poetic conceit. Yet feminist epistemologies of embodiment, speech, and inscription have mapped a not dissimilar territory, in which the poetic and the practical are just another pair of binaries to be reintegrated. Luce Irigaray writes:

> A *single word* cannot be pronounced, produced, uttered by our mouths. Between our lips, yours and mine, several voices, several ways of speaking resound endlessly….One is never separable from the other. You/I: we are always several at once. And how could one dominate the other? impose her voice, her tone, her meaning? One cannot be distinguished from the other; which does not mean that they are indistinct. You don't understand a thing? No more than they understand you. Speak, all the same. It's our good fortune that your language isn't formed of a single thread, a single strand or pattern.[2]

Suppose that, composing through, with, and for the body, *Scolytidae* are writing Linear X. Its meaning would arrive for us, as post-Babel people, only through an Evelike refusal of linguistic splits and rationalistic hubris, a Satanic openness to morphological overabundance, a willingness to see the self-as-other in nature and not recognize the difference.

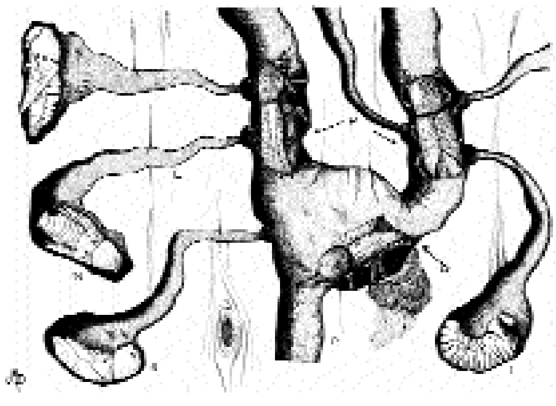

Figure 31. C. Chararas, *Scolytides Des Coniféres*, France.

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[2]Luce Irigary, "When Our Lips Speak Together," *This Sex Which Is Not One,* trans. Catherine Porter (Ithaca, NY: Cornell University Press, 1985), p. 209. Italics original.

A Detail from the Tomb of the Diver

(Paestum 500-453 BC) Second Detail

Anne Carson

Swimming at noon always reminds me of Marilyn Monroe
—Etruscan saying

The Etruscans: Are you blue, Marilyn?
Marilyn: A little blue.
The Etruscans: What do you do when you're blue?
Marilyn: Go underwater.
The Etruscans: Why?
Marilyn: Slow world, I like that.
The Etruscans: Slow bodies?
Marilyn: Bodies pulled around by faces.
The Etruscans: Momentary faces.
Marilyn: Actually, all the same face.
The Etruscans: Frightening? Seductive?
Marilyn: No. Strange. Beautiful.
The Etruscans: Odd sort of beauty.
Marilyn: Like a new brassiere.
The Etruscans: Or a very usual verb.
Marilyn: What?
The Etruscans: For instance the verb 'is'.
Marilyn: I didn't know 'is' was a verb.
The Etruscans: What did you think it was?
Marilyn: A light for the other verbs.
The Etruscans: In written Etruscan it's the only verb we have.
Marilyn: You're kidding.
The Etruscans: Is, was, has been, had been, will be, might be, should be, to be, to have been, to be about to have been, being, being about to be. And of course the negatives of these.
Marilyn: How do you get married or go to the beach?
The Etruscans: We do such things, just don't write about them.
Marilyn: No novels, no screenplays?
The Etruscans: No literature.

Marilyn: Why bother with writing at all then?
The Etruscans: It is needed on tombstones.
Marilyn: Oh I see.
The Etruscans: Now there's a slow world.
Marilyn: You got that right.
The Etruscans: Now you're sad again.
Marilyn: No just thinking. My pain self etc.
The Etruscans: Les choses derriere les choses.
Marilyn: I guess.
The Etruscans: Getting colder now.
Marilyn: Time to go in.
The Etruscans: And tomorrow?
Marilyn: Tomorrow will certainly be.
The Etruscans: You are very funny.
Marilyn: So I'm told.

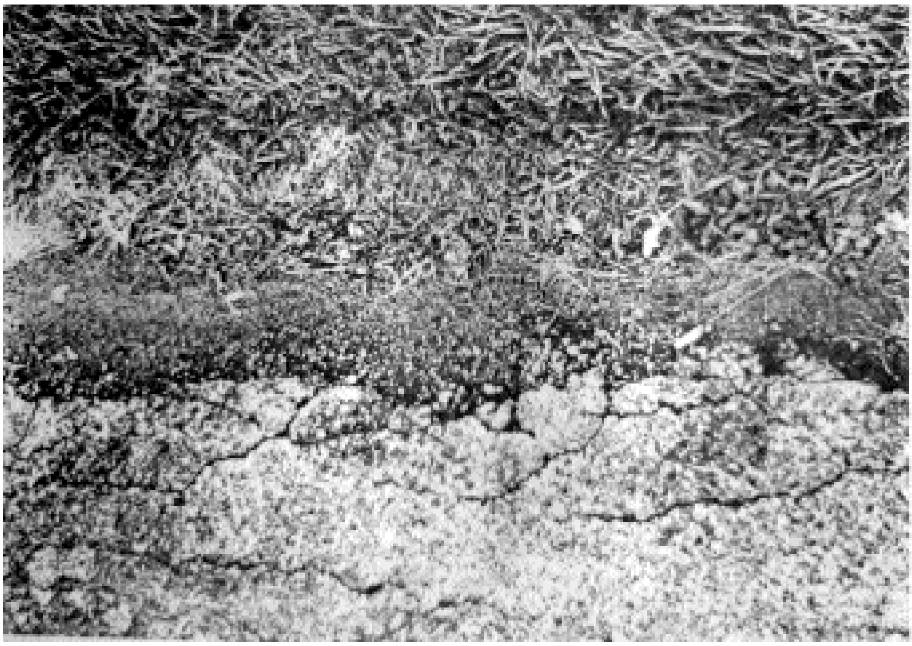

Figure 32. Another Linear X site.

The Library of Babel

Jorge Luis Borges

By this art you may contemplate the variation of the 23 letters....
—*Anatomy of Melancholy*, Pt. 2, Sec. II, Mem. IV

The universe (which others call the Library) is composed of an indefinite, perhaps infinite number of hexagonal galleries. In the center of each gallery is a ventilation shaft, bounded by a low railing. From any hexagon one can see the floors above and below—one after another, endlessly. The arrangement of the galleries is always the same: Twenty bookshelves, five to each side, line four of the hexagon's six sides; the height of the bookshelves, floor to ceiling, is hardly greater than the height of a normal librarian. One of the hexagon's free sides opens onto a narrow sort of vestibule, which in turn opens onto another gallery, identical to the first—identical in fact to all. To the left and right of the vestibule are two tiny compartments. One is for sleeping, upright; the other, for satisfying one's physical necessities. Through this space, too, there passes a spiral staircase, which winds upward and downward into the remotest distance. In the vestibule there is a mirror, which faithfully duplicates appearances. Men often infer from this mirror that the Library is not infinite—if it were, what need would there be for that illusory replication? I prefer to dream that burnished surfaces are a figuration and promise of the infinite.... Light is provided by certain spherical fruits that bear the name "bulbs." There are two of these bulbs in each hexagon, set crosswise. The light they give is insufficient, and unceasing.

Like all the men of the Library, in my younger days I traveled; I have journeyed in quest of a book, perhaps the catalog of catalogs. Now that my eyes can hardly make out what I myself have written, I am preparing to die, a few leagues from the hexagon where I was born. When I am dead, compassionate hands will throw me over the railing; my tomb will be the unfathomable air, my body will sink for ages, and will decay and dissolve in the wind engendered by my fall, which shall be infinite. I declare that the Library is endless. Idealists argue that the hexagonal rooms are the necessary shape of absolute space, or at least of our *perception* of space. They argue that a triangular or pentagonal chamber is inconceivable. (Mystics claim their ecstasies reveal to them a circular chamber containing an enormous circular book with a continuous spine that goes completely around the walls. But their testimony is suspect, their words obscure. That cyclical book is God.) Let it suffice for the moment that I repeat the classic dictum: *The library is a sphere whose exact center is any hexagon and whose circumference is unattainable.*

Each wall of each hexagon is furnished with five bookshelves; each bookshelf holds thirty-two books identical in format; each book contains four hundred ten pages; each page, forty lines; each line, approximately eighty black letters. There are also letters on the front cover of each book; those letters neither indicate nor prefigure what the pages inside will say. I am aware that that lack of correspondence once struck men as mysterious. Before summarizing the solution of the mystery (whose discovery, in spite of its tragic consequences, is perhaps the most important event in all history), I wish to recall a few axioms.

First: *The Library has existed* ab æternitate. That truth, whose immediate corollary is the future eternity of the world, no rational mind can doubt. Man, the imperfect librarian, may be the work of chance or of malevolent demiurges; the universe, with its elegant appointments–its bookshelves, its enigmatic books, its indefatigable staircases for the traveler, and its water closets for the seated librarian–can only be the handiwork of a god. In order to grasp the distance that separates the human and the divine, one has only to compare these crude trembling symbols which my fallible hand scrawIs on the cover of a book with the organic letters inside–neat, delicate, deep black, and inimitably symmetrical.

Second: *There are twenty-five orthographic symbols.*[1] That discovery enabled mankind, three hundred years ago, to formulate a general theory of the Library and thereby satisfactorily solve the riddle that no conjecture had been able to divine–the formless and chaotic nature of virtually all books. One book, which my father once saw in a hexagon in circuit 15-94, consisted of the letters M C V perversely repeated from the first line to the last. Another (much consulted in this zone) is a mere labyrinth of letters whose penultimate page contains the phrase *0 Time thy pyramids*. This much is known: For every rational line or forthright statement there are leagues of senseless cacophony, verbal nonsense, and incoherency. (I know of one semibarbarous zone whose librarians repudiate the "vain and superstitious habit" of trying to find sense in books, equating such a quest with attempting to find meaning in dreams or in the chaotic lines of the palm of one's hand.... They will acknowledge that the inventors of writing imitated the twenty-five natural symbols, but contend that that adoption was fortuitous, coincidental, and that books in themselves have no meaning. That argument, as we shall see, is not entirely fallacious.)

For many years it was believed that those impenetrable books were in ancient or far-distant languages. It is true that the most ancient peoples, the first librarians, employed a language quite different from the one we speak today; it is true that a few miles to the right, our language devolves into dialect and that ninety floors above, it becomes incomprehensible. All of that, I repeat, is true–but four hundred ten pages of unvarying M C V's cannot belong to any language, however dialectal or primitive it may be. Some have suggested that each letter influences the next, and that the value of M C V on page 71, line 3, is not the value of the same series on another line of another page, but that vague thesis has not met with any great acceptance. Others have mentioned the possibility of codes; that conjecture has been universally accepted, though not in the sense in which its originators formulated it.

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[1]The original manuscript has neither numbers nor capital letters; punctuation is limited to the comma and the period. Those two marks, the space, and the twenty-two letters of the alphabet are the twenty-five symbols that our unknown author is referring to. [Ed. note.]

Some five hundred years ago, the chief of one of the upper hexagons[2] came across a book as jumbled as all the others, but containing almost two pages of homogeneous lines. He showed his find to a traveling decipherer, who told him that the lines were written in Portuguese; others said it was Yiddish. Within the century experts had determined what the language actually was: a Samoyed-Lithuanian dialect of Guaraní, with inflections from classical Arabic. The content was also determined; the rudiments of combinatory analysis, illustrated with examples of endlessly repeating variations. Those examples allowed a librarian of genius to discover the fundamental law of the Library. This philospher observed that all books, however different from one another they might be, consist of identical elements: the space, the period, the comma, and the twenty-two letters of the alphabet. He also posited a fact which all travelers have since confirmed: *In all the Library, there are no two identical books*. From those incontrovertible premises, the librarian deduced that the Library is "total"—perfect, complete, and whole—and that its bookshelves contain all possible combinations of the twenty-two orthographic symbols (a number which, though unimaginably vast, is not infinite)—that is, all that is able to be expressed, in every language. *All*—the detailed history of the future, the autobiographies of the archangels, the faithful catalog of the Library, thousands and thousands of false catalogs, the proof of the falsity of those false catalogs, a proof of the falsity of the *true* catalog, the gnostic gospel of Basilides, the commentary upon that gospel, the commentary on the commentary on that gospel, the true story of your death, the translation of every book into every language, the interpolation of every book into all books, the treatise Bede could have written (but did not) on the mythology of the Saxon people, the lost books of Tacitus.

When it was announced that the Library contained all books, the first reaction was unbounded joy. All men felt themselves the possessors of an intact and secret treasure. There was no personal problem, no world problem whose eloquent solution did not exist—somewhere in some hexagon. The universe was justified; the universe suddenly became congruent with the unlimited width and breadth of humankind's hope. At that period there was much talk of The Vindications—books of *apologiæ* and prophecies that would vindicate for all time the actions of every person in the universe and that held wondrous arcana for men's futures. Thousands of greedy individuals abandoned their sweet native hexagons and rushed downstairs, upstairs, spurred by the vain desire to find their Vindication. These pilgrims squabbled in the narrow corridors, muttered dark imprecations, strangled one another on the divine staircases, threw deceiving volumes down ventilation shafts, were themselves hurled to their deaths by men of distant regions. Others went insane.... The Vindications do exist (I have seen two of them, which refer to persons in the future, persons perhaps not imaginary), but those who went in quest of them failed to recall that the chance of a man's finding his own Vindication, or some perfidious version of his own, can be calculated to be zero.

At that same period there was also hope that the fundamental mysteries of mankind—the origin of the Library and of time—might be revealed. In all likelihood those profound mysteries can indeed be explained in words; if the language of the philosophers is not sufficient, then the multiform Library must surely have produced the extraordinary

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[2]In earlier times, there was one man for every three hexagons. Suicide and diseases of the lung have played havoc with that proportion. An unspeakably melancholy memory: I have sometimes traveled for nights on end, down corridors and polished staircases, without coming across a single librarian.

language that is required, together with the words and grammar of that language. For four centuries, men have been scouring the hexagons.... There are official searchers, the "inquisitors." I have seen them about their tasks: they arrive exhausted at some hexagon, they talk about a staircase that nearly killed them—some steps were missing—they speak with the librarian about galleries and staircases, and, once in a while, they take up the nearest book and leaf through it, searching for disgraceful or dishonorable words. Clearly, no one expects to discover anything.

That unbridled hopefulness was succeeded, naturally enough, by a similarly disproportionate depression. The certainty that some bookshelf in some hexagon contained precious books, yet that those precious books were forever out of reach, was almost unbearable. One blasphemous sect proposed that the searches be discontinued and that all men shuffle letters and symbols until those canonical books, through some improbable stroke of chance, had been constructed. The authorities were forced to issue strict orders. The sect disappeared, but in my childhood I have seen old men who for long periods would hide in the latrines with metal disks and a forbidden dice cup, feebly mimicking the divine disorder.

Others, going about it in the opposite way, thought the first thing to do was eliminate all worthless books. They would invade the hexagons, show credentials that were not always false, leaf disgustedly through a volume, and condemn entire walls of books. It is to their hygienic, ascetic rage that we lay the senseless loss of millions of volumes. Their name is execrated today, but those who grieve over the "treasures" destroyed in that frenzy overlook two widely acknowledged facts: One, that the Library is so huge that any reduction by human hands must be infinitesimal. And two, that each book is unique and irreplaceable, but (since the Library is total) there are always several hundred thousand imperfect facsimiles—books that differ by no more than a single letter, or a comma. Despite general opinion, I daresay that the consequences of the depredations committed by the Purifiers have been exaggerated by the horror those same fanatics inspired. They were spurred on by the holy zeal to reach—someday, through unrelenting effort—the books of the Crimson Hexagon—books smaller than natural books, books omnipotent, illustrated, and magical.

We also have knowledge of another superstition from that period: belief in what was termed the Book-Man. On some shelf in some hexagon, it was argued, there must exist a book that is the cipher and perfect compendium *of all other books*, and some librarian must have examined that book; this librarian is analogous to a god. In the language of this zone there are still vestiges of the sect that worshiped that distant librarian. Many have gone in search of Him. For a hundred years, men beat every possible path—and every path in vain. How was one to locate the idolized secret hexagon that sheltered Him? Someone proposed searching by regression: To locate book A, first consult book B, which tells where book A can be found; to locate book B, first consult book C, and so on, to infinity.... It is in ventures such as these that I have squandered and spent my years. I cannot think it unlikely that there is such a total book[3] on some shelf in the universe. I pray to the unknown gods that some

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[3]I repeat: In order for a book to exist, it is sufficient that it be *possible*. Only the impossible is excluded. For example, no book is also a staircase, though there are no doubt books that discuss and deny and prove that possibility, and others whose structure corresponds to that of a staircase.

man—even a single man, tens of centuries ago has perused and read that book. If the honor and wisdom and joy of such a reading are not to be my own, then let them be for others. Let heaven exist, though my own place be in hell. Let me be tortured and battered and annihilated, but let there be one instant, one creature, wherein thy enormous Library may find its justification.

Infidels claim that the rule in the Library is not "sense," but "non-sense," and that "rationality" (even humble, pure coherence) is an almost miraculous exception. They speak, I know, of "the feverish Library, whose random volumes constantly threaten to transmogrify into others, so that they affirm all things, deny all things, and confound and confuse all things, like some mad and hallucinating deity." Those words, which not only proclaim disorder but exemplify it as well, prove, as all can see, the infidels' deplorable taste and desperate ignorance. For while the Library contains all verbal structures, all the variations allowed by the twenty-five orthographic symbols, it includes not a single absolute piece of nonsense. It would be pointless to observe that the finest volume of all the many hexagons that I myself administer is titled *Combed Thunder*, while another is titled *The Plaster Cramp*, and another, *Axaxaxas mlö*. Those phrases, at first apparently incoherent, are undoubtedly susceptible to cryptographic or allegorical "reading"; that reading, that justification of the words' order and existence, is itself verbal and, *ex hypothesi*, already contained somewhere in the Library. There is no combination of characters one can make—*dhcmrlchtdj*, for example—that the divine Library has not foreseen and that in one or more of its secret tongues does not hide a terrible significance. There is no syllable one can speak that is not filled with tenderness and terror, that is not, in one of those languages, the mighty name of god. To speak is to commit tautologies. This pointless, verbose epistle already exists in one of the thirty volumes of the five bookshelves in one of the countless hexagons—as does its refutation. (A number n of the possible languages employ the same vocabulary; in some of them, the *symbol* "library" possesses the correct definition "everlasting, ubiquitous system of hexagonal galleries," while a library—the thing—is a loaf of bread or a pyramid or something else, and the six words that define it themselves have other definitions. You who read me—are you certain you understand my language?)

Methodical composition distracts me from the present condition of humanity. The certainty that everything has already been written annuls us, or renders us phantasmal. I know districts in which the young people prostrate themselves before books and like savages kiss their pages, though cannot read a letter. Epidemics, heretical discords, pilgrimages that inevitably degenerate into brigandage have decimated the population. I believe I mentioned the suicides, which are more and more frequent every year. I am perhaps misled by old age and fear, but I suspect that the human species—the *only* species—teeters at the verge of extinction, yet that the Library—enlightened, solitary, infinite, perfectly unmoving, armed with precious volumes, pointless, incorruptible, and secret—will endure.

I have just written the word "infinite." I have not included that adjective out of mere rhetorical habit; I hereby state that it is not illogical to think that the world is infinite. Those who believe it to have limits hypothesize that in some remote place or places the corridors and staircases and hexagons may, inconceivably, end—which is absurd. And yet those who picture the world as unlimited forget that the number of possible books is *not*. I will be bold enough to suggest this solution to the ancient problem: *The Library is unlimited but periodic.* If an eternal traveler should journey in any direction, he would find after untold centuries that the same volumes are repeated in the same disorder—which, repeated, becomes order: the Order. My solitude is cheered by that elegant hope.[4]

Mar del Plata, 1941

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[4]Letizia Alvarez de Toledo has observed that the vast Library is pointless; strictly speaking, all that is required is *a single volume*, of the common size, printed in nine- or ten-point type, that would consist of an infinite number of infinitely thin pages. (In the early seventeenth century, Cavalieri stated that every solid body is the super-position of an infinite number of planes.) Using that silken *vademecum* would not be easy: each apparent page would open into other similar pages; the inconceivable middle page would have no "back."

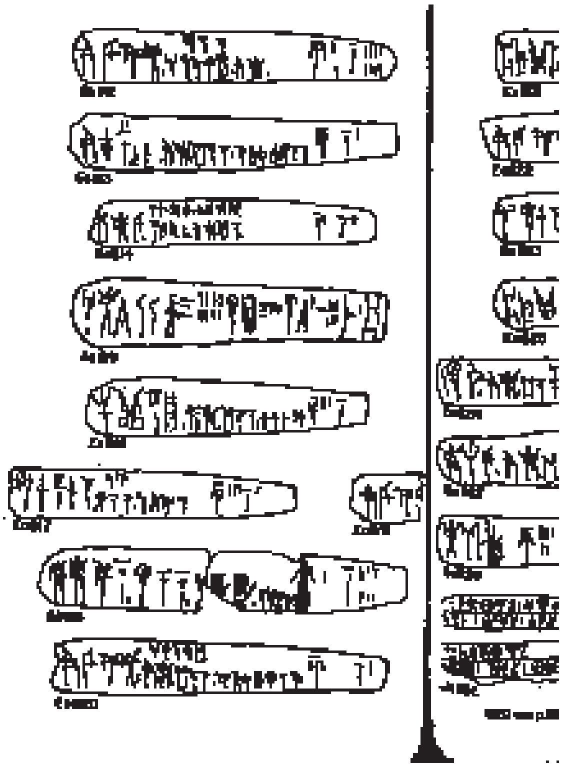

Figure 33. One of the first drawings of the inscribed marks on Linear B tablets.
Source unknown.

References

Brian Conley: Decipherment of Linear X, p.5

Camazine, Scott, [et al.], 2001. *Self-Organization in Biological Systems* (Princeton Studies in Complexity). Princeton University Press, New Jersey.

Chadwick, J., 1980. *The Decipherment of Linear B.* Cambridge University Press, Cambridge.

Darwin, Charles, 1897. *The Power of Movement In Plants.* D. Appleton and Company, New York.

Descartes, Rene, 1970. Trans. Anthony Kenny. "Letter to Marquess of Newcastle, 23 November, 1646." Clarendon Press, Oxford. pp.205–8

Ferry, David, 1992. *Gilgamesh: A New Rendering in English Verse.* Farrar, Straus and Giroux, New York.

Foucault, Michel, 1970. *The Order of Things.* Random House, Inc., New York.

Lewis, David K., 1969. *Convention: A Philosophical Study.* Harvard University Press, Boston.

Montaigne, Michel, 1991. Trans. M.A. Screech. *Complete Essays.* Penguin Books, New York.

Pope, Maurice, 1999. *The Story of Decipherment.* Thames and Hudson, London.

Robinson, Andrew, 1999. *The Story of Writing.* Thames and Hudson, London.

Wittgenstein, Ludwig, 1958. Trans. G.E.M. Anscombe. *Philosophical Investigations.* Macmillan Publishing Company, Inc., New York

Michael Ryan: The Ambrosia Beetle and Genetic Intelligence, p. 13

Coulson, R.N., 1979. *Population Dynamics of Bark Beetles.* Ann. Rev. Entomol. 24: 417-47.

Evans, H.E., 1984. *Insect, A Textbook of Entomology*. Addison-Wesley Publishing Co, MA.

Horn, D.J., 1976. *Biology of Insects.* WB Saunders Co, Philadelphia.

Lovenwirth, S.M., 1999. "Bark Beetles and This Year's Drought." *Regulatory Horticulture* 25: 18-20.

Metcalf, C.L. and W.P. Flint, 1939. *Destructive and Useful Insects.* McGraw-Hill Book Company, Inc., New York

Safrank, L., 1995. *Bark Beetles in Forest Insect Pests in Canada.* Eds. JA Armstrong, WGH Ives. Natural Resources Canada, Ottowa.

Stark, R.W., 1982. "Generalized Ecology and the Life Cycles of Bark Beetles," published in *Bark Beetles in North American Conifers.* University of Texas Press, Austin.

Sturgeon, K.B. and J.B. Mitton, 1982. "Evolution of Bark Beetle Communities," published in *Bark Beetles in North American Conifers.* University of Texas Press, Austin.

Swain, R.B., 1948. *The Insect Guide: Orders and Major Families of North American Insects.* Doubleday & Co, New York.

Luc Steels: Gallery Structure Formation in Conleyborus Scarabaeoides, p. 17

Camazine, S., J-L Deneubourg, N.R. Franks, J. Sneyd, G. Theraulaz, and E. Bonabeau, 2001. *Self-Organization in Biological Systems*, Princeton University Press, Princeton, New Jersey.

Chadwick, J., 1980. *The Decipherment of Linear B.* Cambridge University Press, Cambridge.

Deneubourg, J-L., J.C. Grégoire, and E. Le Fort., 1990. "Kinetics of the Larval Gregarious Behaviour in the Bark Beetle *Dendroctonus micans*." *Journal of Insect Behavior,* 3:169-182.

Grégoire, J.-C., 1988. "The Greater European Spruce Beetle," published in Berryman, A. (ed.) *Population Dynamics of Forest Insects.* pp. 455-478. Plenum, New York.

INRA HYPP Zoology pages http://www.inra.fr/Internet/Produits/HYPPZ/

Steels, L., 1990. "Cooperation through Self-organisation," published in De Mazeau, Y. (ed.) *Distributed*

Artificial Intelligence. North-Holland Pub., Amsterdam.

Steels, L. and P-Y Oudeyer, 2000. "The Cultural Evolution of Syntactic Constraints in Phonology." pp. 382-394, published in Bedeau, et al. (ed.) *Proceedings of Artificial Life VII*. The MIT Press, Cambridge, MA.

Steels, L. and Kaplan, F., 2000. "Collective Learning and Semiotic Dynamics." pp. 679-688, published in Floreano, D. and Nicoud, J-D. and Mondada, F., (ed.) *Advances in Artificial Life* (ECAL 99), Lecture Notes in Artificial Intelligence 1674, Springer-Verlag, Berlin.

LUC STEELS: The Origins of Intelligence, p. 61

[1] Ashby, R., 1952. *Design for a Brain.* Chapman and Hall. London.

[2] Deneubourg, J-L., 1977. "Application de l'Ordre par Fluctuations a la Description de Certaines Etapes de la Construction du Nid Chez les Termites." *Insectes Sociaux*, Tome 24, 2, pp. 117-130.

[3] De Duve, C., 1995. *Vital Dust: Life as a Cosmic Imperative*. Basic Books, New York.

[4] Edelman, G., 1987. *Neural Darwinism: The Theory of Neuronal Group Selection*. Basic Books, New York.

[5] Eigen, M. et al., 1981. "The Origin of Genetic Information." *Scientific American*, 244, pp. 88-118.

[6] Holland, J.H., 1975. *Adaptation in Natural and Artificial Systems*. The University of Michigan Press, Ann Arbor, Michigan.

[7] Cliffs, D, P. Harvey and P. Husbands, 1995. "Using Genetic Evolution for Autonomous Agents." In: *Journal of Robotics and Autonomous Systems*, 1995, 1-2. North-Holland Pub., Amsterdam.

[8] Kauffman, S.A., 1993. *The Origins of Order: Self Organization and Selection in Evolution*. Oxford University Press, Oxford.

[9] Fleischacker, G., S. Colonna, L. Luisi, 1994. "Self-Production of Supramolecular Structures," published in *Synthetic Structures to Models of Minimal Living Systems*. Kluwer Academic Publishers, Dordrecht.

[10] Margulis, and T. Toffoli, 1987. *Cellular Automata Machines*. MIT Press, Cambridge, MA.

[11] Maturana, H.R. and F.J. Varela, 1987. *The Tree of Knowledge: The Biological Roots of Human Understanding*. Shambala Press, Boston.

[12] Maynard-Smith, J. and E. Szathmary, 1994. *The Major Transitions in Evolution*. Oxford University Press, Oxford.

[13] McClelland, J.L. and D.E. Rumelhart (Eds.), 1986. *Explorations in Parallel Distributed Processing*. The MIT Press/Bradford Books, Cambridge, MA.

[14] Newell, A., 1982. "The Knowledge Level." *Artificial Intelligence Journal*. Vol 18. pp. 87-127.

[15] Penrose, R., 1990. *The Emperor's New Mind*. Oxford University Press, Oxford.

[16] Prigogine, I. and I. Stengers, 1984. *Order Out of Chaos*. Bantam Books, New York.

[17] Steels, L. and R. Brooks, Eds., 1995. "Building Situated Embodied Agents." *The A life route to Al.* Lawrence Erlbaum Assoc., New Haven.

[18] Steels, L., 1996. "Self-Organizing Vocabularies." *Fifth Conference on Artificial Life*. Nara. Japan. The MIT Press, Cambridge, MA.

[19] Steels, L., 1996b. "A Self-Organizing Spatial Vocabulary." *Artificial Life Journal*. Vol 3.

[20] Steels, L., 1996b. "Emergent Adaptive Lexicons." *Proceedings of the Simulation of Adaptive Behavior Conf*. The MIT Press, Cambridge, MA.

[21] Steels, L., 1996d. "A Selectionist Mechanism for Autonomous Behavior Acquisition." *Journal of Robotics and Autonomous Systems*. Vol. 16. North-Holland Pub., Amsterdam.

[22] Steels, L., 1996e. "Discovering the Competitors." *Journal of Adaptive Systems*. 4(2) 1996. The MIT Press, Cambridge, MA.

[23] Torras, C., 1995. "An Overview of Neural Network Learning," published in Steels, L., ed.: *The Biology and Technology of Intelligent Autonomous Agents*. Springer-Verlag, Berlin.

Alexander Marshack: The Meander as a System: The Analysis and Recognition of Iconographic Units in Upper Paleolithic Compositions, p. 70

Alcalde del Rio H., H. Breuil and L. Sierra, 1911. *Les cavernes de la region cantabrique (Espagne)*. Publiées sous les Auspices de S.A.S. le Prince Albert I de Monaco: Monaco.

Blanc G. A., 1928. "Grotta Romanelli, II." *Archivio per l'antropogia e l'etnologia*, 58:365411.

Bordes F., 1969. "Os percé moustérien et os grave acheuleen du Pech de I'Aze II." *Quaternaria*, 2:1-6.

Bordes F., 1972. *A Tale of Two Caves*. Harper and Row, New York.

Breuil H., 1952. *Four hundred centuries of cave art*. Centre d'Études et de Documentation Prehistoriques, Montignac.

Breuil H., H. Obermaier and W. Verner, 1915. "La Pileta a Benaojan (Malaga)." Institute de Paleontogie Humaine, Monaco.

Breuil H. and H. Obermaier, 1935. *The cave of Altamira at Santillana del Mar, Spain*. Tip de Archivos, Madrid.

Capitan L. and J. Bouyssonie, 1924. "Limeuil: son gisement a gravures sur pierres de Page du renne." Institut International d'Anthropologie, Paris.

Graziosi P,. 1932-33. "Les gravures de la grotte Romanelli (Puglia, Italie)." Essai comparatif. *Ipek*, pp. 26-36.

Graziosi P.,. 1960. *Palaeolithic Art*. McGraw-Hill, New York.

Laming A., 1959. *Lascaux: Paintings and Engravings*. Penguin, Harmondsworth.

Lemozi A., 1929. "La Grotte-temple du Pech-Merle." Un Nouveau Sanctuaire Paleolithique. Picard, Paris.

Leroi-Gourhan A., 1958. "La fonction des signes dans les sanctuaires paleolithiques." *Bulletin de la Societe Prehistorique Francaise*, 55, pp. 307-321.

Leroi-Gourhan A., 1965. *Prehistoire de Part Occidental*. Mazenod, Paris.

Leroi-Gourhan A., 1972. "Animals of the old stone age," published in *Animals in Archaeology*, A. H. Brodrick (ed.), pp. 1-14. Praeger, New York.

Marshack A., 1972. *The Roots of Civilization*. McGrawHill, New York.

Munn N. D., 1973. *Walbiri Iconography*. Cornell University Press, Ithaca.

Munn N. D., 1974. "The spatial presentation of cosmic order in Walbiri iconography," published in *Primitive Art and Society*, A. Forge (ed.), pp. 193-220. Oxford University Press, London and New York.

Nougier L. R. and R. Robert, 1959. *Rouffignac I: Galerie Henri Breuil et Grand Plafond*. Sansoni, Firenze.

Pericot-Garcia L., 1942. "La Cueva del Parpallo (Gandia)." *Consejo Superior de Investigaciones Cientificas*, Madrid.

Plenier A., 1972. *L'Art de la Grotte de Marsoulas*. Institut d'Art Prehistorique, Toulouse.

Ucko P. J. and A. Rosenfeld, 1967. *Palaeolithic Cave Art*. Weidenfeld and Nicolson, London.

Zervos C., 1959. *L'art de 1'epoque A renne en France*. Cahiers d'Art, Paris

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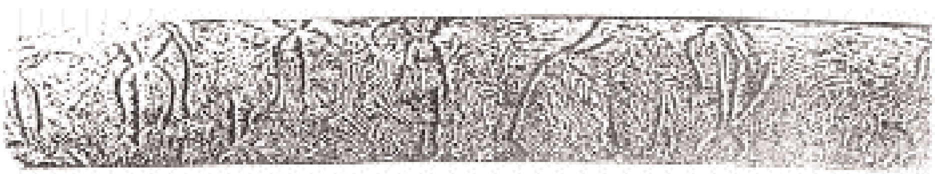

Figure 34. Stick showing Linear X incisions. (Field Data, Upstate New York. B. Conley)