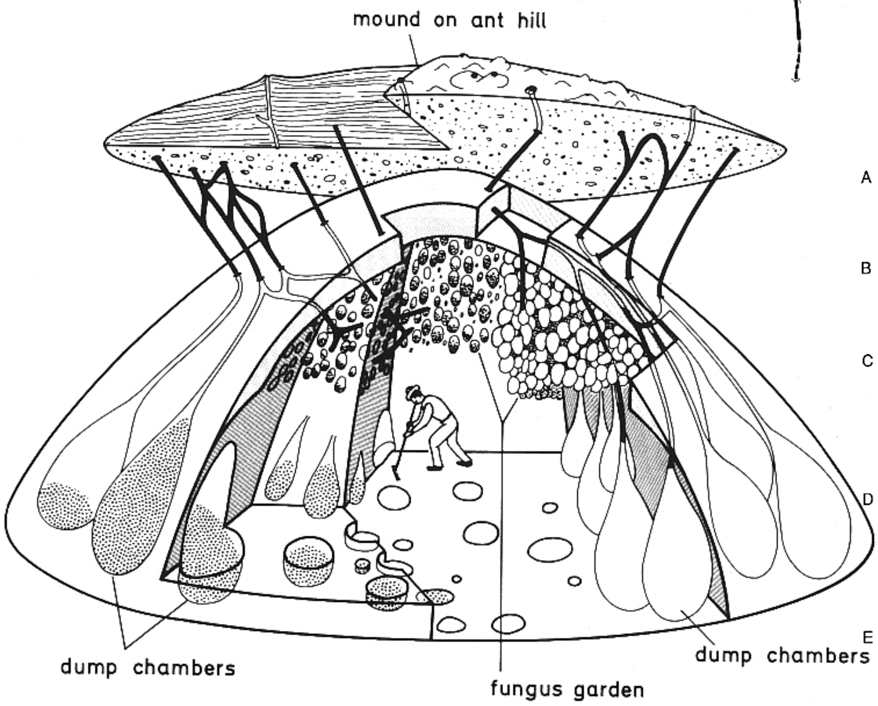
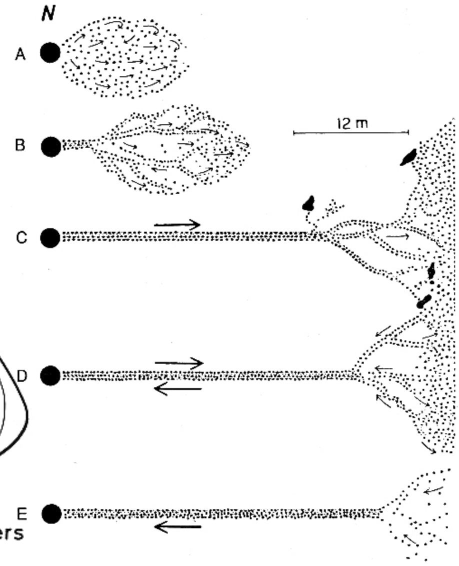
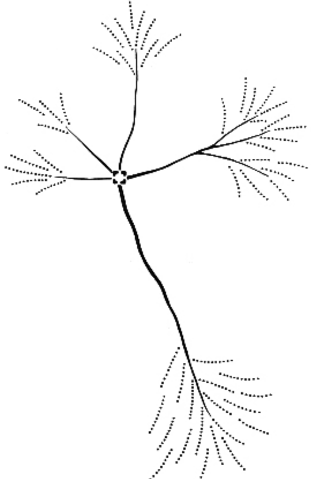
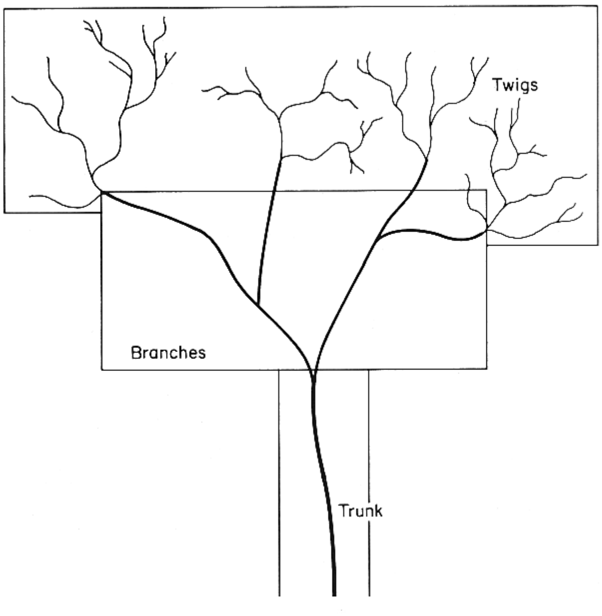
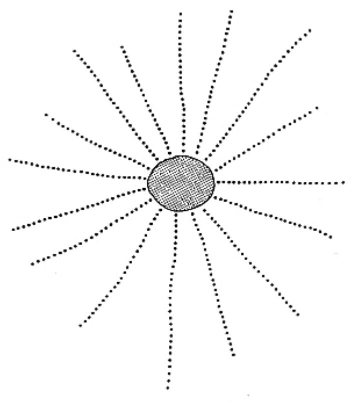


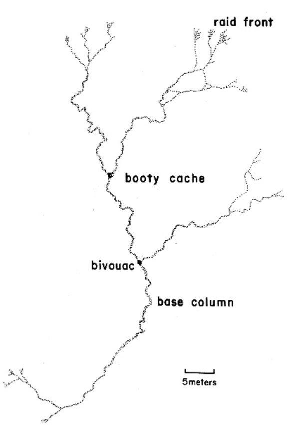


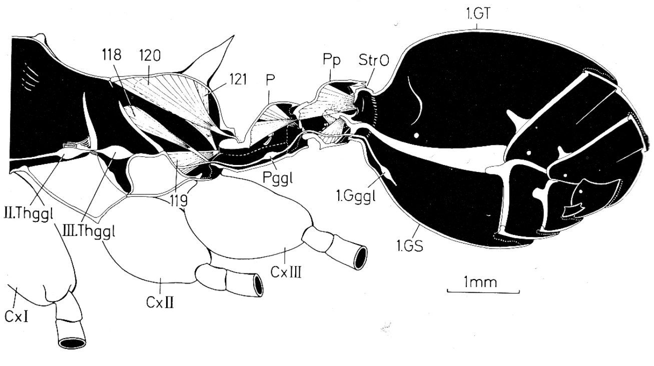




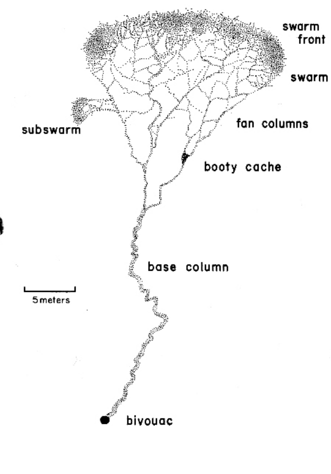


Eciton hamatum Column Raid





Eciton burchelli Swarm Raid



AN ARTISTIC APPROACH TO

THE CYBERNETIC EMERGENCE OF ANTS

Kuaishen Auson

THEM!

- 1954 sci-fi film about mutant killer ants from director Gordon Douglas

They show how it is possible to "speak" in complex messages with pheromones...

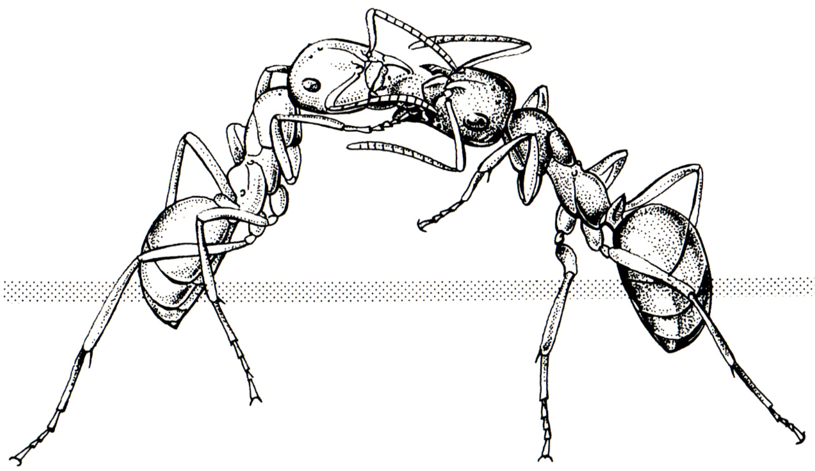
They illustrate, through thousand of examples, how the division of labor can be crafted with flexible behavior programs to achieve an optimal efficiency of a working group...

Their networks of cooperating individuals have suggested new designs in computers and shed light on how neurons of the brain might interact in the creation of mind...

They are in many ways an inspiration.

- Bert Hölldobler and Edward O. Wilson, *The Superorganism*

Contents



(Illustrations taken from the *The Ants* and *The Superorganism* for academic purposes)

SUPERORGANISMIC

"Schaut her, das sind Geschöpfe. Und zwar vollwertige Geschöpfe, keine kleinen, unbedeutenden Insekten. [Und das, das hat mein Onkel sofort begriffen]...Die ameisen bilden die zweite große Zivilisation auf der Erde und mein onkel ist eine art Kolumbus, der zwischen unseren zehen einen anderen Kontinent entdeckt hat. Er hat als erster erfaßt, daß man, bevor man außerirdische Wesen in den letzten Winkeln des Weltalls sucht, erst einmal Kontakt mit den Innerirdischen aufnehmen sollte."[1]

Do ants have a cybernetic behavior in the way they live and self-organize by means of stridulation, body language, pheromone and tactile communication? If so, can we consider the system of self-organization in ants a successful model that can be applied to other social organizations, like ours? Can we understand their nature by means of cybernetics and emergence? What about the cybernetic process that emerges out of the biological observations of ants' behavior bred in a partially controlled laboratory system? Can we culture a colony of ants, and according to feedback, influence its growth, teach the ants to learn? Or is it the other way around, we culture ants to learn from them? I am pursuing the praxis of a sociobiological artistic environment with emergent qualities that combines the nature of ant's communication and their social behavior with the practice of media art. My goal is to apply theoretical approaches like cybernetics, emergence, chaos, systemics and biomimetics in order to address, understand and be inspired by the social behavior of ants. I will be focusing my thesis based on rich examples of emergence in ants, that emergence is part of their self-organized behavior, and that this emergence all together with the ecological environments they live in, and help nurse and cultivate, encircles a cybernetic network based on decision algorithms transmitted by pheromones, stridulations and intricate tactile rituals that identifies them as one of the principal and strongest superorganisms on this planet.

Ants represent to me an example of life, life represents to me an example of self-organization, self-organization represents to me an example of emergence and emergence represents to me an example of life. The ants are the most successful living beings after humans. The success of these little creatures is based on their evolutionary achievement as social predators. Ants are arguably the oldest form of society on the planet, for over 50 million years they have been roaming this world. The social system of ants provides an illuminating contrast to the hierarchical centralized structure of human beings, and how things in a society can be done in a different way. Though some ants measure less than a 1 millimeter in length, they represent a magnificent collective force, an example of effort, sacrifice, team work, self-organization, parallel networking and social communication. Ants are the dominatrices of the terrestrial world, a matriarchal organization powered by its female working caste, dividing and distributing labor according to environmental conditions. They swarm and emerge to keep the ground clean, recycle the soil and channel new energies in this planet. Their impact on the overall terrestrial habitat is so remarkable that leafcutter ants of the genus Atta and Acromyrmex are by far considered the most destructive vegetation pests in Central and South America. They are the principal herbivores of these regions, eating more grass in

---

1 Werber Bernard. Die Ameisen (aus dem französischen von Michael Mosblech). München: R. Piper GmbH & Co, 1992.

the Argentinean pampas, for example, than the cows. Whereas harvester ants of the species Pogonomyrmex rank as the principal granivores in the deserts of southwestern United States, competing against other mammals in gathering seeds.

Ants dominate the insect kingdom as a secret underground society that spontaneously generates and contributes to shape and reconstruct any ecosystem they inhabit. It is a matriarchal sisterhood that employs the most complex forms of chemical communication, tactile rituals and stridulating sounds in order to organize from bottom to top, without commands from above, no leader telling them what to do, using local feedback from neighboring agent to neighboring agent to act and react for the well-being of the colony as a unified entity, as a superorganism. They share with us uncanny and marvelous similarities, specially at the level of social warfare and territorial competition, the identification of friends or family, the discrimination of strangers, and the education and protection of younger generations. If we know how the dynamics of an ant colony functions, we might also understand how complexity in the world works, from brains to ecosystems, from human-made-systems to robotic simulations, from artificial intelligence to new emergent forms of art.

I have been observing and researching ants for about 3 years only. While most of the experts and excellent entomologists in the world have already smoked too much cigarettes, drunk too much beer, already grown a white beard and have been stung and bitten by the rarest creatures on earth, I humbly risk to take a step forward and share my novel experiences and artistic adventures with ants, for I felt the need and impelling force to prove ants represent a leading model towards successful social networking in life. Moreover, I believe that science and arts can wonderfully join forces, as they already have in other areas, to adapt ant's emergent principles of self-organization to human nature for a better understanding of what we are, and what we can be to the world we live in. With the help of emerging media technologies and the artistic knowledge acquired throughout my investigations about ants, I will embody the hypothesis that ants possess cybernetic characteristics which make them a successful and powerful superorganism, with so much relevancy and interdependency to mother earth, and of course, to the rest of living beings, including us humans.

First things first, as we humans like it. We shall begin with the definition of a somewhat complicated term. Let us address the meaning of emergence[2]:

1. The arising of emergent structure in complex systems.

2. The act of rising out of a fluid, or coming forth from envelopment or concealment, or of rising into view; sudden uprising or appearance.

2 From http://en.wiktionary.org/wiki/emergence (accessed December, 2008).

The soil mound you see rising out of the ground is the extension of the ant's nest underground, it is a symbol of their social and architectural organization; just like the bivouac, a temporary organic nest construction out of the bodies of army ants who connect themselves forming a living mass that protects the queen and the brood, which appears and disappears according to the needs of the colony.

Second, let's address the meaning and function of cybernetics as formulated by Norbert Wiener, the man who originated the theory[3]:

Cybernetics: from ancient greek, kubernētikos ("good at steering, good pilot").

1. The control, regulation and transmission of information in living beings and the machine.

2. The study of controlling processes and communication

3. A system whose functions can be determined by feedback mechanisms.

Ants can be considered, not obligatory though, as agents of a higher social structure, whose main goal is the propagation of genetic information based on natural selection. The history of the colony, its experience and instincts, have to be passed on to the next generations. All these represents relevant information that has to be transmitted, like the elders from a tribe passing their wisdom to the younger apprentices. The good pilot becomes then the unforeseen and invisible system reigning fluidly, blending and bending according to internal and external circumstances. The cybernetics of the ant colony is embedded within the spirit of the swarm, when ants go hunting in mass, when ants construct the nest, when they raid and attack other colonies. The life of the ant colony is regulated by feedback mechanisms that allow the transmission of information from one agent to the next.

The goal of my study and research on ants is the combination of arts and sciences for the creation of self-organized, reactive and organic artistic installations. Therefore, it is impelling to manifest, after addressing the meaning of these two principal terminologies, emergence and cybernetics, that I am thrilled to introduce The Cybernetic Emergence of Ants. Needles to say, the foundations of my thesis are connected, broadly outlined and inspired, by pioneer cyberneticians who transcended mental barriers and limitations to be able to enlighten an organic and holistic integration of communication theories on the way biological systems work. Consequently, there is a common resonance on the observations achieved by these cyberneticians, which can help illustrate my interest to ants as a cybernetic emergent social superorganism:

3 Wiener Norbert. Kybernetik: Regelung und Nachrichtenübertragung im Lebewesen und in der Machine. Düsseldorf: Econ Verlag, 1992.

■ Norbert Wiener saw the function of the thermostat, which regulates the needed temperature according to the outside temperature, as one of many examples to his first order of cybernetics; on the case of the ants, a colony sends some workers, when the temperature inside is too low, to recharge their exoskeletons under the sun and then return back inside to regulate the nest's temperature, a strategy carefully performed by many Ponerinae species.

■ Francisco Varela presented the difficulty of not realizing that information processing systems are in fact self-organizing mechanisms, which work from the inside to the outside as well as from the outside to the inside, and when you do something to a neuron or antibody, this individual intervention will inevitably affect the immune system or the neural system; when everything is calm inside the nest of Formica fusca, the common black ant of european forests, if one single ant detects danger in the form of enemies, a slight wind blowing, or water dropping, then the local alert state of this ant transforms into a general panic alarm, which spreads to the other ants influencing the whole colony to take action, either by defending or by migrating to a safer ground, like our immune system against pathogens and tumors.

■ Gregory Bateson stated that one organism is a communication system, which individual as it may seen, it is nevertheless altogether a complex organization of interdependent elements; ants, like the weaver ants Oecophylla Longinoda in Africa, build supercolonies in the canopy of more than one tree, where every ant constitutes part of a single colony which is connected to other colonies, which are in turn connected to much more bigger colonies, which at the end build a supercolony altogether that possesses the territorial control of a group of trees in a particular ecosystem.

■ Heinz Von Foerster liked to tell stories, and one of his focus was the relation between trivial and non-trivial machines as systems, to which extent he would say that a non-trivial machine is: synthetic determinable, dependent on its past, analytic undefinable and unpredictable; ants are synthetic determinable: by the many robotic engineering experiments and computer simulations that have been done based on their behavior. Ants are dependent on its past: by the heritage in the morphology and phylogeny of past generations that allow them to cope with the challenges in the environment. Ants are analytic undefinable: because they, being the observed, communicate using pheromones, a language we humans don't understand directly, whereas we, being the observer, communicate by phonetic signs and symbols. Last but not least, ants are unpredictable: because, who would have predicted an invasive migratory species from South America, Linepithema humile better known as the argentinean ant, could build an underground supercolony, connected by colonial control posts, that stretches along the mediterranean coast approximately 6.000 km from Italy to Portugal and that is around 80 years old?[4]

4 From http://news.bbc.co.uk/1/hi/sci/tech/1932509.stm (accessed December, 2008).

GENERATIO SPONTANEA

"The human brain generates too many ideas, suppositions and possibilities at the same time, that the resultant ideas, suppositions and possibilities transform in ants traveling space and time, foraging for realities to construct."

The spontaneous generation of life out of inanimate and inorganic molecules, non-living matter, better known scientifically as abiogenesis, in contrast to biogenesis which is the process of living organisms producing life forms sequentially, an ant queen lays an egg and so on, is a theory which states that the origin of life on earth emerged as a chemical reaction between isotopes of carbon, iron and sulfur in order to give birth to minerals and sediments which in turn generated the first microorganisms. These microorganisms learned to survive by taking energy from the sun to transform it into oxygen and carbohydrates, thus engaging in what we know now as photosynthesis. While this theory of spontaneous generation arguably started as far as in Aristotle's' time and concisely refers to one of many theories about the beginning of life on earth, the sole idea that life emerges out of nothing, is rough and crude for most scientists. It is not difficult to imagine, but scientifically difficult to confirm: big life emerged from inanimate matter, which gave birth to rare small ancestors of microbes, bacteria and spores, who apparently did not possess free will, but somehow managed to create a collective that consequently created life. The interactions from the inside to the outside were dynamically embedded with something capable to assemble and construct, out of simple starting elements, complex breeding forms. This complexity in nature creates life as a form of emergent art, perceivable to those who are crazy enough to see it. Digicult Director Marco Mancuso does a marvelous reflection on Ernst Haeckel's 'Kunstformen der Natur': "It is undeniable that nature is able not only to create spontaneously real art forms but also produce a direct correspondence between a certain generative aesthetics, starting from a fundamental unit/nucleus to come to a complex entity, and a consequent adaptive and evolutionary practice."[1] Moreover, he continues reinforcing his thoughts on nature as an art form by citing the italian architect and one of the pioneers of generative art, Celestino Soddu: "Generative Art is the idea realized as genetic code of artificial events, as construction of dynamic complex systems able to generate endless variations. Each Generative Project is a concept-software that works producing unique and non-repeatable events, as possible and manifold expressions of the generating idea strongly recognizable as a vision belonging to an artist/designer/musician/architect/mathematician. This generative idea/human-creative-act makes an unpredictable, amazing and endless expansion of human creativity. [...] This approach opens a new era in Art, Design and Communication: the challenge of a new naturalness of the artificial event as a mirror of Nature."[2]

The point is not to focus on whether the Earth was spontaneously generated, but to focus on the emergence of a greater

1-2 Mancuso, Marco. Generative Nature. Aesthetics, repetitiveness, selection and adaptation (Online version shared via Email by Spectre Newsletter). For Mr. Bruce Sterling's workshop "Designing Processes Rather Than Art", which took place November 25-28, 2008 at Fabrica in Treviso, Italy (accessible on http://www.digicult.it/digimag/article.asp?id=1349).

need without really wanting or knowing that there is a greater need, nor that there will be a greater need at the end; it has to begin, perform the basics and let the created network explode to do whatever it can to do, be a network of unknown causes. The big bang is still ideologically nothing more than a spontaneous generation, because something greater and unexpected was born out of the active relation between an infinite density of energy and temperature at a finite time in the past. Spontaneity is unpredictability. Spontaneity is a very common term in human society. We humans like to be spontaneous be impulsive and achieve what we want, we like to "act-without-thinking" and sometimes this "act-without-thinking" derives in a creative artistic process, and such process creates greater things. Nature creates beautiful fractal forms spontaneously: a natural act, the generation of art, like the spirals of the seashells lying on a beach in galapagos, the mountain ranges along the andes, snowflakes falling in your face in the cold winter of Berlin, the rhizome and other ramifications of a tree, or a fern in the Amazonas, the electrical forms originated from a lightning bolt and the blood vessels of our circulatory system. Altogether, these natural formations look so alike that it shouldn't be far-fetched to think that the creative process generated inside our brain could perhaps be part of this vital code existent in nature's network. So, by spontaneous generation I don't mean the theory of abiogenesis per se. I am referring to the organic flow of ideas and thoughts that materialize into a living network of possibilities, regardless of the inanimate or animate components participating in the process, and regardless of definition, determination or destiny. I am referring to the fact that local becomes spontaneously global, singular becomes spontaneously plural, individual becomes spontaneously collective, small becomes spontaneously big, and that this evolution from single beings to common beings, which has been a preferred design template of mother nature for the past couple billion years[3], could be the product of generatio spontanea to the extent that there is no plan or guide to execute, but that it all generates recursively out of a network of diverse realities influenced by the ecologies where life and art takes place; where a beneficial distortion of the environment is inevitable and unpredictable, like Gordon Pask puts it.[4] Some of the thinking procedures that occur in our brain, our microcosmical ecology inhabited by neurons, could therefore be addressed as a consequence of spontaneous generation.

The brain is more or less a neurocomputing machine able to arrange its basic computing elements, the estimated 100 billion neurons[5], to make computations by massive hardware parallelism. Parallelism is a key term. Neurons are organized so that clustered groups work on the same problem at the same time, balancing the energy needed and economizing the force required. Since there are huge numbers of neurons in our brain, the reason why we humans can plan, calculate, solve problems and so on, is because the brain, like an ant colony, combines the weak computing powers of these slow logical elements together to form a more powerful resultant[6]. If we take this into account, we must consider that each of us on earth is a monological single being able to interact by means of 'yes' and 'no' in a social environment. Each of us is an individual parallel computing machine with character connecting 10 thousands synaptic nodes in real time and generating activity mediated by personal behavior and diverse communication abilities to connect ideas worldwide. The

3 From http://en.wikipedia.org/wiki/Earth (accessed February, 2009).
4 Spiller, Neil. Cyber Reader: Critical Writings for the Digital Era. Phaidon Press, 2002.
5 From http://en.wikipedia.org/wiki/Brain (accessed November, 2008).
6 Anderson James A. and Rosenfeld, Edward, ed. Neurocomputing. Cambridge: the Mit Press, 1989.

functionality and simulation of this parallel networking system has become an obsession, a pursue of ultimate knowledge for us humans. We want to understand how we understand, we want to understand the brain. Even though, the operations of individual neurons and synapses are nowadays understood in considerable detail, the way they really cooperate, and how they cooperate in ensembles of thousands of millions, has been very difficult to decipher[7]. And here is where ants enter the game. Ants have become a model for artificial intelligence, robotic engineering, network simulation, and a living system to observe for social research and biological investigation, because its collaborating parts work effectively as a whole. We humans have invented many team strategies, team spirit, team management and nonetheless, in this matter, the ants are way ahead of us.

Army ants swarm in the jungle, expanding at first glance chaotically, but then forming the very same figure we see in trees, lightning bolts, blood vessels and other rhizomatic phenomena found in nature. The tree trunk and its branchlike extremities are painted organically on the amazonian soil, with every soldier ant following the pheromonal trail of the other ant, forming the rhizomatic image of the tree, as if it were always the perfect formula, for it is always a different tree drawn but a tree indeed it is. The ant swarm compiles the genetic code of mother nature and renders the necessary energy for the colony to survive. Ants act as an extension of nature designing life, because they are a system of parallel collaboration that self-organizes and generates solutions to any kind of problem. Exactly that is helping us in the simulation of how to respond effectively to unpredictable circumstances that require team participation or group collaboration. Even if we don't want to apply this to humans, we could then apply this to the design of artificial intelligence and the engineering of robots as social entities. The brain, our microcosmical ecology of neurons, with its synaptic connections producing flowing rivers of thoughts, is but an image of the botanical rhizome found in the generative art of nature, an image of thought as coined by Gilles Deleuze[8]. The brain is a rhizomatic ecology extending ideas like the swarm raiders in the amazonian jungle extend its army of self-organized hunters and gatherers.

A botanical rhizome found in nature is multiple like the supercolonies of leafcutter ants in the tropics and like the neural system of our brain. The idea behind multiplicity in a living system, like in an ant colony or in the human brain, comes from the spontaneous generation of emergent properties in nature, which:

a) are unpredictable, hence become spontaneous according to the principles that apply to fractal formations; we cannot predict their presence but are nevertheless generated.

b) are ready to connect and combine to create a greater unforeseen effect or macro-behavior out of the active interactions of its basic units; parallel networking serves the purpose of finding the adequate solutions within an efficient framework of time, economizing the resources available for obtaining that purpose, like the parallel processes of neurons in the brain or the division of labor in the ant colony.

c) are the manifestation of a circular system of ramification, a rhizome, that provides a feedback mechanism which is

---

7 Sejnowski TJ. 23 Problems in Systems Neuroscience. New York: Oxford University Press, 2005.
8 Deleuze Gilles and Guattari Felix. A Thousand Plateaus: Capitalism and Schizophrenia. University of Minnesota Press, 1987.

multiple and heterogeneous and could therefore, in any moment, fragment but reorganize and reconnect, because its emergent properties are multiple; if one ant dies, the colony keeps on living, if one neuron dies, the brain keeps on thinking.

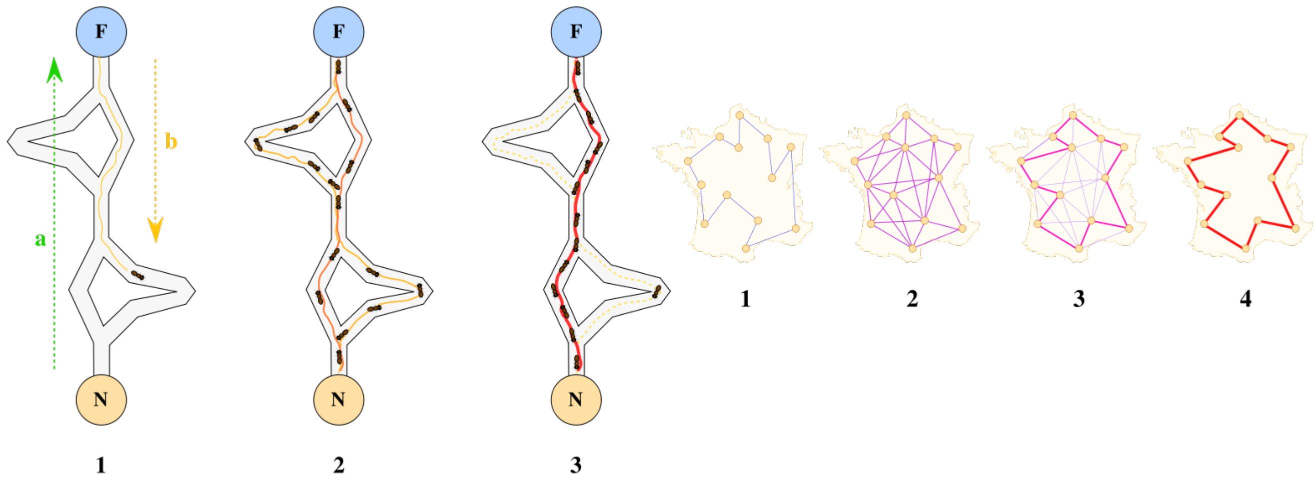
The generation of a supercolony of ants is as unpredictable as the unpredictability of a human brain that suffers under schizophrenia or multiple personality disorder. To my point of view what happens in the brain is that unpredictability and parallel activity flows, flourishes and emerges as a microcosmical ecology inhabited by neurons. The neurocomputing machine we call brain opts for a beneficial distortion of its environment: emerges as the tree, rooting and branching its rhizomatic ecology as the image of thought, or emerges as the swarming army ants of the amazonas. The human brain has been able to fragment and combine imagination and science to use algorithms that explain natural phenomena like fractals, achieving the simulation of natural processes that in nature are generated unpredictably and in a parallel fashion. The swarm intelligence algorithms are successful applications of the emergent properties of natural systems that have inspired generatio spontanea in the human mind[9]. Here are some outstanding examples:

- the ant colony optimization algorithm (ACO), an approach to solve the traveling salesman problem by finding the shortest round trip to connect a series of cities (fig. 2-1).
- particle swarm optimization (PSO), a population-based computer algorithm for problem solving that simulates social optimization and social fitness in social networks (fig. 2-2).
- stochastic diffusion search (SDS), a pattern matching algorithm, inspired by the tandem running mechanism exhibited by many ant species, specially within the ponerini tribe, to recruit nestmates to food sources. The pattern matching algorithm evaluates the different recommendations of the agents conforming a group to find the best solution to a search problem (fig. 2-3).

The generatio spontanea occurring in ants is indeed an emergent rhizomatic structure that self-organizes in a cybernetic manner, just like the human brain. We are progressively learning to adapt the behavior of ants to solve problems in our society.

9 From http://en.wikipedia.org/wiki/Swarm_intelligence (accessed February, 2009).

Figure 2-1



(a) (b)

(a) When one ant finds a good path from the colony to a food source, other ants are more likely to follow that path, and positive feedback eventually leads all the ants following a single path. The idea of the ant colony algorithm is to mimic this behavior with "simulated ants" walking around the graph representing the problem to solve. In a series of experiments on a colony of ants with a choice between two unequal length paths leading to a source of food, biologists have observed that ants tended to use the shortest route.

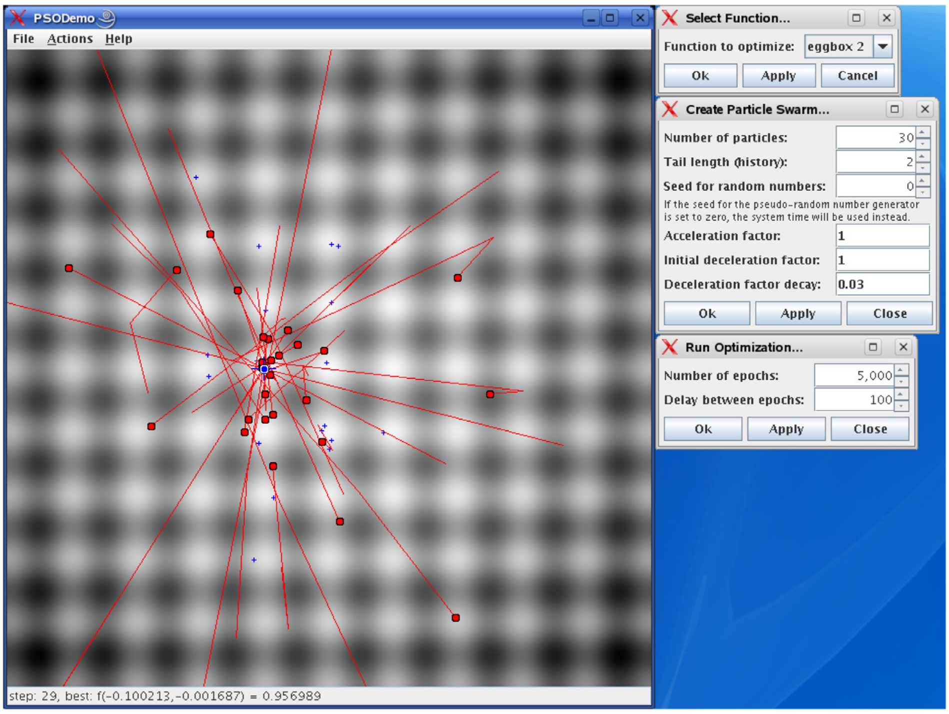
1. An ant runs more or less at random around the colony;
2. If it discovers a food source, it returns more or less directly to the nest, leaving in its path a trail of pheromone;
3. These pheromones are attractive, nearby ants will be inclined to follow, more or less directly, the track;
4. Returning to the colony, these ants will strengthen the route;
5. If two routes are possible to reach the same food source, the shorter one will be, in the same time, traveled by more ants than the long route will
6. The short route will be increasingly enhanced, and therefore become more attractive;
7. The long route will eventually disappear, pheromones are volatile;
8. Eventually, all the ants have determined the shortest route.

(b) As a very good example, ant colony optimization algorithms have been used to produce near-optimal solutions to the travelling salesman problem, in which the goal is to find the shortest round-trip to link a series of cities. The general algorithm is relatively simple and based on a set of ants, each making one of the possible round-trips along the cities. At each stage, the ant chooses to move from one city to another according to some rules:

1. It must visit each city exactly once;
2. A distant city has less chance of being chosen (the visibility);
3. The more intense the pheromone trail laid out on an edge between two cities, the greater the probability that that edge will be chosen;
4. Having completed its journey, the ant deposits more pheromones on all edges it traversed, if the journey is short;
5. After each iteration, trails of pheromones evaporate.

From http://en.wikipedia.org/wiki/Ant_colony_optimization (accessed February, 2009).

■ Figure 2-2



PSOpt[10] is a Java based program to demonstrate the optimization process of particle swarm optimization. A two-dimensional objective function is visualized by levels of grey: the lighter the color, the higher the function value. The particles are shown as red circles, their trajectory as red lines. The global memory (best point found up to now by the whole swarm) is shown as a blue cross-hair, the local memory (best points found by each of the particles) as small blue crosses.

Particle swarm optimization is a stochastic, population-based computer algorithm for problem solving. It is a kind of swarm intelligence that is based on social-psychological principles and provides insights into social behavior, as well as contributing to engineering applications. The particle swarm optimization algorithm was first described in 1995 by James Kennedy and Russell C. Eberhart. Social influence and social learning enable a person to maintain cognitive consistency. People solve problems by talking with other people about them, and as they interact their beliefs, attitudes, and behaviors change; the changes could typically be depicted as the individuals moving toward one another in a socio-cognitive space. The particle swarm simulates this kind of social optimization.

10 Borgelt Christian. Ameisenkolonienalgorithmen und andere schwarmbasierte Optimierungsverfahren. Institut für Wissens- und Sprachverarbeitung Otto-von-Guericke-Universit, Magdeburg.
From http://en.wikipedia.org/wiki/Particle_swarm_optimization (accessed February, 2009).

Figure 2-3

The restaurant game

A group of delegates attend a long conference in an unfamiliar town. Each night they have to find somewhere to dine. There is a large choice of restaurants, each of which offers a large variety of meals. The problem the group faces is to find the best restaurant, that is the restaurant where the maximum number of delegates would enjoy dining (given that all delegates have more or less the same preference). Even a parallel exhaustive search through the restaurant and meal combinations would take too long to accomplish. To solve the problem delegates decide to employ a Stochastic Diffusion Search.

Each delegate acts as an agent maintaining a hypothesis identifying the best restaurant in town. Each night each delegate tests his hypothesis by dining there and randomly selecting one of the meals on offer. The next morning at breakfast every delegate who did not enjoy his meal the previous night, asks one randomly selected colleague to share his dinner impressions. If the experience was good, he also adopts this restaurant as his choice. Otherwise he simply selects another restaurant at random from the list in the Yellow Pages.

Using this strategy it is found that very rapidly a significant number of delegates congregate around the best restaurant in town.

SDS uses a form of direct (one-to-one) communication between the agents similar to the tandem calling mechanism employed by one species of ants, Leptothorax acervorum. In SDS agents perform cheap, partial evaluations of a hypothesis. They then share information about hypotheses, through direct one-to-one communication. This is a diffusion process. As a result of the diffusion mechanism, high-quality solutions can be identified from clusters of agents with the same hypothesis. The operation of SDS is most easily understood by means of a simple analogy - The Restaurant Game.

SDS has been applied to diverse problems such as text search [Bishop, 1989], object recognition [Bishop, 1992], feature tracking [Grech-Cini, 1993], mobile robot self-localisation [Beattie, 1998] and site selection for wireless networks [Whitaker, 2002].

From http://www.rdg.ac.uk/cirg/sds/cirg-stochasticdiffusionsearch.asp (accessed March, 2009).

GOD SAVE THE QUEEN

"the successful sexy matriarchy"

Imagine beautiful females, all possessing thin waists and athletic bodies, powerful and elegant, with 8 body extensions that can handle almost everything. And they all smell like heaven, a least if you are an ant they smell like heaven. I am fascinated and inspired by ants' aesthetic morphology, by the way they look and how they harness their body construction. They are indeed nature's secret power, attractive and cybernetic, armed with stings and toxic chemical weapons, sharp-cutting mandibles, strong chitin-hardened bodies and the talent to communicate via semiochemicals and stridulations to recruit, forage for food, attack and defend: dangerous femmes fatales of the insect world. The ants are a superior collective force among invertebrates, and even compared to vertebrates they leave a formidable impression when it comes to the survival of the fittest: adaptation, resilience, colonization, expansion, territoriality, competition for resources and above all reproduction capacity. Ants can reproduce thousands of millions. They literally build factory fortresses, self-managed by a predominant female division of labor that cares for their own, empathetically and altruistically rearing and educating the young. This factory fortress contains the winning formula of strategic eusociality design. Natural selection has favored ants not only because they self-organize in reproductive and non-reproductive castes, but because an ant colony is proven to be successful in their life when it contributes to the reproduction of the largest numbers of mature colonies in a competing environment, when it contributes to the expansion and immanent ecological presence of that species. Ants dominate, and the explanation for their dominance lies in a basic set of rules exercised by a matriarchal organization. I am attracted to this powerful matriarchal organization. The idea that only females carry the burden of raising, educating and organizing a society, makes one wonder if such a system can function in the real human world. It is inevitable to contemplate that ants are beautiful, cybernetic and sexy, after you have spent some time getting acquainted wit them, observing and culturing them. The matriarchal organization is a powerful system that has proven successful in nature, relying almost completely on a female working force. The matriarchal organization in ants is driven by the altruistic self-organization of mothers and daughters who sacrifice their lives for the colony, fiercely, mercilessly, aggressively but involving love and care. And it all begins with a virgin queen flying around, looking for a good place to hide and start the procreation. When the biorhythm of nature sets the right chemical energies for life reproduction on the planet, virgin ant queens depart from the colony and swarm in the air, signalizing the birth of the ant's division of labor. "the life cycle of an ant colony can be efficiently thought to begin as an egg destined to produce a virgin queen."[1]

Insemination, fertilization, reproduction, sex, are all different terms that can be explained as cybernetic events triggered by chemical signals. The partners participating in the mating act have to perceive and interpret correctly these chemical signals, in order to recognize the right time to stop or continue with the kinetics of the mating act. These chemical signals

1 Wilson Edward O. and Hölldobler Bert. The Ants. Harvard University Press, 1990.

of attraction (pheromones) are usually overlooked by us humans, as we are more susceptible to be seduced visually. But for ants, this cybernetic event represents the first communication mechanism for sexual attraction, in which the males and queens develop a pulsating active state of pheromonal production. This cybernetic behavior induces a change in the behavior of males and queens. It is the system inside the colony saying the time has come. The males become sexually aggressive and obsessed with the queen, whereas the queen herself becomes irresistible, extremely attractive and ready for anyone who can 'seduce' her (fig. 3-1). The single virgin queen mates occasionally with one or two males, but frequently she is inseminated by a dozen or more, and she does so by flying, rising up in the sky leaving the colony behind. She then sprays her attractive pheromone aroma in the air, signalizing the start of the reproduction race. Attracted by the sweet mating fragrance, the competing males swarm around her in search for the glory. This kind of glory is ephemeral because ant males don't live long enough to tell how great it was to have sex with the queen. Males have a short life span and their purpose in the ant world, their unique contribution to the sexy matriarchy, is to pass over their genetical information for the creation of future ant generations. The chances of a male to successfully mate with the queen are scarce, because all the males compete against each other to determine the sibling relatedness in the caste system of the future colony. Such genetic information is so precious that everyone wants to be the father of most of the female force the queen will reproduce. Comparing human-ant-male with human-ant-female behaviors, it seems that in both cases the female is always in charge of the calls. The role of the male is to earn the invitation to come inside. The role of the queen is to inform the males that her spermatheca is sufficiently supplied and that she is ready to settle down and start the founding stage. There are 3 stages in the life cycle of the ant colony (fig. 3-2): the founding stage, where the newly inseminated queen starts the colony, the ergonomic stage, where the colony has already triumphed over difficulties and adversities, has established a solid system of division of labor and it is only concerned with colony growth and expansion, and last but not least the reproductive stage, where the ant system, as an already mature colony, produces males and new queens to release them in nature and start the process all over again. Nevertheless, this life cycle can only be set in motion if the queen survives the perils of her initial journey.

The longevity of a founding queen is so relative and dependent on many factors like the fragility of life itself. The mortality of founding queens is extremely high; queens from large nest's populations like Atta or Solenopsis can reach hundreds or thousands in numbers during the swarm flight. From 1000 queens that are released, only 1 to 10 survive[2]. They become mostly victims of predators and perish in their attempt to found the new colony. To determine the life expectancy and age of an ant queen, patience and dedication have to become a talent on the observer, because an accute research of many years has to be done to surveil the life of the principal caste of an ant colony: the reproductive caste, the queen. Porter and Jorgensen in the year 1988 achieved to record the maximum longevity of an ant queen of the species Pogonomyrmex owyheei in the wild: 30 years of life[3]. Based on this result, the queen ant is the most longevous eusocial insect found in

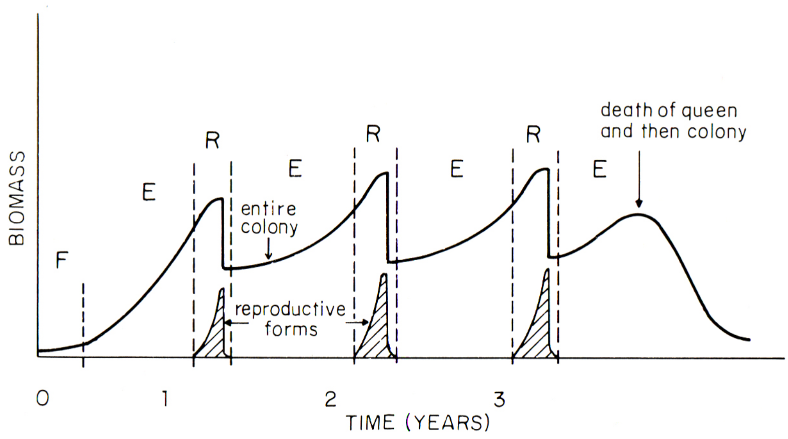
2 Wilson Edward O. and Hölldobler Bert. Queen Numbers and Domination. The Ants. Harvard University Press, 1990.
3 ibid.

■ Figure 3-1

Queen ant and 3 males during the act of copulation

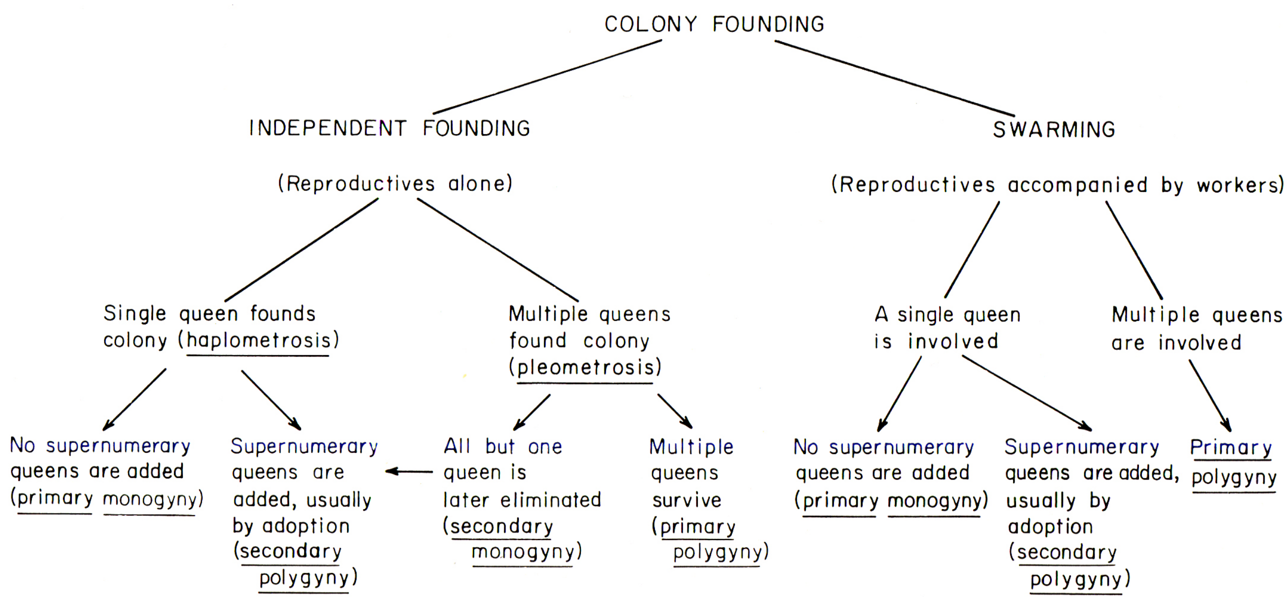
It is interesting to notice the grasping and holding by the males with their mandibles and tarsal claws.

Figure 3-2



The life cycle of the ant colony is divided in 3 stages: (F) founding stage, (E) ergonomic stage and (R) reproductive stage.

When the virgin queens and males leave the nest to breed, the colony size decreases, and reenters the ergonomic stage.



Several possibilities of the founding stage in ants.

Figure 3-3

Species	Caste	Locality	Average longevity or range	Maximum recorded longevity	Authority	Comments
Aphaenogaster rudis	Queen	United States	8.7 yrs	4.6–13 yrs	Haskins (1960)	Based on 11 queens in laboratory nests
A. rudis	Worker	United States	?	>3 yrs	Fielde (1904b)	
Atta sexdens	Queen	Guyana	?	14 yrs	K. M. Horton and E. O. Wilson (unpublished)	Based on 1 queen in laboratory nest
A. sexdens rubropilosa	Queen	Brazil	?	15.3 yrs	Autuori (1950b)	Based on 1 queen in laboratory nest
Camponotus consobrinus	Queen	Australia	>7 yrs		B. Hölldobler (unpublished)	Based on 1 queen in laboratory nest
C. herculeanus	Queen	Germany	?	>10 yrs	B. Hölldobler (unpublished)	Based on 1 queen in laboratory nest
C. lateralis	Queen	Italy	8 yrs		K. Hölldobler (unpublished)	Based on 1 queen in laboratory nest
C. lateralis	Queen	France	>5 years		Palma-Valli and Délye (1981)	Based on 1 queen in laboratory nest
C. perthiana	Queen	Australia	?	21 yrs	Haskins and Haskins (personal communication)	Based on 1 queen in laboratory nest
Ectatomma ruidum	Queen	Australia	?	8.8 yrs	Haskins and Haskins (1980)	Based on 1 queen in laboratory nest
E. ruidum	Queen	?	?	9 yrs	Haskins and Haskins (1980)	Based on 1 queen in laboratory nest
Formica rufibarbis	Queen	Germany	?	14 yrs	H. Appel (in Kutter and Stumper, 1969)	Based on 1 queen in laboratory nest
F. sanguinea	Queen	Germany	?	20 yrs	H. Appel (in Kutter and Stumper, 1969)	Based on 1 queen in laboratory nest
Lasius alienus	Queen	France	?	9.25 yrs	Janet (1904)	Based on 1 queen in laboratory nest
L. flavus	Queen	Germany	18 yrs	18 yrs	H. Appel (in Kutter and Stumper, 1969)	Based on 3–4 queens in laboratory nests
L. flavus	Queen	England	?	22.5 yrs	Prescott (1973)	
L. niger	Queen	Germany	?	29 yrs	H. Appel (in Kutter and Stumper, 1969)	Based on 1 queen in laboratory nest
Leptothorax lichtensteini	Worker	France	2.5 yrs	?	Plateaux (1986)	Based on laboratory observations
L. lichtensteini	Queen	France	?	12–15 yrs	Plateaux (1986)	Based on laboratory observations
L. nylanderi	Worker	France	3 yrs	?	Plateaux (1986)	Based on laboratory observations
L. nylanderi	Queen	France	?	15 yrs	Plateaux (1986)	Based on laboratory observations
Messor semirufus	Queen	Lebanon	?	9 yrs	Tohmé and Tohmé (1978)	
Monomorium pharaonis	Queen	England	?	39 wks	Peacock and Baxter (1950)	
M. pharaonis	Worker	England	?	9–10 wks	Peacock and Baxter (1950)	
Myrmecia gulosa	Worker	Australia	1.7 yrs	1.3–2.2 yrs	Haskins and Haskins (1980)	Based on 3 workers in laboratory nest
M. nigriceps	Worker	Australia	2.2 yrs	2.1–2.4 yrs	Haskins and Haskins (1980)	Based on 2 workers in laboratory nest
M. nigrocincta	Worker	Australia	1.2 yrs	1.1–1.3 yrs	Haskins and Haskins (1980)	Based on 5 workers in laboratory nest
M. pilosula	Worker	Australia	1.3 yrs	1.12–1.6 yrs	Haskins and Haskins (1980)	Based on 6 workers in laboratory nest
M. vindex	Worker	Australia	1.9 yrs	1.4–2.6 yrs	Haskins and Haskins (1980)	Based on 5 workers in laboratory nest
Myrmecocystus mimicus	Queen	United States	?	>11 yrs	B. Hölldobler (unpublished)	Based on 1 queen in laboratory nest
Myrmica rubra (= *laevinodis*)	Worker	England	?	2 yrs	Brian (1951b)	
Odontomachus sp.	Queen	?	?	4 yrs	Haskins and Haskins (1980)	Based on 2 queens in laboratory nests
Pogonomyrmex badius	Queen	Florida, USA	?	17 yrs	K. M. Horton and E. O. Wilson (unpublished)	Inferred from colony longevity in laboratory
P. owyheei	Queen,	Idaho, USA	17 yrs	30 yrs	Porter and Jorgensen (1988)	Age of colonies in the field; evidence presented that colonies last only as long as founding queen

Longevity of various ant species.

nature. A de facto relationship, because the queen's age provides the colony's age, that's why the society of collaborating agents can also be considered as one of the most longevous superorganisms on earth (fig. 3-3). Therefore, the formation of tight clustering protective ants sticks to the queen, reacting extremely aggressive when the nest is infiltrated.

The queen has to be always protected by a royal entourage that makes sure she has all the care needed, so that she can exercise the benefits of her caste. This entourage consists of nurse workers and a special caste known as nanitics[4], who take care of the brood and attend the queen (fig. 3-4). But there is also the presence of workers who apply a parallel task distribution, which is necessary for the homeostasis of the whole colony, expanding as a rippling wave from the queen's private entourage to the peripherals of the nest. The workers have to decide what working caste they will become, based on a sequence of decision points which are written by an internal genetic program but also influenced by the flow of cybernetic behaviors of the adult social agents around. The first decision instance for the new born agent is to choose between developing as an adult reproductive, queens or males, or as an adult worker (fig. 3-5). The products of this social algorithm include the following castes: nanitics, minims, minors, submajors, majors, soldiers and supersoldiers. it is relevant to mention that within species and genera, there is some unique caste variations that perform very specific tasks. Two remarkable examples are the living food storage caste of Myrmecosistus mexicanus and the nest guarding soldiers of Colobopsis truncatus (fig. 3-6). It's all based on a genetic program that step by step lets the agent decide what to be and also what decisions to make during its evolution. The self-organization of the colony as a whole is channeled by a social algorithm of decision making that despite being a sequential conditioning program (fig. 3-7), produces a higher level of organization, because of the many diverse interactions and connections originated by this network of simple agents. "A particular program may guide the gradual anatomical and physiological development of individual colony members into one caste or another, or it may cause changes in a member's behavior within the ambit of its caste repertoire."[5]

Nanitics, minims and minors are infertile workers who most of the time spent their whole life inside the nest, specializing in the care of the brood and even altruistically feeding the queen from time to time unviable eggs laid by themselves, known as trophic eggs, which are eggs that cannot develop as adults but serve as food. Submajors, majors, soldiers and supersoldiers are infertile workers as well, who specialize in the defense of the colony from intruders and strangers. There are some variations in this adult caste, that according to the feedback produced by the factory/fortress-environment relationship, channels a different path for decision making in which the ants can become specialized leafcutters or gardeners, in the case of Atta and Acromyrmex (fig. 3-8). The strategic design of the matriarchal organization is so organically engineered that the emergence of new ants in the colony can be defined as a time-lapsed circular expansion during the colony's life cycle. From the core of the factory, the queen chamber, the new born ant start her life around the queen, then gradually as she ages, starts moving outward, to the outskirts of the fortress. If she chooses to become a soldier, in her mature stages of life she will be spending most of her time patrolling and guarding the colony around the

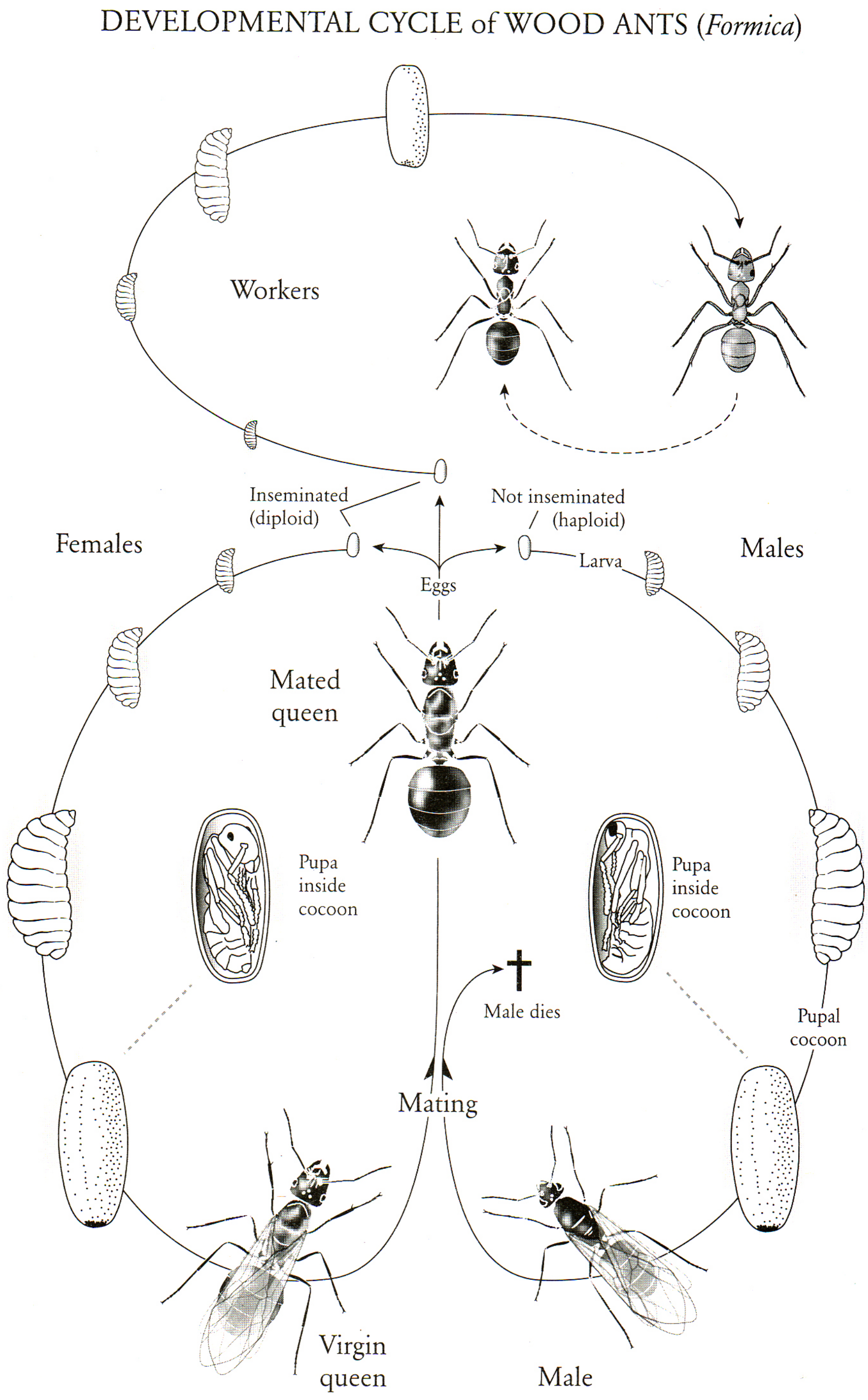
4 The first miniature workers produced by the queen, who are characterized by a timid behavior but perform the basic tasks of any other worker. Their existence is based on the limited resources and energies the queen has to optimize in order to raise the first generation of workers. Wilson Edward O. and Hölldobler Bert. Caste and Division of Labor. The Ants. Harvard University Press, 1990.

5 Wilson Edward O. and Hölldobler Bert. Altruism and the Origin of the Worker Caste. The Ants. Harvard University Press, 1990.

Figure 3-4

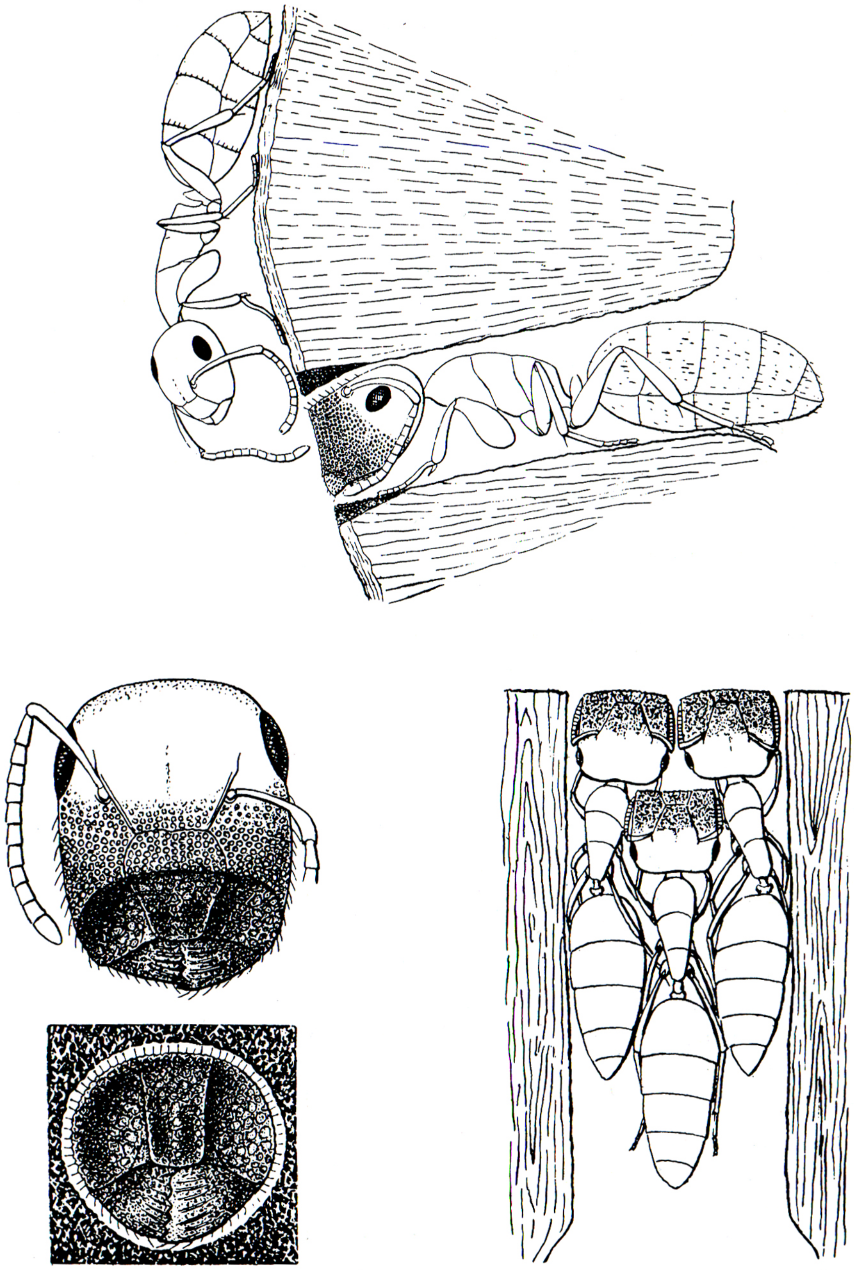
Ants protect above all the brood and the larvae.
Here an unknown species from Otonga, Ecuador, cluster around the chamber nest. (Photo: Kuaishen Auson)

Figure 3-5

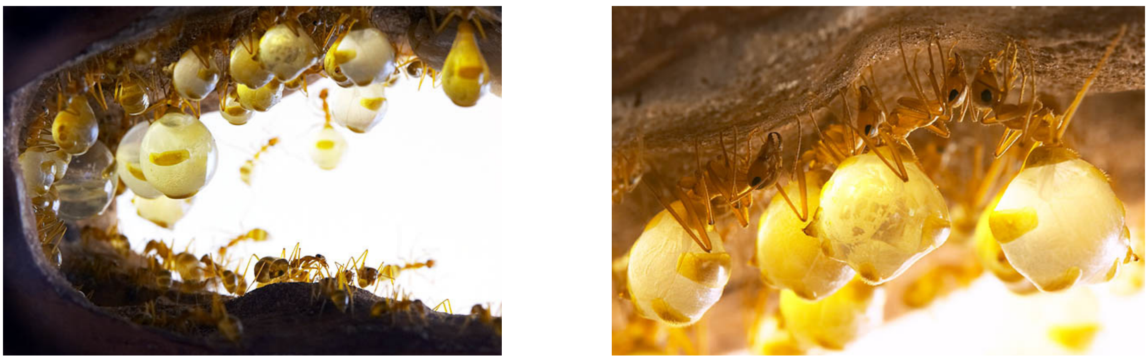


Life cycle of the european wood ant Formica polyctena.

Figure 3-6

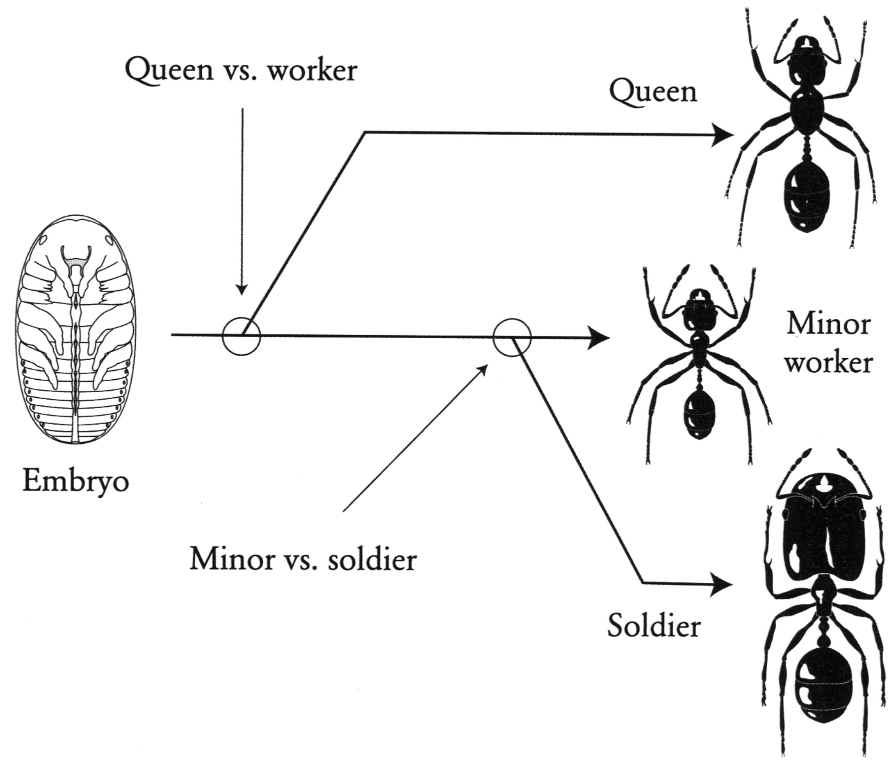


Colobopsis truncatus special “door-caste“ blocking the entrance of the nest.



Myrmecosistus mexicanus, better known as the honeypot ants, possess a special caste that stores food in their expandable social stomachs. (Photo: Alex Wild)

Figure 3-7


Queen vs. worker
Queen
Embryo
Minor worker
Minor vs. soldier
Soldier

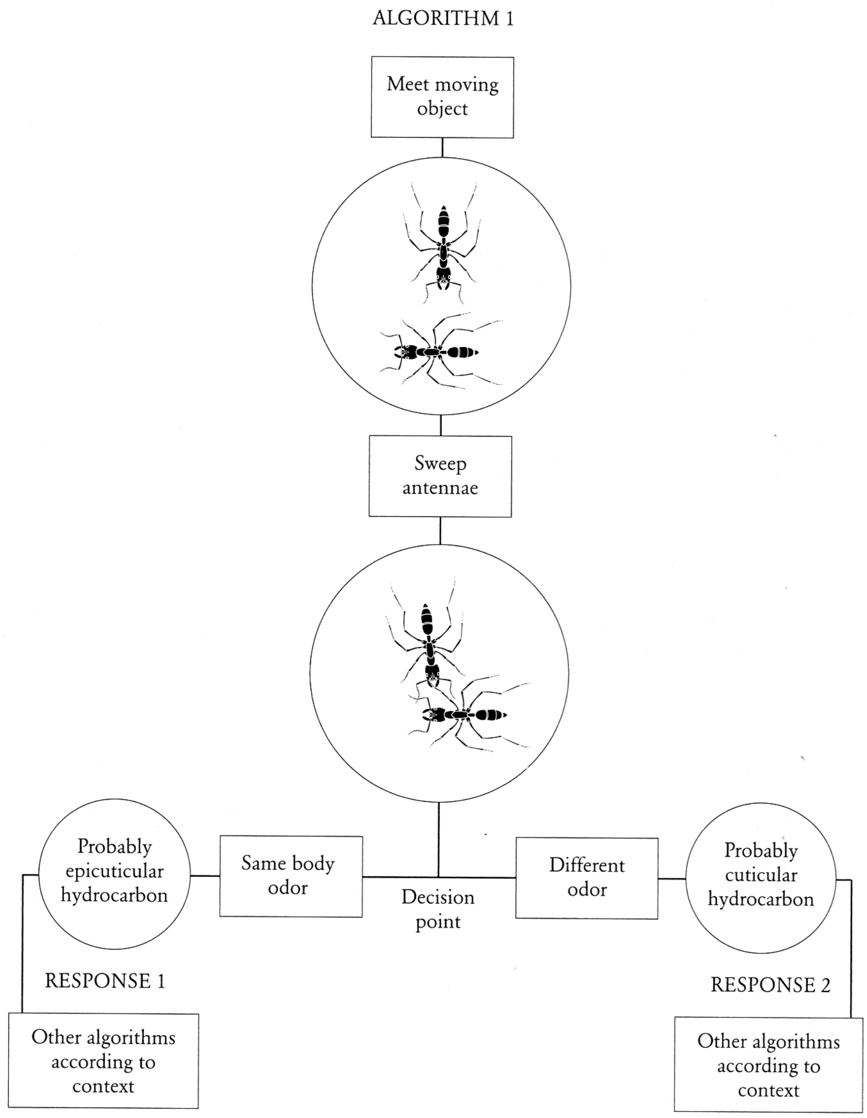
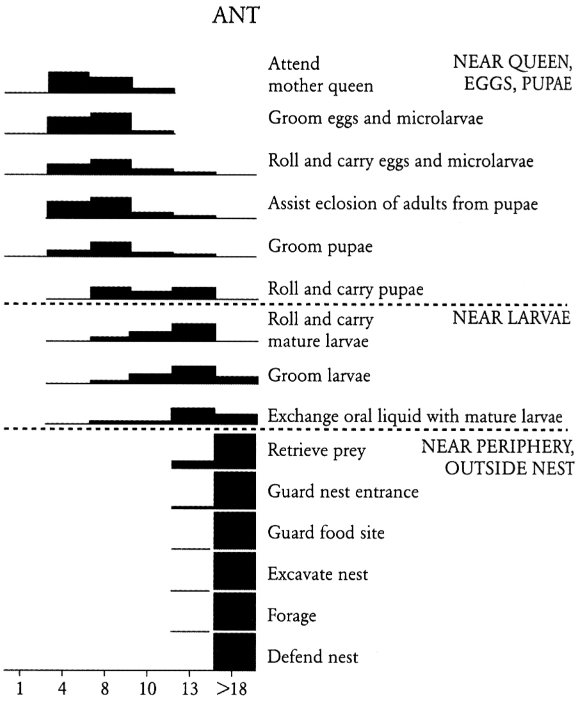

ALGORITHM 1
Meet moving object
Sweep antennae
Probably epicuticular hydrocarbon
Same body odor
Decision point
Different odor
Probably cuticular hydrocarbon
RESPONSE 1
RESPONSE 2
Other algorithms according to context
Other algorithms according to context

Figure 3-8

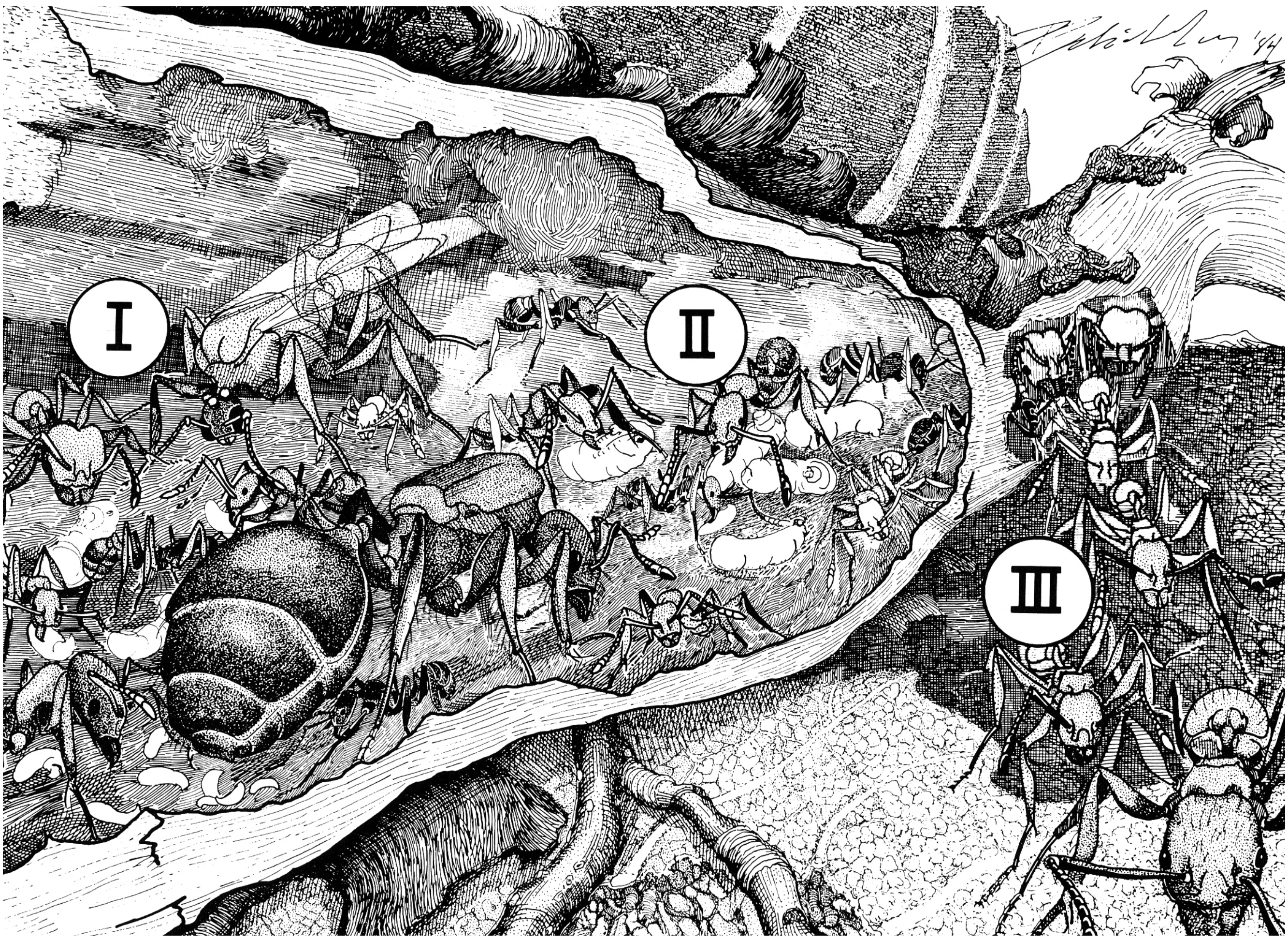
Atta Cephalotes with super soldier in the center and various sizes of minors cultivating the fungus nest. (Photo: Shiggy Takato)

Acromyrmex sp. in the Yasuni rainforest of Ecuador transporting vegetation back to the nest. (Photo: Kuaishen Auson)

■ Figure 3-9



The temporal division of labor for minors workers of a laboratory colony of Pheidole Dentata, based on changes in behavior with aging: the insects shift in central tendency from one linked set of task to another as they move their activities outward from the nest center.



Workers of Pheidole Dentata pass through 3 stages as they age:

I) concentration on the care of the queen.

II) attention to the care of larvae and other nest activities.

III) foraging outside the nest.

front of the nest's primacies. As a matter of fact, studies have proven that the age of ants can be deduced by the most frequent task such ant performs in the nest. Another relevant feature to recognize the age of ants is the coloration of their exoskeletons. Normally young ants show a pale color while adults show a darker opaque color. The young spend most of their activity when they are born near the queen, at the core of the nest, and advancing in a circular fashion outwards, the division of labor gradually gets older with the first line of defense located far outside the peripheral barracks of the nest, composed mostly by the oldest adults in the colony (fig. 3-9).

The system established by the queen at the founding stage is altruistic, based not on individuality but on collaboration, sacrifice and team spirit. Altruism and collaboration are inherited programs that emerge from the initial caste development program. When the colony reaches maturity, the collective interaction of tiny brains runs throughout the complete network in parallel, transmitting vital information like queen status, food resources, labor processes, nest construction, and it is all run in parallel, allowing the participation of every individual. No single ant contains the intelligence of the collective, it is the sum of the individual working forces that construct from bottom to top an emergent intelligence. It is essentially a complex system based on labor division, composed by simple agents. Hence, the division of labor in the ant colony originates from the existence of reproductive and non-reproductive castes and the overlap of generations, which enables adults to care and stimulate behavioral changes in the young ants. The passing of knowledge from one generation to the other, the insight and wisdom of the elders, even if this knowledge has a primitive or limited nature, still contains the principle of cybernetics applied to a sociobiological system: the exchange of information. It is indeed a factory inside a fortress that can be addressed in cybernetic terms. The ant colony establishes itself as a matriarchal system where the queen acts like a reproduction machine, rearing new working force into the factory/fortress. The ultimate goal is to reproduce a new factory/fortress to expand the species in the ecological environment. The factory/fortress is organized by self-stimulation in an intricate division of labor where the individual workers, as functioning organs of the production machine, perform specific tasks that contribute to the ergonomic growth of the colony. These tasks range from foraging or hunting for food, caring for the brood and educating younger generations, building, repairing and guarding the architecture of the nest, collecting, distributing and storing food sources, patrolling and scouting for new territories suitable for expansion to defending the factory/fortress of any invasion or intrusion. It's a circular chain of events run in parallel: the environment influences the development of the factory/fortress, thus, influencing the behavior of the workers, who in return react adapting their behavior to cope with the environment, feeding back the initial input to the surrounding environment, now as a mutated emergent form.

Technically analyzed as a production chain, every new ant represents the final product of a self-regulated process. The division of labor in the ant colony is always reborn and renewed because the inputs of the environment into this production chain, the initial variables that condition behavioral development, are never the same. The environment is a macro-system where the ant colony resides, and this environment is a product itself of the interaction of trillions of living beings sharing the superecology known as Earth. The division of labor and the type of castes that participate in the construction of the nest, as a housing dwelling expansion organ, differs from one colony to the other and this division of labor is highly dependent on the phylogeny[6] of its correspondent genera and species and their history of interaction with the environment. One can state it's actually the history of molecular and morphological evolution of the related organs that construct every new society. "There can be little doubt that the target of selection molding caste systems is the emergent properties of the colony. The colony as a whole, the superorganism, contains feedback loops of communication among nestmates that regulate both the proportions of castes and the tasks they undertake."[7]

For instance, the strong and distinctive pheromonal emission of queens of the leafcutter genus, Atta, attracts workers to groom her, offer her trophic eggs, regurgitated food or self-organize and form the nursery team that cares for the brood. Thus, the distinctive colony odor serves as clan insignia, starts with the queen and expands to the outskirts of the nest where the concentration of pheromones gradually vaporizes. The colony, the factory/fortress, is covered by a bio-spherical invisible cloud of pheromones. By these means, the workers are attracted to the queen, habituated by the familiar daily odor, with a strong predisposition to stay as close as possible, driven by a royal aroma that impregnates the thin air in the queen's chamber in such a manner that all the workers in the vicinities feel inevitably drawn to attend and follow her, to pay attention and inform the others of her status. That is the first event of the self-organized conscience to determine who does what. It is a pulsating informational wave that instantiates feedback every time something occurs. "Decision by decision, the insect responds to those stimuli to which its sensory and nervous systems are programmed to respond."[8] It is true that this system can be approached with cybernetic terms, but the outcome of the sum of the interactions between the social agents participating in the process produce emergent consequences that cannot be foreseen. These emergent consequences reassemble social algorithms upon one another molding the basic social interactions that create complexity in the cybernetic ant system.

The queen and her daughters construct a matriarchal society that benefits from an inherent program of decision rules to self-organize and flexibly adapt to the ecological flow of changes. This flow is always changing, for the feedback in the ant's system is interdependent to the environment where the ants exist. The division of labor in ants, therefore, is a system where input and output produce positive and negative feedback loops. These auto-regulated mechanisms characterize the formation of the colony, somewhere between the founding stage and the ergonomic stage, and can be regarded in two manners upon human observation. For the expert myrmecologist, and from the cybernetic perspective also, the formation of the matriarchal organization could be analyzed by the chemical attraction mediated by the discharge of pheromones and cuticular hydrocarbons (fig. 3-10) coming from the individual agents participating in the social interaction with the queen. This is similar to the pheromonal mediation in swarm flight phenomena when the queen

6 Phylogeny: The evolutionary history of an organism. From: http://en.wiktionary.org/wiki/phylogeny (accessed on June 2009).
7 Wilson Edward O. and Hölldobler Bert. The Division of Labor. The Superorganism: the beauty, elegance and strangeness of insect societies. New York: W. W. Norton & Company, 2008.
8 ibid.

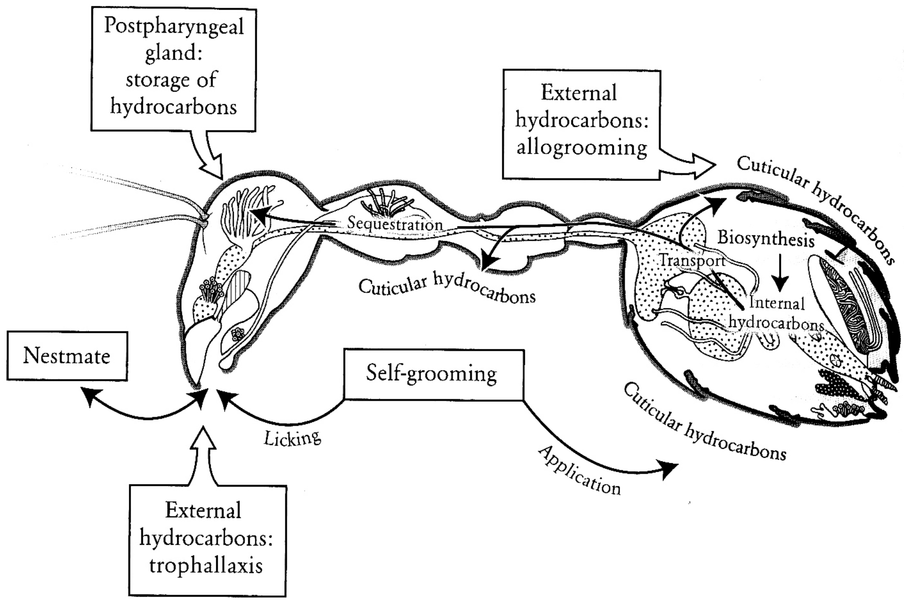
starts the mating call. But for the naked eye, without expert knowledge, this whole division of labor that surrounds the queen and self-organizes its expansion could be witnessed as a ritual or a ceremony.

Is not a program code a repeated set of actions, a series of either sequential or parallel instructions that can be read, processed and compiled to render specific behaviors according to available conditions? (fig. 3-11) Are not rituals also a repeated set of actions carried out carefully to produce a desired result, a miracle? Rituals and ceremonies, reverence and adoration have been part of the history of human cultures. These cultures produced rituals that influence social contexts, conditioning the behaviors of the individuals living and nurturing from that culture. Most of the rituals in human cultures are linked to religious networks of devotions. We have always payed attention to the gods even if we cannot see them. These gods are invisible, are intangible, but somehow exist because of the rituals we carry out. The ants, with their female pride, carry out set of actions embedded in their genetic code, that are invisible. Yet these rituals exist because they influence the behavior and development of the whole colony allowing the colony to emerge from the underground to the surface. The colony turns into an emergent reverberating system of information, a system of beliefs. The self-organization in ants is a ritual that is carefully carried out, like a sequence of decision rules. One can say that ants have a blind faith towards their queen, not mechanizing the production machine, because the rules are dynamic not static, but ritually organizing their network of interactions. In fact, many ant species studied by far and who have shown successful social organization systems don't possess compound eyes, so they are literally blind: from the oldest Dorylus species to the recently new discovered Martialis heureka (fig. 3-12).

The Mayans built pyramids to worship their gods. The Incas also built pyramids to worship their gods. Postmodern humanity built churches, meccas and synagogues, even small altars inside homes. Maybe this religious practice is not that familiar to the europeans, as different cultures possess different rituals and beliefs, but in South America this custom is very strong. Is not a belief an instruction, a permanent piece of information that describes how a god is made? The fact is that the different cultures of the world engage in the construction of a spiritual throne of power, a sanctuary that expands with the goal to influence the behavior of others, specially those that are near the ritual epicenter, beginning with the family circle and extending to friends and strangers. We start recruiting new members for our clan, for our protective expanding ring enclosing the throne of power, the sanctuary we want to protect and defend. It's a rippling wave effect that goes beyond the structure and architecture of the factory/fortress. It is a communication loop in a cybernetic system based on social algorithms of simple decisions that allow the exchange of vital information among it members, allowing them to grow strong and expand. The metaphorical comparison I am making now, between the ritual believes we possess as humans that enable us to protect that belief and carry on our lives, and the ritual of matriarchal self-organization in a cybernetic division of labor the ant factory/fortress promotes, is that both actions correspond to a chain of events present only in social beings.

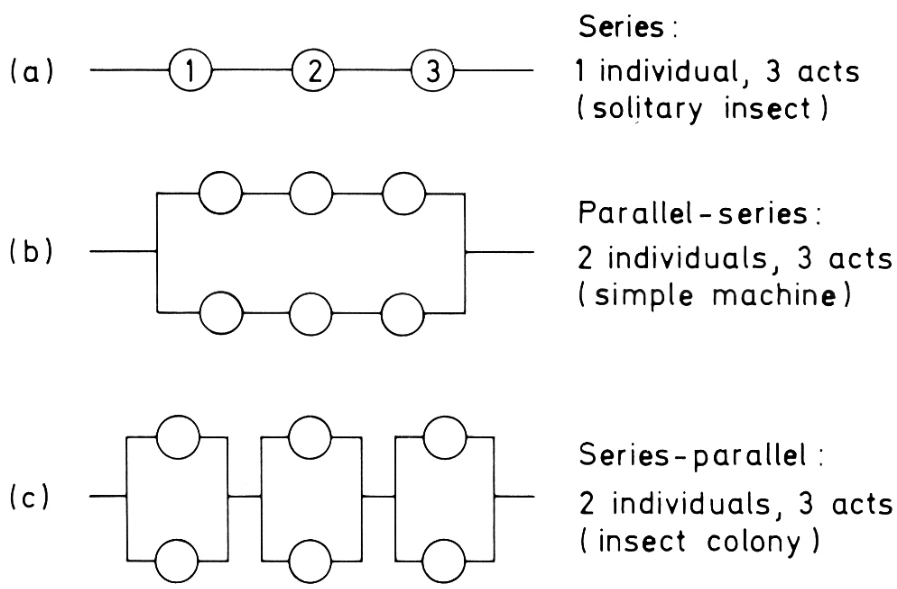
The ants built, and are still building, underground security chambers and palaces out of organic matter around the queen to protect her, not because she orders so or because she has become a deity to her daughter/workers, but because her pheromone compounds and exoskeleton odors unchain a massive call for attention and care: attraction. This is a feedback loop that contains a very important set of information, a load of semiochemical labels that stenches the whole architecture of the nest as the main insignia of colony odor, and injects the message in the network of simple agents connecting every nestmate informing she is the one, she is the reproductive caste where the life cycle of the colony begins. Does this behavior called by the pheromone message of the queen imply some sort of ritualized adoration or is it just a simple rule of attraction for social recognition? Despite the duality nature of the question, both answers can be right, depending on the personal point of view one wishes to choose.

Figure 3-10



The pathways of generation and distribution of the cuticular hydrocarbons used by ants to identify colony membership.

Figure 3-11



■ Figure 3-12

Martialis heureka specimen found on the jungle of Manaos, Brasil. This ant is blind and subterranean. Studies suggest she still retains the features of her ancestors since the Cretaceous period. (Photo: C. Rabeling and M. Verhaagh)

SOCIAL LEARNING: ERRATIC ECOLOGICAL FLEXIBILITY

"a great deal of the flexibility observed in the behavior of individual ants can be attributed to learning".[1]

To progress is to learn based on trial and error in order to prevent future mistakes which could affect the natural course of evolution. It's all about making the right decisions during the course of actions in our lives, based on past experiences. Individuals assemble in societies propelled by a set of social algorithms that condition decision making. There is always conditions to what we can and cannot do. The environment, as an ecology of possibilities, presents opportunities and natural challenges, so that a set of social algorithms is needed to operate accordingly within society. The life cycle of societies seems to be always changing, adapting, advancing towards an ideal equilibrium, which we may never achieve, but nevertheless seek constantly to achieve, making mistakes in the past while trying to amend them in the future. But we humans have an individual instinct for perfection and control that stays within the individual level. We fall in the trap of making the same mistakes over and over again, but to our luck we have lessons to learn, for every new experience enlightens us. Younger generations will perform better in the future as a society, because ideally they won't make the same mistakes we did, but rather new ones. That is self-education, to learn from past experiences and apply a method of trial and error for every new enterprise we haven't face before. We try to adapt to the changes in the environment by trying new things. Nonetheless, as the majority of cases in human social interaction have demonstrated, a nepotistic learning disposition prevails over the altruistic share of knowledge. This means, we prefer to share our learning experience, derived from personal committed errors, with our own relatives and closer kind, rather than with strangers. And that is where we may be failing.

On the contrary, ants have evolved general instincts towards the benefit of the whole society they live in, favoring the swarm spirit of common ecology as some sort of religion, with an almost complete altruistic predisposition. Because ants live in an open environment[2], where danger is inevitably around the corner, they have to stay together, they apply the altruistic 'trial and error' method together, they keep on collaborating and sharing with each other. All points out, within the history of ants evolution, as well as within the history of human and animal evolution in general, that a unified living force, has more chances to dominate and survive than an individual force acting as a single organism alone. To this respect, associative learning plays a major role in the integration and adaptation of individuals who share common ideals and live together in community. Ants, as individuals of an insect society sharing a common goal, possess an extraordinary feature in the way they behave, an almost complete altruistic predisposition, which presupposes a strong tendency for social learning, that enables them to be extremely adaptive to almost any situation or difficulty that emerges, because they can rely on each other to effectively overcome obstacles, problems and even defeat larger enemies. They have learned to do so associatively and being doing so, they have even learnt to coevolve with other interspecific species if necessary.

1 Wilson Edward O. and Hölldobler Bert. Social Homeostasis and Flexibility. The Ants. Harvard University Press, 1990.
2 And by open I mean open to exchange information with the outside world.

The flexibility to adapt by associative learning to the ecology the ants dwell in, represents a key aspect for understanding the cybernetic mechanisms active in the ant's system of self-organization. Ants have perform exquisitely well during the past 100 million years of planet evolution. 100 million years implies a lot of changes. During these changes, the ants have endured, and are still here 'among'[3] us because they applied a rather simple cybernetic set of rules to adapt to the changes in the environment: learning by means of erratic ecological flexibility.

Ants do learn and they do so either by habituation or by associative learning. The following two examples illustrate these learning methods more precisely: when an ant colony is being attacked (based on laboratory experiments) by introducing a strange object into the nest like a rod or other large living insect, the ants react the first time immediately attacking the intruder. But if the simulated attack is repeated on close intervals, they tend to habituate to the alien presence and either accept it as part of the colony-environment relation, or just don't react aggressively anymore. "in this fashion ant workers can be tamed. [...] Even large, venomous species can be picked up, allowed to walk over the hand, and fed carefully with sugar water."[4] Ants react accordingly to the level of stimuli they are exposed to, principally influenced by odors strange to the colony. They do so very fast, either with aggressive attacks or defensive strategies when they sense dangerous stimuli. Furthermore, the association of familiar odors, specifically nest pheromones constitute the most distinctive characteristic for ants to embrace fellow and reject foe. In the human early stages of growth when we cry as babies, we also learn to associate the familiar surrounding that responds to our needs, likewise the ants also start their associative learning during the larval stage.

Most of the ants during larval development are very sensitive to pheromonal information released while being nursed by older ants, thus the pheromones being communicated will later determine the social behavior of that larva ant, and most important the caste that ant will acquire while growing up. It's a two way communication channel. The opposite transmission of information also applies, the larva informs the nurse ant when necessary, what it needs to be fed. "There is additional evidence that when no contact with nestmates is permitted during the sensitive period, later social behavior can be seriously disturbed. [...] Workers kept in complete isolation during larval development grew aggressive and could, however, be integrated only with difficulty into their colony of origin"[5] It's like an orphan kid that starts to present symptoms of social rejection at school, who will however learn to cope with society, later on by means of associative learning. Associative learning is, thus, integral to the development of social entities. We need to identify fellow from foe, or friend from family. In the case of the ants, the association of colony pheromones to identify the queen and the nest, the smell of mother, home and sisters, is perhaps the first relation the ants recognize that will prevail throughout their

3 Among, as in top or above... and not below, us.
4 Wilson Edward O. and Hölldobler Bert. Social Homeostasis and Flexibility. The Ants. Harvard University Press, 1990.
5 ibid.

whole life. Hence, the very different reactions of the ants, when strange odors infiltrate the colony domain. We associate the ecology where we grow, and we associate the living beings, elements and tools that ecology makes available to us.

But probably the most genuine example of associative learning in ants is that one displayed when territorial competition, slavery or war takes place. The principal predators of ants are ants themselves. Colonies of Pheidole dentata or Formica fusca associate violent invasions of their main enemies with 'protect the queen and the brood' or 'abandon the nest completely and run for your life' when any intrusion or aggression is accompanied by high concentrations of enemy pheromones (fig. 4-1). Normally pheidole dentata are very sensible in reacting automatically to invasions of their archenemies Solenopsis invicta, like Formica fusca are used to enter in panic when invaded by their common slave-makers Formica rufa or Formica sanguinea. That panic has also been shown to me the many times I clumsily opened the lid of my Formica fusca's habitat to introduce some food. The habituation of Formica fusca to he constant attacks of their enslavers is still hunting their behavior. Formica fusca is a very sensitive ant who reacts upon the sight perturbation. This association of activating defense against attack is, however, not only related to the specific aggressive pheromones released by the attackers, but it rather relies generally on a sequence of events: continuity of the wave of aggression, increasing death tow, and intensity of foreign pheromones present within the perimeters of the nest. The reactions, thus, become part of an habituation process, where the aggressors and the victims will always play the same roles, almost always, as long as new generations suffer the same consequences and live under the same conditions. It is also the ecology that plays a very important role. That is why ants bred in laboratory cannot easily show an extreme shift in behavior, because many generations will also have to be born in captivity under the same conditions to be able to habituate by means of associative learning. Yet, the probabilities to succeed in taming and habituating captive colonies are great, if we take into consideration the many private and scientific ant breeders in the world who have succeeded in rearing generations of colonies, plus the flexible behavioral pattern put in action by the ants to adapt to almost any environment they find themselves in. Based on observation, there is an associative learning and capacity to memorize the meaning and differences of 'this is friend' and 'this is stranger' when two strange colonies clash.

On my last trip to the jungle, in the Yasuni rainforest, I was lucky to admire the interaction between two titans: Eciton burchelli vs. Eciton hamatum, same gender, different species. These army ants rover over the rainforest destroying everything in their path, like the passing of a hurricane. What happens then when two different army ant colonies collide? I can only testify that they do not harm each other, but rather test their strengths and weaknesses, as to prove who is more powerful to stay in the territory. My observation was that they were flexible enough to recognize the strength and numbers of the other army ants, so they compete for the territory but do not kill each other, like they normally do when faced against other ant species. That is not the case when slave-maker ants and slave ants encounter each other. Formica fusca is a very reactive and defensive social unit that informs the rest of the collective to protect and sacrifice themselves to avoid slavery. On the other hand, their enslavers Formica sanguinea, play the active attacking role raiding and stealing the pupae and brood. The fact is that the habituation of being slaved is probably not learned until a mature age, since the procedure of slavery in ants (and a clever one) is to steal the new born ants in order to raise them as workers and foragers for the new colony that enslave them. Therefore the slave ants are called so, because they work for their new 'master'

■ Figure 4-1

The workers of Pheidole dentata (black) respond much more aggressively to fire ants, Solenopsis invicta (white), than to other kinds of ants.

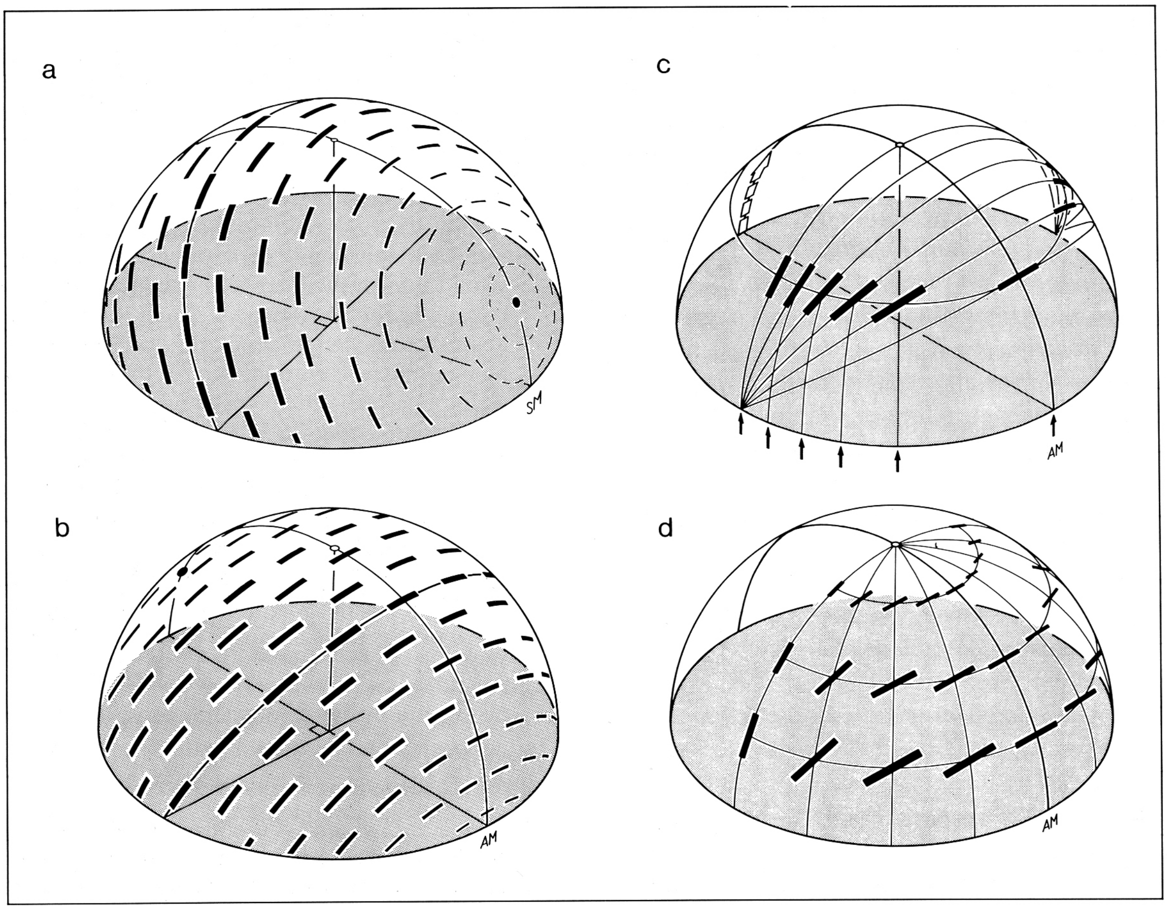
ants, but they don't know they are slaves because they grew in the nest fed and nursed by other Formica fusca ants that went through the same process and now are adults living under the dominion of Formica sanguinea. A very interesting artistic project will be to localize objects, inside the nest of a slave ant species, impregnated with the pheromones of their common slave maker species, in order to activate videos of people smiling or crying according to the reaction of the ant when she approximates the object. And from there on try to simulate a machine that can express at least two basic feelings when exposed to people's body odor: happiness and sadness.

Memory along with associative learning and habituation are considered to be important abilities related to cognitive evolution in humankind. Although field and laboratory experiments have not yet completely proven that all ants are capable of short and long term memory retention, there are a couple of experiments worth mentioning: "Workers of Formica pallidefulva studied by Schneirla (1953) learned a six-point maze with relative ease at a rate only two times slower than that achieved by laboratory rats. Workers of Formica polyctena can remember their way through mazes for periods of up to four days (Chauvin, 1964). Those of Formica rufa, operating under natural circumstances, can simultaneously memorize the position of four separate landmarks and remember them well enough for use in orientation for as long as a week (Jander, 1957)."[6] What is then the definition of memory? The definition of memory, as far as I know, is connected to how well one individual, me for example, can occupy a space and position in time in relation to the other objects, events or living organisms occupying that same space at that same time while I exist. Hence, we can speak of memory as an equation of how efficient I can navigate and interact within that moment in time surrounded by those objects and living organisms around me. Or basically how efficient can I recall what I have learnt from past experiences to locate myself and become a successful meaningful social being inside a given ecology, composed by a collection of objects, living organisms and events interacting with me. A cybernetic culture has to be flexible and pay attention to the unpredictable environment to be able to constitute itself with ease and consciousness against the maze of obstacles and perils set on its destiny, in order to attain what its nature demands. visual memory and celestial navigation play a major role in insect life, specially in ants that must hunt and gather food from the environment. The interaction to that which the environment provides and what the ants give in return to the environment is vital for a long lasting relationship. The symbiosis is therefore inevitable, and the reading and decodification of what each party has to offer is part of the cybernetic deal. The ant colony is part of the ecology just as the ecology is part of the ant colony because there are feedback processes that directly shape both natural entities. A network system emerges, and here, every element participating in this information exchange plays an important role.

Celestial and polarized light navigation (fig. 4-2) is an example of ecological adaptation. Ants have learnt to associate those elements that can be exploited towards finding energy sources needed for the colony to efficiently grow strong, healthy and successful. If the foragers and workers of a colony can visually memorize landmarks, landscapes, tunnels,

6 Wilson Edward O. and Hölldobler Bert. Social Homeostasis and Flexibility. The Ants. Harvard University Press, 1990.

Figure 4-2



"The basis of celestial navigation by ants and some other insects. (a,b) The geometrical design of the pattern of polarized light in the sky. The e-vectors (black bars) are arranged along concentric circles around the sun (black point). The direction and width of each black bar is the direction and degree of polarization, respectively. Figure b is rotated relative to Figure a, so that the reader faces either the solar meridian (SM) in a or else the antisolar meridian (AM) in b. The other great circle marks the line of maximum polarization. (c,d) The celestial map used by the insect is a simplified version of the actual e-vector patterns. It is based on just one feature of skylight polarization: the line of maximum polarization. As the sun moves up (white arrows in c) the line of maximum polarization tilts down. This results in a distribution of maximally polarized e-vectors as shown for an elevation of 45 degrees. The distribution is very similar for all elevations except those close to the horizon. By taking the mean of all these distributions and assigning the resulting mean distribution to all elevations above horizon, one arrives exactly at the insects's ceöectial map, illustrated in d." From The Ants, Social Homeostasis and Flexibility.

■ Figure 4-3

Gigantiops destructor of Yasuni, Ecuador. (Photo: Kuaishen Auson)

As soon as she sensed me approaching with my camera, she started antennating

and turned into my direction while carefully moving from left to right.

rivers, vegetation, friends, enemies, pheromonal impregnated trails, then those same individuals that forage for food outside, transmit that information to the whole colony, and enable them as a living superorganism to navigate the same trials and tribulations with ease and consciousness throughout the maze of obstacles and perils set on its destiny in order to attain what its nature demands. Gigantiops destructor (fig. 4-3) is one example of an ant that thrives through the jungle by memorizing visual landmarks. The other magnificent example is Cataglyphis bicolor, who uses celestial navigation in the extreme hot deserts to cleverly find the shortest way back home, and in this manner avoid death by asphyxiation or sun burn. When Von Frisch around 1950 confirmed that insects navigate by sun-compass perceiving polarized light as vectors in the sky and calculating angles for pattern orientation[7], the myrmecological world was fascinated by the navigation methods used by Cataglyphis bicolor and started studying her behavior and relation to the desert. In fact, the desert ant Cataglyphis bicolor, more precisely the solitary foragers of this species, read the sun position, sense its polarized light, and calculate the angle they take relative to the sun during each of their turns, to find the straightest and shortest route back to the nest without hesitation once a prey is captured. The sun and the heat are key components of the deserted, dry and hot ecology the ant lives in, so she learned to adapt to that heat in order to survive. Not only that, but she also takes advantage of the heat to prey on their victims, slow insects that get grilled by the heat. Cataglyphis can also get easily broiled under the high temperatures of the desert, after all her body is an exoskeleton made of chitin that can absorb heat quickly. But they adapted to this inhospitable environment constructing nests 40 centimeters deep under the soil, and developing an increased speed and very long thin legs that enables them to run over surfaces with temperatures above 50° Celsius (fig. 4-4). "In analyzing skylight patterns insects do not behave like human astrophysicists. [...] They do not seem to rely on some abstract knowledge about the laws of atmospheric optics, but get along quite well without such mathematics. What they use instead is a simple celestial map based on the most remarkable feature of light polarization: the intrinsic symmetry line of the e-vector patterns which is identical with the line of maximum polarization. In the real sky, this line is confined to that half of the sky that lies opposite to the sun, and so is the insect's celestial map. [...] All it must do in later trying to reestablish the former compass course is to match the template as closely as possible with whatever e-vector pattern it experiences in the sky. Using such a generalized map based on a simple rule implies that under certain skylight conditions navigational errors must occur."[8]

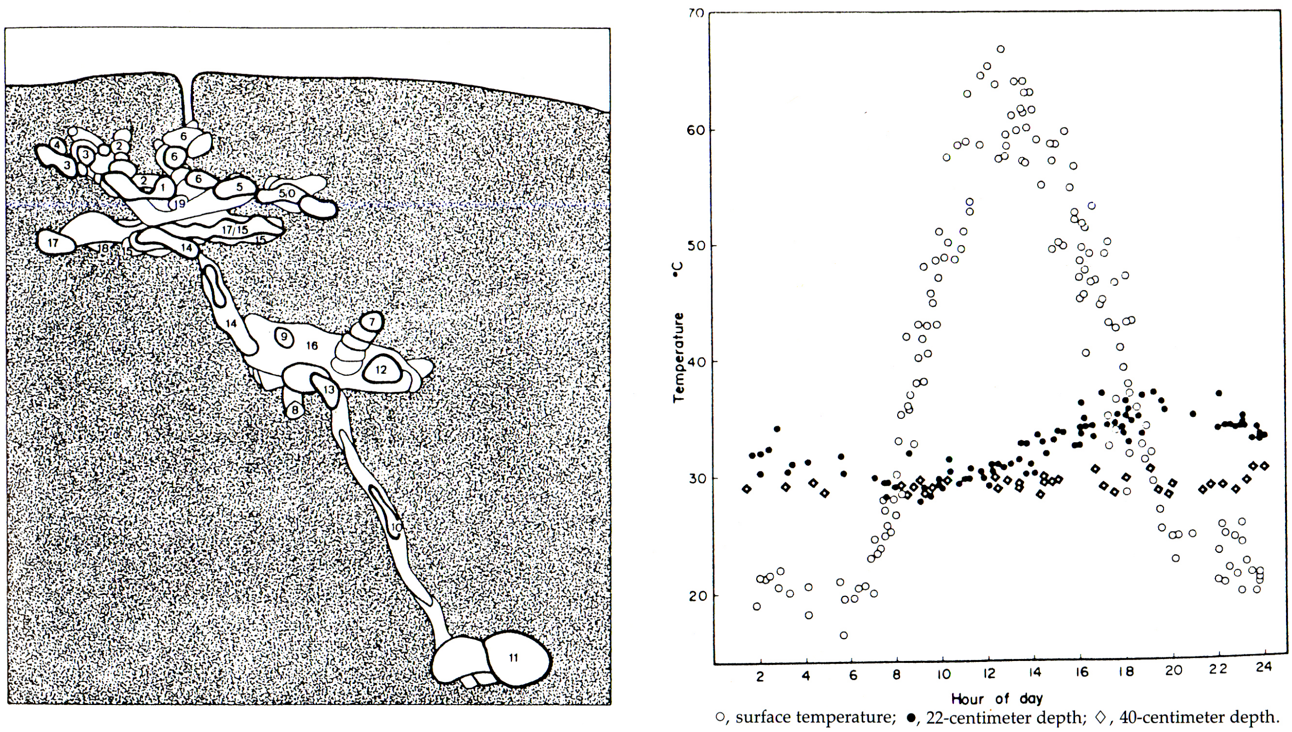
Erratic

Take for instance two different species of different ant subfamilies but whose goal is the same and who can also be organized in the same category: carnivore hunters. The unpredictable hot movements observed on the safari ants, Dorylus erraticus, highly contrast the tactical cool movements of solitary hunters of the ponerinae species Pachycondyla apicalis. The former forms raiding columns of thousands of ants to overwhelm prey and gather food, bivouac mimetics, while the latter hunts in a solitary fashion around the nest, initially without team support. The foraging tempo of these two species is directly proportional to the maturity of the colony they belong to. Here it will be appropriate to mention

---

7 Wilson Edward O. and Hölldobler Bert. Foraging Strategies, Territory, and Population Regulation. The Ants. Harvard University Press, 1990.
8 ibid.

■ Figure 4-4



“Cataglyphis bicolor, a desert ant of the Mediterranean region, avoids extremely high temperatures by building soil nests.
(LEFT) Diagram of a 7 days old nest in Tunisia. Numbers indicate quantities of ants found in each chamber.
(RIGHT) Temperatures at a nest site in Greece in August.”
From The Ants, Social Homeostasis and Flexibility.

that maturity refers to the age of a colony, therefore on most of the cases, the quantity of workers the colony has. Swarm hunters such as dorylus dominate in numbers compared to any other ant species in their territorial range, and exhibit rapid, chaotic, hot movements when foraging: some ants run in one direction carrying stolen brood or killed prey away from the nest, while others simply run in the opposite direction heading to the nest with no booty at all. Sometimes the saturation of ants at the end of the swarm looks so chaotic and with no apparent order that it may look like the ants are lost or just randomly moving forward. In fact, labor saturation is an erratic behavior manifested by almost all the ants, but it is present predominantly on the army ants (Ecitonini and Dorylini genera) and the fire ants (Solenopsidini genera), where too many ants perform the same task overcrowding the activity. Even though this erratic behavior may look like an unnecessary waste of colony energy, it has nevertheless proven to be a fruitful technique to randomly find food. "Pasteels et al. (1982) and Deneubourg et al. (1983) have pointed out that errors committed by ants during recruitment actually have other adaptive advantages when colonies are labor saturated [...] Errors during recruitment could allow the ants to discover nearby food sources. Finally, a scattering of ants in this manner allows the colony to follow and capture moving prey more efficiently than if the recruitment were highly precise."[9]

Meanwhile solitary hunters from the Pachycondyla family usually perform cooler acts, moving slowly, being gracefully careful (fig. 4-5), even keeping a frozen guard on strategic posts while waiting for the right moment to catch a prey passing by. The Ectatommini ants is another example, they freeze completely when a stranger approaches, even staying so for more than 2 minutes (fig. 4-6). Also Ectatomma ants tend to play dead when grabbed with the hand, and also stay in that position until the danger is gone. Now how did they learn that, or since when, nobody knows for sure. The relation between workers' quantity and activity tempo of a given colony appears to be relevant to the envelope of movement applied by each ant in that colony, may it be for the cases of capturing prey or carrying brood while migrating. How fast or how slow the ants of a given colony act, depends variably on the size of the colony. Larger colonies like safari ants may risk losing workers, for there is always new ant generations being bred as well as many spare ants within each caste to restore the ones that may get killed. On the other hand, smaller colonies cannot risk losing single hunters on foraging trips because it could be fatal for the colony growth, wealth and productivity. Hence, large colonies can afford some degree of inefficiency, understood in this case as 'hot movements', risk of getting killed, by saturating each task with many individuals, for instance Dorylus army ants in Africa need to do so in order to kill and transport bigger prey. While small colonies follow a more careful plan of actions, in which each worker precisely performs what is rational, 'cool movements' to make sure they capture their objective without risking wounds or putting life at stake. Thus, the ant colony as a whole, be it small or large, possesses some degree of community consciousness, which plays a major role on the behaviors and actions of its members. More workers means we could risk and ambition more, less workers means we shouldn't risk too much, let's save us problems and stress. And taking this into account, we have the safari ants, great in numbers with erratic hot actions, and the Ponerine hunters, fewer in numbers and with, to some extent, predictable cool movements.

9 Wilson Edward O. and Hölldobler Bert. The Organization of Species Communities. The Ants. Harvard University Press, 1990.

Figure 4-5

This Pachycondyla just hunted a small arthropod in the Yasuni rainforest. (Photo: Kuaishen Auson)

Figure 4-6

Ectatomma ants sometimes stay completely still when hunting. This one froze for almost 2 minutes when I came closer with my camera in the Yasuni rainforest. (Photo: Kuaishen Auson)

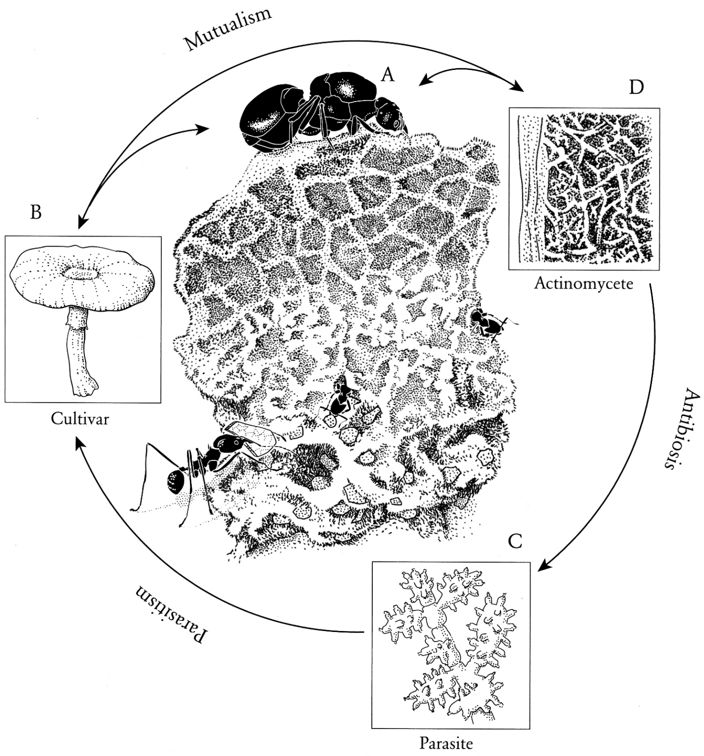
Ecological

Humanity is recently embracing and understanding the effects of the 'we-are-the-world' network mostly because of globalized media, the internet, migration and an open cultural movement. We have been channeling our ideas for an open environment for decades. In other words, our natural ecologies, the ones we have grown into and have been profiting from, have been connecting and interacting since the beginning of the global village, since the start of the medium as the vessel for expressions and desires. Furthermore, information has been spreading, breaching mental barriers, reaching new levels and achieving consciousness throughout these years. And it is now that we have acquired an overall consciousness, a collective spirit. Everything is bio or eco nowadays, and it has become a social status. Today we live in the era of the world as a common ecology, that which we all contribute to destroy or cultivate. The pulsating living network of information has achieved a global stage, is being processed in parallel fashion by everyone as one ecological culture we need to listen to and take care of. We have not yet fully evolved in the societies we live in, we are still riding the wave and seeing that there are others emerging and riding along with us, who are influenced and afflicted by our actions. It takes time for an autonomous system to warm up in order to produce results and activate an overall consciousness of its state, to realize and assume a just position towards the ecology it is part of. The emergence of this global ecological consciousness we are experiencing nowadays is the result, among many other factors, of an empathy network built on neighbor immediacy along the years of evolution. Just like ants, humans have no mental frontiers anymore. We are kind to our brothers and sisters as we become more and more flexible to accept the introduction of foreign cultures and learn to live together, adapting together, embracing the features that make us different, with the purpose of pursuing a common ecological sphere.

This same empathy network built on neighbor immediacy occurs in ants, and this social echo may well have started there, way before we assessed it as a relevant mechanism for the future of humanity. Even though many do not dare to address consciousness in ants, this neighbor immediacy consciousness is in fact a very important initial requisite for the evolution of the ant colony as an autonomous social system. Just as we try to pursue and induce a conscious ecology as a synonym for a better life, the ants already operate ecological, fueled by a hidden consciousness. Ecology is a virtual intention for us humans, whereas for ants, I risk to say, it is actually part of their cybernetic nature. "Human agriculture, which originated about 10,000 years ago, was a major cultural transition that catapulted our species from a hunter-gatherer lifestyle to a technological and increasingly urban existence [...] Humanity thereby turned into a geophysical force and began to alter the environment of the entire planetary surface. Approximately 50 to 60 million years before this momentous shift, some social insects had already made the evolutionary transition from a hunter-gatherer existence to agriculture [...] Attine ants in the New World invented the culturing of fungi, which then became an essential part of their diet. The most advanced agricultural insect societies, like their human counterparts, rose to ecological dominance."[10] The leafcutter ants

10 Wilson Edward O. and Hölldobler Bert. The Attine Leafcutters: The Ultimate Superorganism. The Superorganism: the beauty, elegance and strangeness of insect societies. New York: W. W. Norton & Company, 2008.

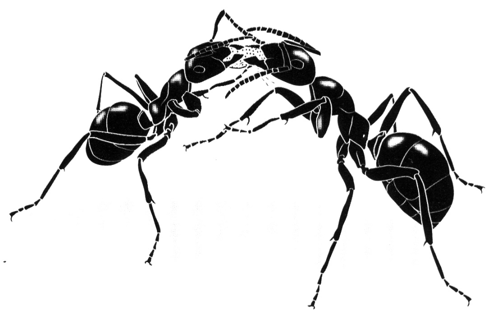
■ Figure 4-7

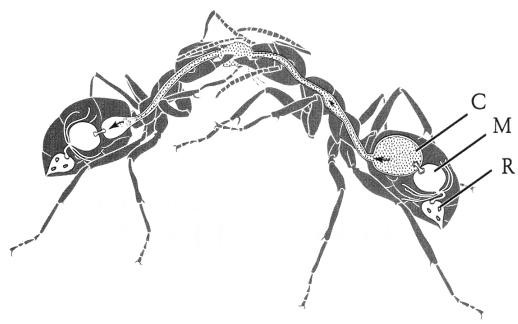


The symbiosis in leafcutter ants:

(A) The queen is the reproductive unit; (B) Mushroom culture (leucocoprineous fungi); (C) The parasitic microfungus Escovopsis;

(D) The filamentous actinomycete Pseudonocardia, which grows on the cuticle of the ants and produces antibiotics that suppress the growth of Escovopsis





2 workers of Formica species exchange liquid food.
(C) crop or social stomach; (M) midgut or normal stomach; (R) rectal bladder where waste material is expelled

reuse, recycle and grow, giving back to mother nature what mother nature offers them. "In laboratory experiments with Atta and Acromyrmex colonies, P. Ridley and his collaborators demonstrated that the ants learn to reject plant material that contains chemicals harmful to the fungus."[11] Leafcutter ants are farmers, who like their human equivalent, learn to associate what is good and bad for the harvest, they learn to know what stimulates a healthy crop and reject what sickens it. The suggestion is that the ants associate odor with food, so if a contaminated orange, for example, is fed to the fungus, the fungus will present some signs of illness afterwards, which in turn will be perceived by the ants, making them take the decision to avoid harvesting oranges. The system becomes quickly aware of the consequences, for the ants share their food through their social stomach, so the information of the state of the fungus literally flows from one ant to the other (fig. 4-7). "This shows again that ants get information from the fungus that a particular plant species is not good for the fungus."[12] There is a cybernetic response to the changes in the environment where the leafcutter ants live. In this case the fungus garden, a super ecology, because it serves as housing nest and also provides them with food, exhibits a positive or negative reaction when fed the various leaves the ants harvest. If the fungus grows healthy that will unchain a positive reaction so the ants will keep harvesting that particular plant to the point they develop favoritism, a mutual favoritism for the fungus feeds the ants. There seems to be a conscious for ecology-friendly behavior in leafcutter ants, they eliminate any other type of vegetation that may harm the fungus garden, keeping a clean home. Now who is to tell me, this doesn't resembles the actual human pursue for a clean environment.

Flexibility

Ants are very flexible in the way they grow and produce new generations. They apply an elastic behavior when they organize. They seem to know, based on sociobiological investigations, how to manage available or gathered resources to ergonomically yield the required energy for the optimal growth of the colony, so that every member learns how to coevolve with its neighbor growing together and making the best of the available resources. The queen will not rear new ants that won't stand a chance to survive, when she starts founding the colony, if she doesn't have the necessary energies and resources to take care of them. She has to be flexible and eat some of the eggs she lays to breed stronger eggs that can survive and adjust to the harsh conditions of the environment. By locally listening to each other, each ant has the ability to assert an overall form of social homeostasis, that provides a flexible adaptation to new input or change. Thus, the feedback established between the colony members becomes vital for the parallel flow of information. There are adaptive shifts in behavior that arise only when the colony is lacking balance or in need to return to a successfully proven social organization. The division of labor and the caste system within colony organization are by-products of the active set of algorithms each ant possesses to react to the pressures of the environment. Therefore, one can speak of self-organization by social algorithms, or a "kind of molecular and organismic operating manual by which the colony assembles itself"[13].

11 Wilson Edward O. and Hölldobler Bert. The Attine Leafcutters: The Ultimate Superorganism. The Superorganism: the beauty, elegance and strangeness of insect societies. New York: W. W. Norton & Company, 2008.

12 ibid.

13 Wilson Edward O. and Hölldobler Bert. The Genetic Evolution of Decision Rules. The Superorganism: the beauty, elegance and strangeness of insect societies. New York: W. W. Norton & Company, 2008.

Any disturbance or stress inflicted on the colony consequently becomes an event which inevitably summons regulation and readjustment. And it is a continuous struggle. The communication is spread along the local nodes, as in a network of neurons or telephone signal replicators, to make sure the message reaches not only the ideal recipient, the neighboring ant, but everyone in the system. An assessment is then made and a final choice is more or less the result of a collective awareness election, that is, groups arrange and propose immediate actions, so the group's proposition which has more supporters or followers becomes the right one for the colony. "Individual workers explore promising sites within the colony's territory, pulling at the edges and tips of leaves. when a worker succeeds in turning a portion of a leaf back on itself, or in drawing one leaf edge toward another, other workers i the vicinity join the effort. They line up in a row and pull together, or, in cases where a gap longer than an ant's body remains to be closed, they form a living chain by seizing one another's waist and pulling as a single unit. Often rows of chains are aligned so as to exert a powerful combined force"[14].

Perfection is therefore not attained or pursued on a self-organizing autonomous system based on dynamic homeostasis, for it doesn't rely on the perfect reception of signals. It rather relies on the anomalies and variations those signals may produce to regulate such system, and the response of the colony is to create teams and cliques that attract and repel until a balanced state is achieved, a prey or intruder is killed, or a nest construction problem is solved. It's an ecology where everything is unpredictable because everything is possible. The cybernetic effects of such system are consequent, because a cybernetic ant system always needs to update, to self-organize according to the feedback produced by the same entities involved in the process. This feedback process is always renewed and always stimulates new behavioral responses. The emergence of the new and unexpected is written in the operating manual of every ant. Therefore, attention has to be made to the chain of events that constantly unfold, where the errors of past actions are just as relevant as any other element suddenly and inevitably emerging during the ongoing adaptation process. Learning is an ability of the ant colony as a superorganism of interacting agents. They have to remember the changes in order to adapt to them. In this respect, the behavior observed in ants as a community of autonomous interacting units can be seen as erratic, yet flexible enough to undergo constant changes in response to the ever-evolving ecology the ant themselves create and recreate. "Whether a social process constantly readjust itself back to the state quo ante or shifts to a new adaptive state, it permits the basic life functions such as regulation of temperature and care of the larvae to proceed with little interruption. in the traditional expression, the life functions are homeostatic, and the social responses have evolved as either stereotyped or flexible enabling devices to achieve their end."[15]

14 Wilson Edward O. and Hölldobler Bert. Caste and Division of Labor. The Ants. Harvard University Press, 1990.
15 Wilson Edward O. and Hölldobler Bert. Social Homeostasis and Flexibility. The Ants. Harvard University Press, 1990.

PHEROMONE JUNKIES

"the art of deception through chemical attraction"

Communication in ants is a secret chemical system of attraction mechanisms. But as secretive as it is with its fabulous encrypted semiochemical transmission, it can be, and has been, decoded and exploited by other living organisms, including specially other ant species. Ants have mastered some kind of art of deception, by chemical and tactile mimicry, to unlock the doors of different ecologies and different systems in order to profit from them. They have become social parasites mimicking the codes of conduct and exploiting the pheromone language of other ants species to the point of permanent inquilinism, living in mixed colonies, stealing food resources and even forcing the host species to work as domestic slaves. "The ant society is a decidedly more open system than is a lower unit of biological organization such as the organism or cell. In the course of evolution the tenuous lines of communication among members of ant colonies have been repeatedly open and extended to incorporate alien species."[1] Ants have been in permanent contact with so many alien species during their social expansion and evolution on this planet, that apparently some clever collectives realized the potential to design their pheromone language to attract and deceive other ants. The art of deception in humans has been attained by reading, processing and understanding the feedback mechanisms produced by social agents living in an established system of mass communication. We have mastered this medium instituting the commercialization of desires. The best examples of the art of deception in mankind are based on rhetoric and visual propaganda: Joseph Goebbels and the Reichsministerium für Volksaufklärung und Propaganda, the Russian revolution propaganda movement, the Cuban revolution iconized by El Che, and the immaculate political demagogy still reigning in South America known as Populismo. Nevertheless, there is another form based on chemical attraction: the undetected marketing and concealed industrialization of perfumes and skin related products. Ants, exemplary social beings, are not strangers to this phenomena and have learnt to produce propaganda pheromones to create social symbiosis with unilateral benefits. In fact, the best example of social symbiosis in ants is portrayed by the extreme social parasite Teleutomyrmex schneideri, who has developed morphological mutations, like concave flattened abdomens and larger tarsal claws, permitting her to securely ride the back of their host victims, Tetramorium caespitum queens, holding onto the chitinous body surface of the host their whole life, as if they were part of the ant itself (fig. 5-1). Teleutomyrmex schneideri lacks a working caste, which means the queen alone is the parasitic ant that infests Tetramorium's colonies, faking her status and profiting from the workers' care. By releasing special highly attractive pheromones that induce licking, grooming and feeding, they are treated and attended as normal queens in the infested colony.

The encoded messages manufactured by natural societies, predominantly visual on the human side and pheromonal on the ant side, constitute fragile symbols of a cultural inheritance that can be mimicked and misused, therefore of a cultural

1 Wilson Edward O. and Hölldobler Bert. Symbiosis among Ant Species. The Ants. Harvard University Press, 1990.

nature that can be simulated beyond the systemics applied during the legitimate origin and later evolution of that social communication system. Propaganda pheromones and the art of deception are products of a constant evolving system of mass communication whose cultural values are inherited by the new generations, who feed them back into the system, stimulating the formation of new channels of communication. If well understood and well deployed, these fragile cultural symbols become control mechanisms of the masses. "Regnier and Wilson (1971) discovered that each subintegra worker possesses a grotesquely hypertrophied Dufour's gland, which contains approximately 700 micrograms of a mixture of decyl, dodecyl, and tetradecyl acetates. These substances are sprayed at the defending colonies during the slave raids. They act at least in part as 'propaganda substances' because they evaporate slowly and help to alarm and to disperse the defending workers."[2] It is the emergence of the art of deception as a strategy that enables the use of intelligent methods without violence for the benefit of the most talented and strongest of the species (fig. 5-2). Along the course of ant evolution and during the different stages of colony formation, many ant genera have evolved to incorporate alien species, who by means of hacking the host's pheromone language and even by mimicking physical form and pigmentation, gestures and behaviors, gain the acceptance and the benefits of the strongest superorganism in the environment (fig. 5-3). "Thus it appears that communicative behavior and chemical mimicry are the essential ingredients for acceptance of social parasites."[3] The symbioses among ants and symbioses with other insects[4] are social forms of parasitism, inquilinism or slavery, that constitute a system of mass manipulation mediated by a collection of feedback mechanisms. This feedback mechanisms have been shaping the social integration between many different kinds of social insects in the natural world. Perhaps an exceptional example worth to mention is the experimental study done by Jose Halloy at the Université Libre de Bruxelles. He and a team of scientist-biologists created a robot cockroach that was programed to either look for shelter in the dark or in the light. The special feature of this robot was the coating with cockroach's attraction pheromones that allowed it to be accepted and followed by other real cockroaches: "Collective behavior based on self-organization has been shown in group-living animals from insects to vertebrates. These findings have stimulated engineers to investigate approaches for the coordination of autonomous multirobot systems based on self-organization. In this experimental study, we show collective decision-making by mixed groups of cockroaches and socially integrated autonomous robots, leading to shared shelter selection. Individuals, natural or artificial, are perceived as equivalent, and the collective decision emerges from nonlinear feedbacks based on local interactions."[5]

The production of pheromones is probably number one in the list of important production processes inside the ant colony, because its whole mass communication network depends on the exchange of encrypted identification odors. Any social system that wants to stay together has to develop a form of communication specific to the needs and understanding of that system. During the evolution of ant communication, the main feature was focused on chemical signals for

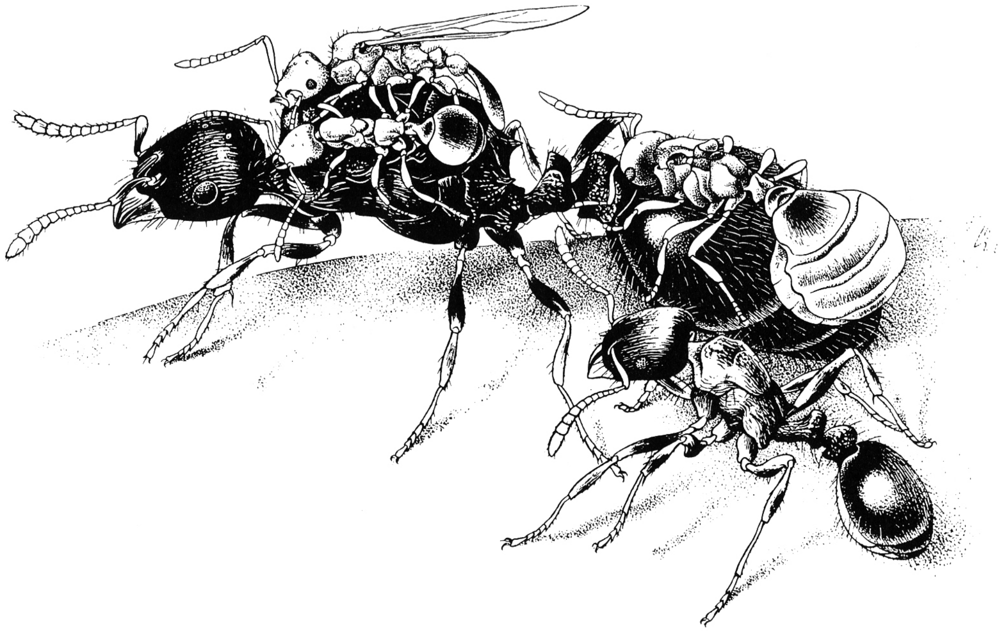
2 Wilson Edward O. and Hölldobler Bert. Symbiosis among Ant Species. The Ants. Harvard University Press, 1990.

3 Wilson Edward O. and Hölldobler Bert. Symbiosis among Ant Species. The Ants. Harvard University Press, 1990.

4 Mostly arthropods: various species of beetles, flies and mites.

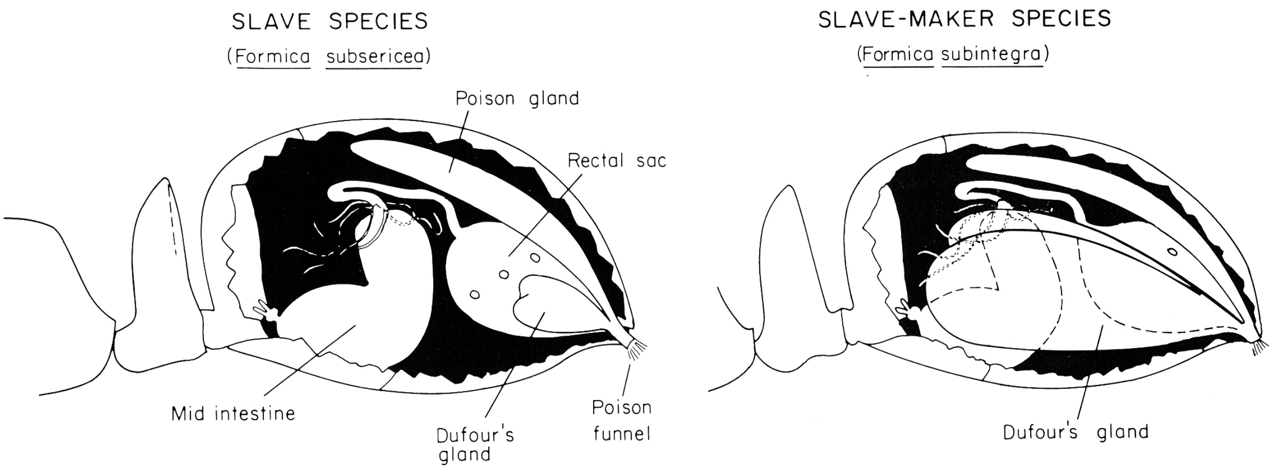
5 Social Integration of Robots into Groups of Cockroaches to Control Self-Organized Choices. J. Halloy, G. Sempo, G. Caprari, C. Rivault, M. Asadpour, F. Tâche, I. Saïd, V. Durier, S. Canonge, J. M. Amé, C. Detrain, N. Correll, A. Martinoli, F. Mondada, R. Siegwart, J. L. Deneubourg. From http://www.sciencemag.org/cgi/content/abstract/318/5853/1155 (accessed on June, 2009).

Figure 5-1



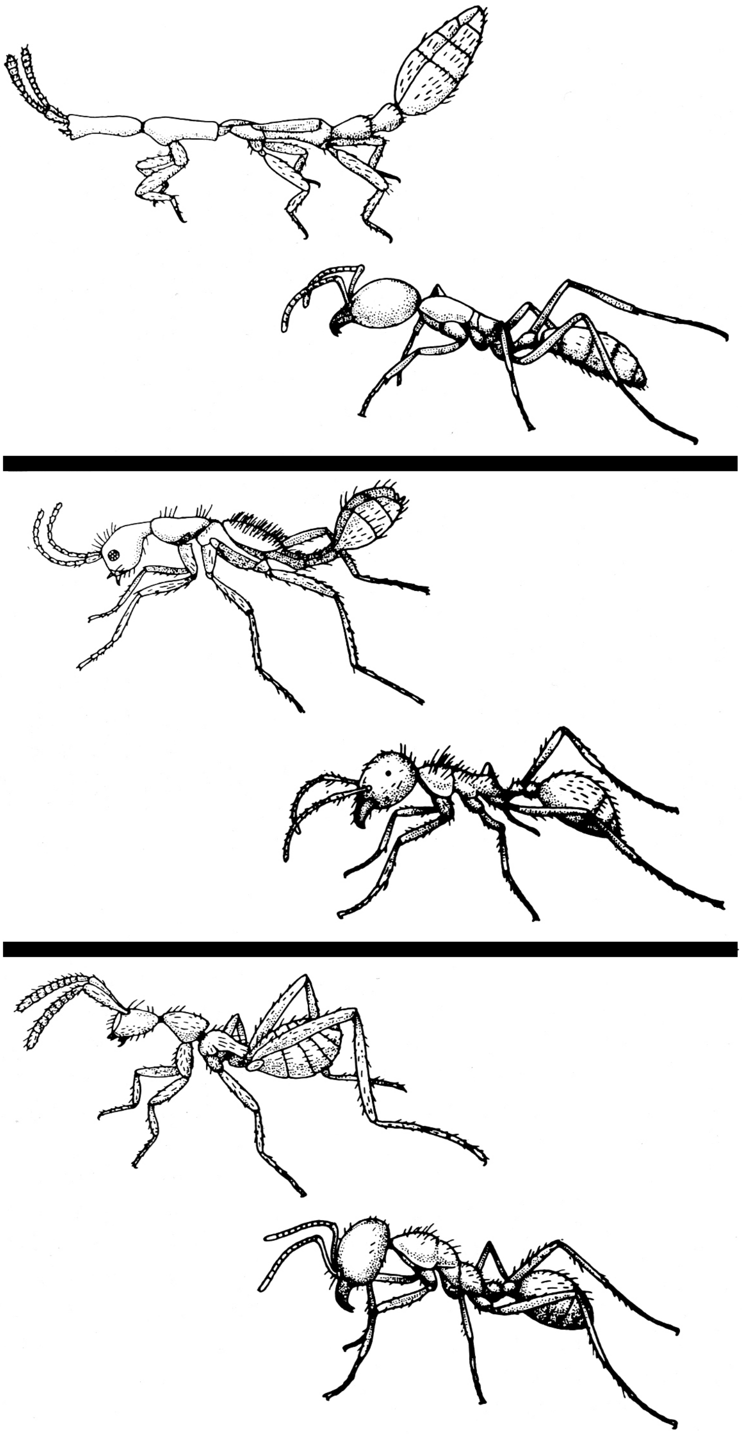
The 2 Teleutomyrmex parasitic queens sitting on the thorax of the host queen are not yet ovulating, therefore their abdomens are flat and unexpanded. One still has wings indicating that she is a virgin. There is a third one clinging on the gaster of her victim, the Tetramorium caespitum queen.

Figure 5-2



Dufour's glands in comparison: Formica subsericea vs. Formica subintegra. Note the size of the gland on the slave-maker species in charge of producing propaganda pheromones to render panic and confuse slave species.

■ Figure 5-3



The army ants attract many interspecific insect species that end up joining them as permanent inquilines in the bivouac. Note the resemblance in the morphology: (TOP) Mimanomma spectrum with its host Dorylus nigricans; (CENTER) Crematoxenus aenigma with Neivamyrmex melanocephalum; (BOTTOM) Mimeciton antennatum with Labidus praedator.

orientation and recruiting, apparently as a unique ability no one else would replicate. Consequently, the ants became geniuses of chemical communication developing an advanced organ that reproduces many molecular compounds which are interspecifically molded to the array of communication of the many species identified by today's scientific taxonomy (fig. 5-4). The pheromonal system of the ants is the key to their mass communication, enabling rapid food retrieval, concerted attacks on enemies and an efficient support and recognition of nestmates in danger (fig. 5-5). Just like in human societies, the idea of control in ants is not perceivable at the micro level, but from a macro perspective and after the system of communication is warm enough, the analytical view yields a cybernetic society massively mediated by individuals, who elect which pheromones to transmit according to context and local feedback (fig. 5-6). If I was meant to be an ant, I will first sense the situation of my neighbor and then go on with the next neighbor and so forth. In this sense, ants adapt correctly to the situations based on what the majority of neighbors in the vicinity are doing at the same time. It is what we call self-organization by the sum of local interactions, and this kind of organization is mediated by feedback mechanisms in order to regulate the activities necessary to achieve a temporary stable state. The colony can be viewed as a parallel processing super machine that reacts on the immediate behavior produced by the different interacting agents performing specific labors in parallel (fig. 5-7). The collection of feedback mechanisms is composed by tactile rituals but predominantly by pheromone signals that act as attractors at the levels of labor division in the colony. Even at early stages of larvae growth, there are feedback mechanisms that inhibit the development of unnecessary castes: like 'don't-become-a-soldier-because-we-have-enough'. It is an economy regulated by pheromones (fig. 5-8). The more we produce as a society, ant or human equivalent, the more specificity we need to inject in the system in order to target and filter messages efficiently to reach a specific population and obtain specific results. That's how an automatic self-controlled ecosystem is produced in the symbiotic culture of ants.

There are 12 functional categories of communication in ants, as stated by E.O. Wilson and Bert Hölldobler[6], that mediate the cybernetic system of self-organization:

- Alarm: as in response to an enemy invasion or breech in the nest wall
- Attraction: leading to assembly
- Recruitment: to food, new nest sites and enemies
- Grooming: including assistance in brood care
- Tropophallaxis: the exchange by feeding of oral, anal, and other body fluids, usually just for distribution of food but often in addition for sharing pheromones
- Exchange of solid food particles

6 Wilson Edward O. and Hölldobler Bert. Communication. The Superorganism: the beauty, elegance and strangeness of insect societies. New York: W. W. Norton & Company, 2008.

- Group effect: collectively either facilitating or inhibiting a particular activity
- Recognition of nestmates and different castes of nestmates: including fertility status and even individual recognition, as well as those injured or dead
- Caste determination: either by stimulation or by inhibition of the transformation of individuals into certain castes
- Control of competing reproductives
- Territorial and home range advertisement and orientation
- Sexual communication: including species recognition, gender recognition, synchronization of sexual activity, and responses to rivals and partners during sexual competition

Ants have a complex communication system that emerges from the simple decisions of individuals reacting to the challenges of the environment. A system regulated by the decision of the individuals is a system which self-organizes based on electoral behavior, creating a greater global effect out of the sum of local interactions. Simple creates complex, and it does so by accumulating nanograms upon nanograms of pheromonal substances[7] constructing an active space for interaction. What actually happens is that the ants become addicted to their own colony odor. They become junkies, dependent on each other to be able to survive. It is a positive addiction though, controlled by negative feedback mechanisms. The attraction mediated by the chemical pheromones is so great, that if a nestmate is impregnated by another odor strange to the colony, she will be immediately attacked until she can show her true pheromone credentials. Even more interesting is the necrophoric behavior when an ant dies. The ants are so lively driven by an active space of pheromones concentrated in the air of the nest, that when an ant dies, her decomposing body starts smelling different, so the nestmates automatically react transporting the body to the near ant's cemetery. For the ants the difference between life and death is recognized by the change of pheromone composition. "The workers do not follow a liquid odor trace on the ground. Instead, they move through the vapor created by diffusion of the substances through the air. There is an active space, which theoretical calculations show to be semi-ellipsoidal in shape, within which the pheromone is detected by the ants."[8] (fig. 5-9) Basically, that is how a complex network of trails and nest chambers get interconnected to render the nest's construction as an organic architecture. The vapor tunnels travels along the tubular passages of the nest, gaining intensity where the ants are tightly clustered, and extend into the open peripheries of the nest creating synaptic highways that connect the colony to permanent foraging areas and food resources (fig. 5-10). The trail and orientation system of ants resembles, though very poorly, the traffic control system of human beings. Whereas we humans are obsessed with control and mediated by visual signs when we travel from one location to another, the ants are obsessed with pheromones[9] and are mediated by a trail system that emerges out of the simple decisions of individuals,

7 Trail pheromone carried by each worker varies greatly among species: in Camponotus, 2 to 10 nanograms; in Atta and Acromyrmex, 0.3 to 3.3 nanograms. Wilson Edward O. and Hölldobler Bert. Communication. The Superorganism: the beauty, elegance and strangeness of insect societies. New York: W. W. Norton & Company, 2008.

8 Wilson Edward O. and Hölldobler Bert. Communication. The Ants. Harvard University Press, 1990.

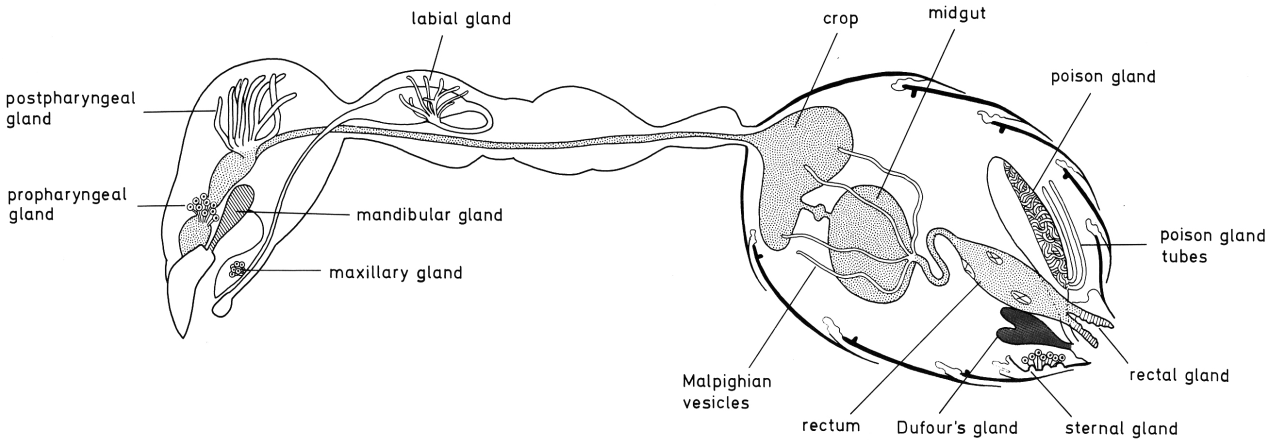
9 Thus, controlled by pheromones. Interesting is to assert the potential of the pheromone system in ants as a control method.

Figure 5-4

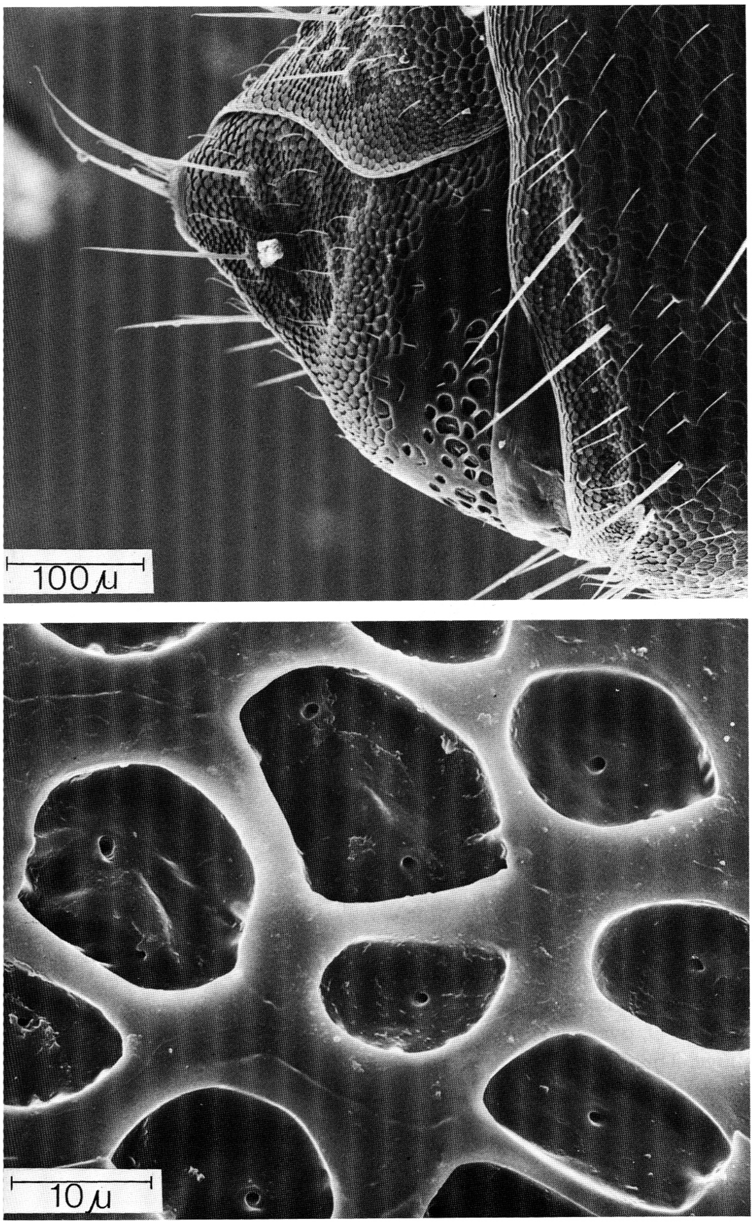
Compound	Function	Occurrence: Family	Occurrence: Genus
Benzaldehyde	Trail pheromone	Apidae	*Trigona*
	Defense	Formicidae	*Veromessor*
Citral	Trail pheromone	Apidae	*Trigona*
	Alarm pheromone	Formicidae	*Acanthomyops*
▸ Citronellol	Aggregation pheromone	Apidae	*Bombus*
	Defense	Formicidae	*Atta*
2,5-Dimethyl-3-isopentylpyrazine	Sex pheromone	Formicidae	*Camponotus*
	Alarm pheromone	Formicidae	*Odontomachus*
Mellein	Sex pheromone	Formicidae	*Camponotus*
	Defense	Termitidae	*Cornitermes*
Methyl anthranilate	Sex pheromone	Formicidae	*Camponotus*
	Alarm pheromone	Formicidae	*Xenomyrmex*
Methyl 6-methylsalicylate	Sex pheromone	Formicidae	*Camponotus*
	Alarm pheromone	Formicidae	*Gnamptogenys*
2-Tridecanone	Alarm pheromone	Formicidae	*Acanthomyops*
	Defense	Rhinotermitidae	*Schedorhinotermes*

A list of the most typical pheromonal compounds found in 3 different eusocial insects: Bees (Apidae), Ants (Formicidae), Termites (Termitidae, Rhinotermitidae). Citronellol, used by the leafcutter genus Atta for defense, is also a common compound used by humans in many household products, body lotions and perfumes.

■ Figure 5-4

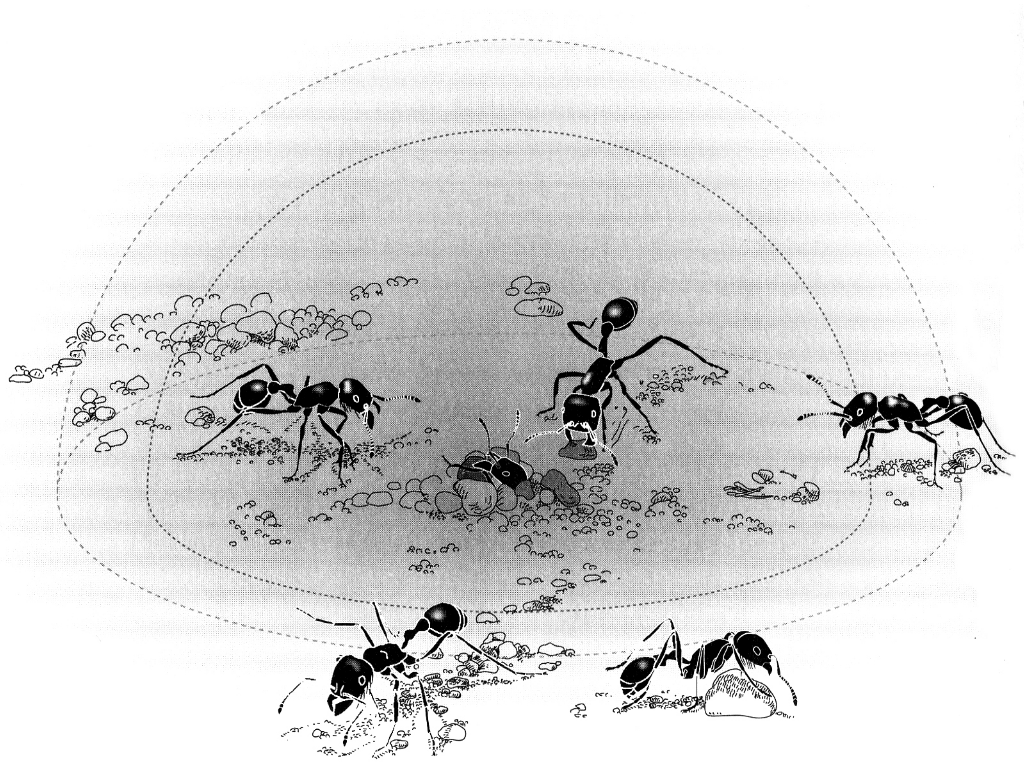


The ant (Oecophylla longinoda, Weaver ants) as a single unit, acting for the colony as a sensor-actor-reactor, possesses an internal glandular system for communication.



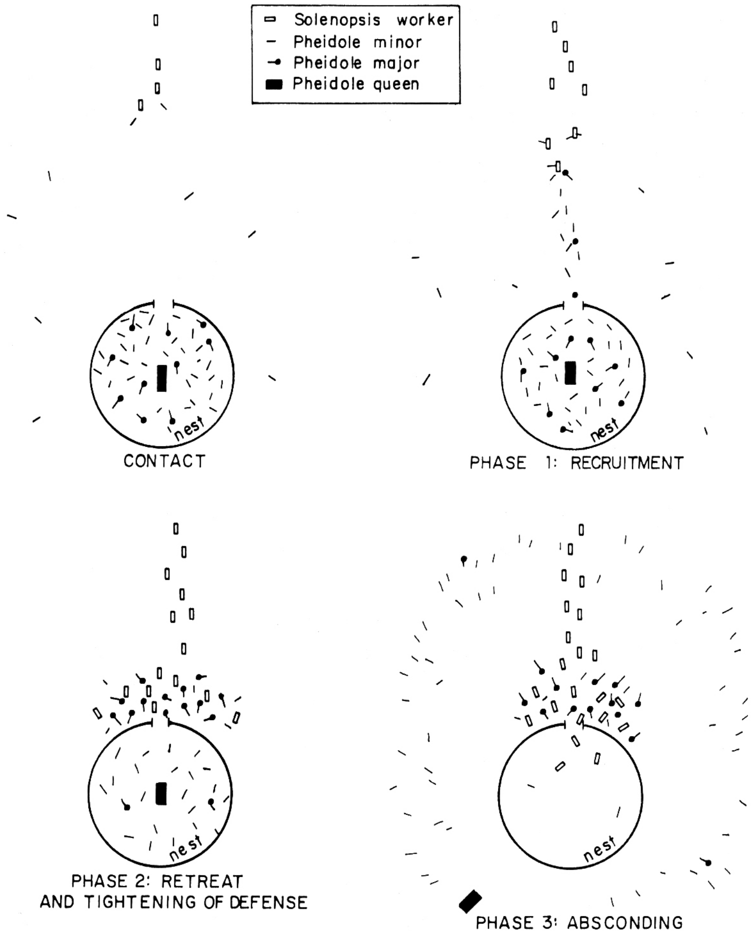
Detail of the sternal gland of Oecophylla longinoda showing the microscopic orifices that enable the ant to spray the pheromones in the air.

■ Figure 5-5



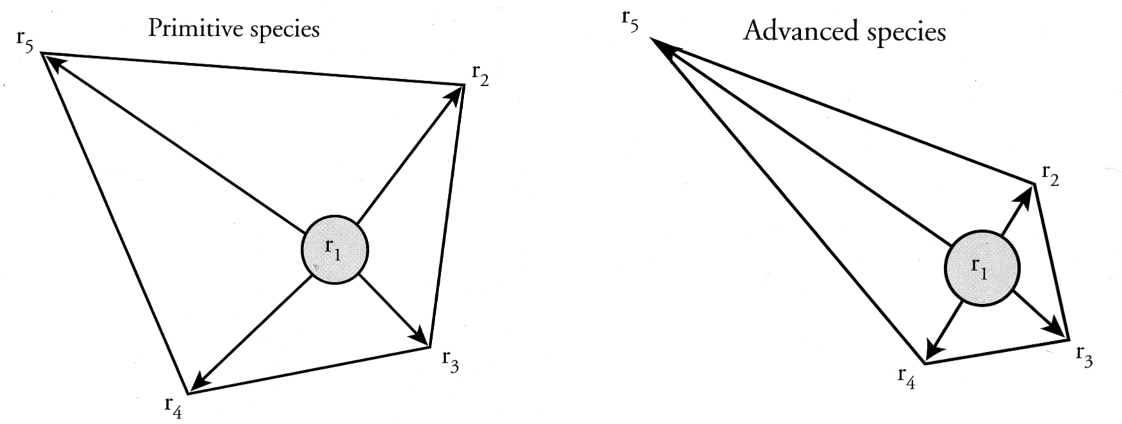
A group of Pogonomyrmex badius, harvester ants, rescue a trapped nestmate. The pheromone communication in ants forms a semi-ellipsoidal active space, which first alert and attracts the ants, then excites them to do specific actions, in this case inducing excavation.

■ Figure 5-6

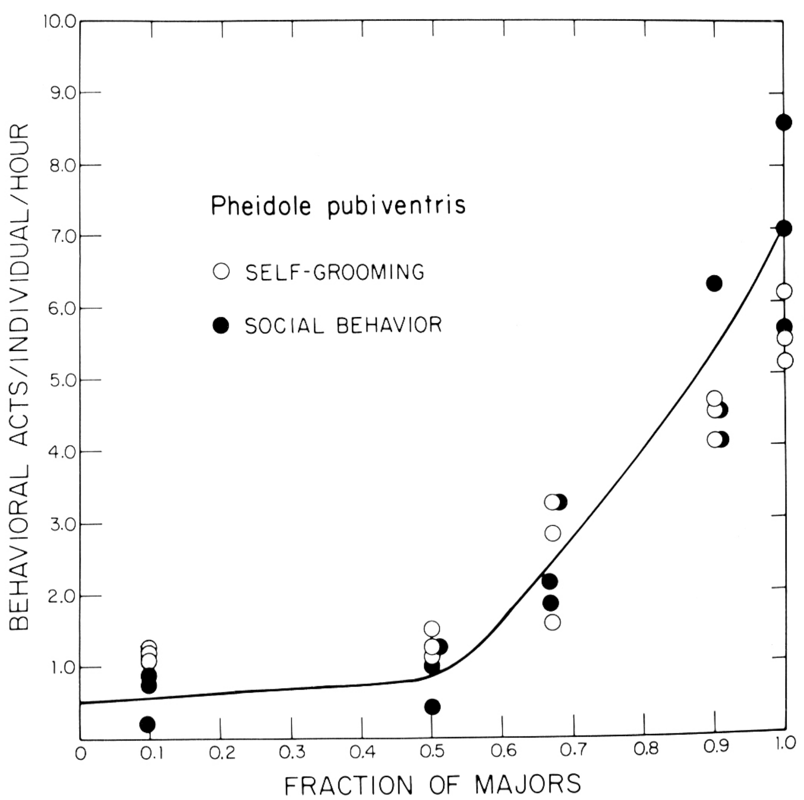


A typical invasion of Solenopsis into a nest of Pheidole produces the complete abandonement of the nest. The increased level of rival pheromones acts as a catalyzer for rejection and retreat.

■ Figure 5-7

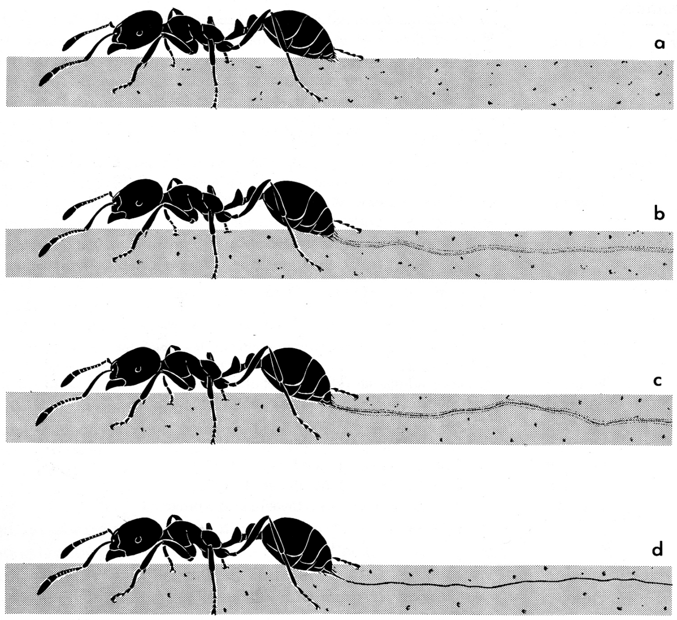


A graphic representation of parallel labor distribution in ants. On primitive species, division of labor is weak and workers tend to easily switch between tasks. On advanced species with more specialized castes, the imaginary labor polygon is expected to be more constricted and less symmetircal. (r1) The actual activity; (r2, r3, r4, r5) Other potential tasks to be performed. The distance of the vectors symbolize the efficiency of finding the right task to do.

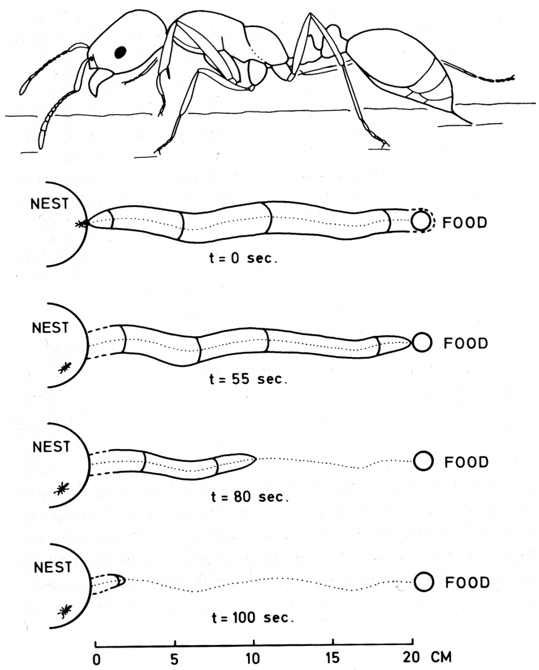


Analysis of the performed behaviors in a colony of Pheidole pubiventris. When there is a decrease in the number of minors, the majors take care of other labors not usually assigned to them.

■ Figure 5-9

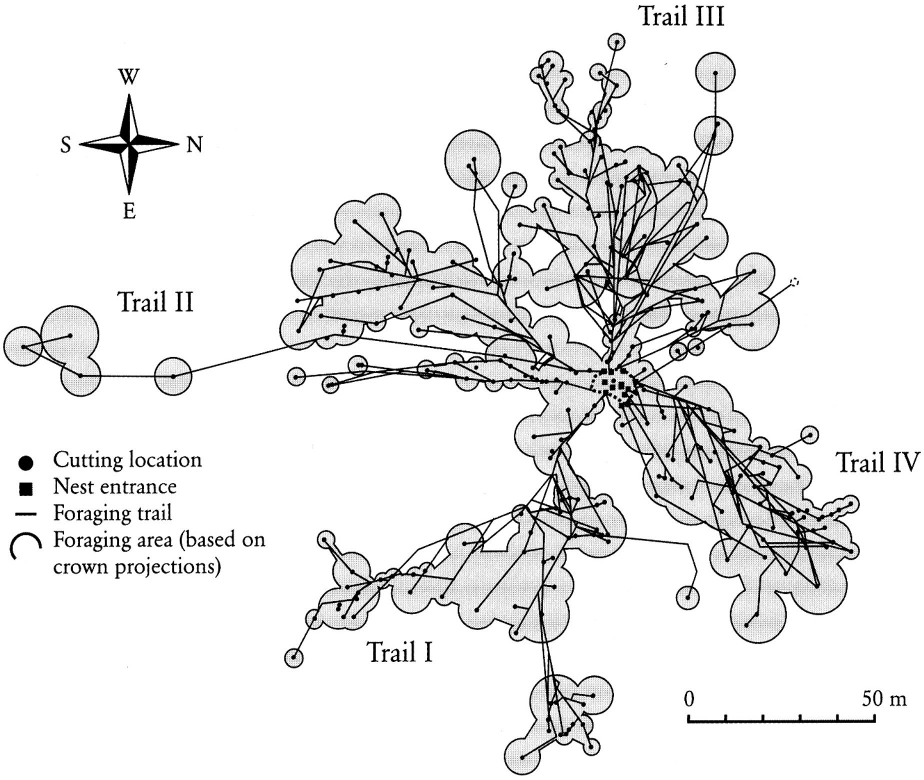


Solenopsis germinata laying an odor trail: (a) hairs in the legs help spread the pheromone trail; (b,c) hairs at the tip of the abdomen strengthen the trail; (d) the extruded sting deposits the pheromone itself.



A study based on the efficiency of food allocation by recruitment pheromones of the fire ant, solenopsis invicta. The semi-ellipsoidal active space is formed by recruitment pheromones (a mix of farnesenes), which diffuses after about 100 seconds.

Figure 5-10



The territorial network and foraging trail system of a mature Atta colombica colony in Panama.

who deposit new pheromones marking new territories or reinforce already existing trails. Indeed, territoriality is another emergent product coming out of the pheromonal interaction between ants and their system of interconnected trails. Territoriality represents a behavioral feature of any group of social beings living in community. Territoriality reinforces the familiar bonds within that colony or community, securing a state of well-being and enabling the aggression to strangers: an addiction to protect and reject.

The weaver ants may be, together with the legionary ants and the leafcutter ants, the most complex social agents, in terms of recruitment and territoriality, in the cybernetic world of insects. These 3 species of ants build supercolonies with extensive territorial range, which is constantly patrolled and guarded by special caste units for defense, known as majors or soldiers. Territorial behavior is almost always an aggressive behavior, because it involves a certain degree of disrespect by the intruder, which automatically stimulates a direct proportional response on the host: a positive feedback mechanism of escalated aggression. For example we humans rely on visual aids to alert strangers no to step into private territory, like wire or electric fences, warning signs, barking dogs and fire weapons. To understand this relationship, one needs to imagine an active spherical space that envelops me, allowing me to recognize my privacy and allowing strangers to recognize 'this-is-not-you-go-away'. The response to the active space the weaver ants create, when alerted by the presence of intruders within their territory, is immediate and of a very aggressive nature. They possess an advanced recruitment system of territorial defense, that allow these formicine creatures to take over more than 3 to 5 trees in average to construct their canopy supercolonies. The weaver ants are canopy dwellers (fig. 5-11). They can control over more than 10 trees[10] by creating overlapping spherical active spaces of pheromones with the secretions of their sternal, rectal and mandibular glands. Combined together, the approximate thousands to half million ants living in each arboreal nest create a gigantic atmosphere of alarm recruitment pheromones. This atmosphere that envelops the colony function as an active space of signalization enabling an easy and secure labor, transportation and travel from one point to another. When the weaver ants are alerted, attracted by a perturbation within the territory of the nest, they assume an aggressive posture (fig. 5-12) to visually warn intruders and stimulate the attention of their nestmates. But what actually activates the altruistic cooperation for ultimate defense is the secretion of chemical substances with various degrees of intensities, which emerge as the so called active space (fig. 5-13). "When agitated, workers of Oecophylla longinoda expel the mixed contents of their mandibular glands, which evaporate and spread outward by diffusion. [...] The pheromones act at different distances from the point of their release and in a sequence of intensifying response toward the point of release. In the outermost shell of the concentric active space, hexanol alerts the workers; next, 1-hexanol attracts them; and finally, 3-undecanone and 2-butyl-2-octenal incite them to attack and bite any foreign object in the vicinity."[11] Thus, the active space becomes a cybernetic cocoon of scents, that enable a quick collective reaction to changes in the environment,

10 Oecophylla longinoda is a dominant species in the forest canopy in a large part of tropical Africa. Workers bind leaves into tight nest compartments with silk spun by the final-instar larvae. One colony usually builds hundreds of such leaf nests, which are distributed over several nest trees and concentrated in the peripheral canopy of the trees. In an area of the Shimba Hills Reserve in Kenya, Hölldobler (1979) studied individual territories, sometimes covering an area of up to approximately 1,600 square meters across the canopies of 17 large trees. Wilson Edward O. and Hölldobler Bert. Foraging Strategies, Territory, and Population Regulation. The Ants. Harvard University Press, 1990.

11 Wilson Edward O. and Hölldobler Bert. Communication. The Superorganism: the beauty, elegance and strangeness of insect societies. New York: W. W. Norton & Company, 2008.

allowing also the control of territory. And this active space is nothing more than the sum of pheromonal compounds each ant decides to secrete. Layer upon layer, the weaver ants create an invisible protective private atmosphere, to which they habituate, giving them the control and authority to do whatever they want to do over the occupied ecosystem.

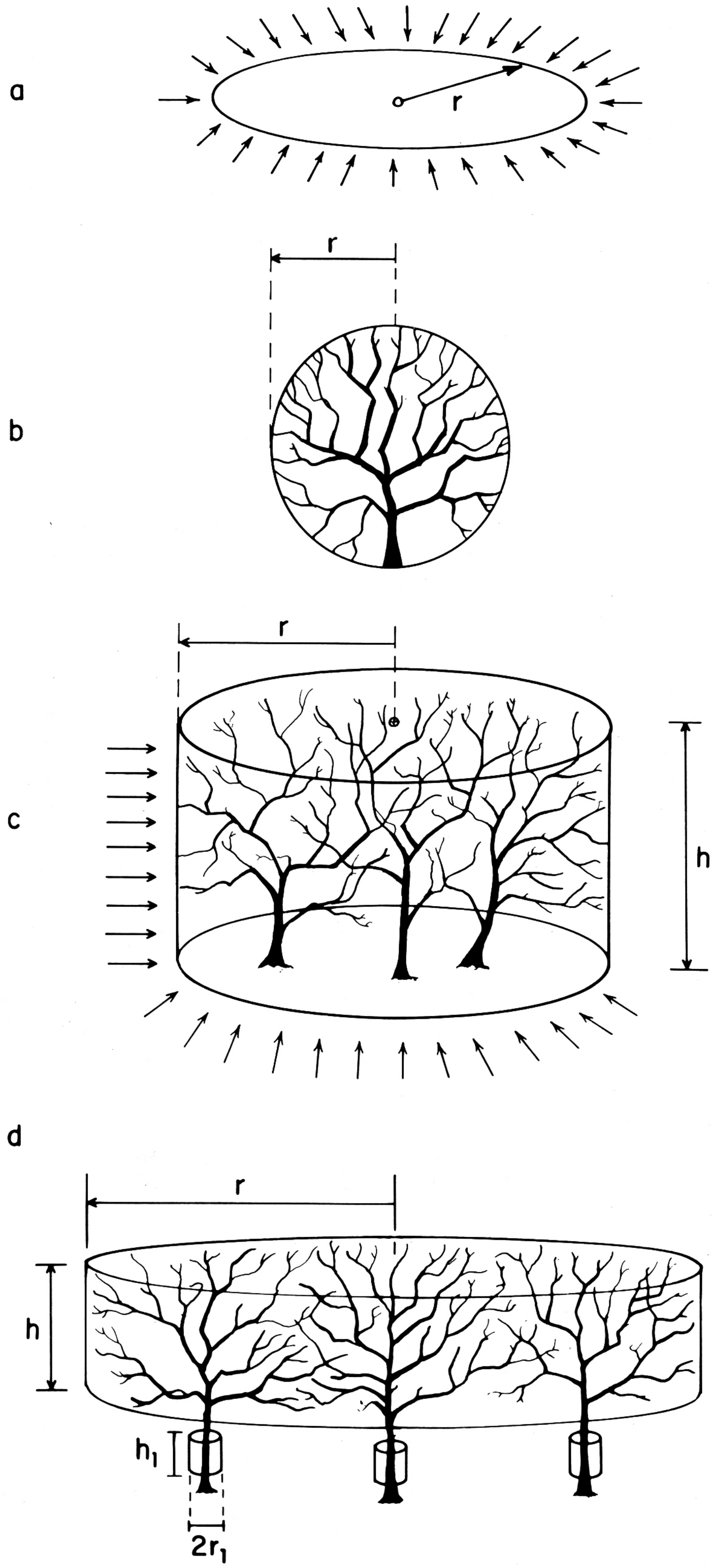
Chemical attraction is an invisible mechanism of control. Are we not attracted to or rejected by the odors in our surroundings? The clustering around the best restaurants in town, characterized by long lines outside the door, is one good example of attraction mediated by the sense of smell, but also by bivouac mimetics[12]. We are attracted by how good food smells. We salivate and our appetite grows when we see something delicious, but also when we smell the rich aroma that helps recreate the flavors in our mouths. It is a cybernetic process of action and reaction, a process that stimulates the transition from one state to another. Do we not associate the pheromones transmitted to us in the wound of our mother with feelings of love? Oral maternal fixation is a dependency on breast feeding, definitely stimulated by many factors and their interrelationship, like the pheromones produced by the sweat in our mother's breasts and the endocrines transported in the lactation process. Hence, babies are more attached to their mothers than to their fathers. Dependencies emerge and establish when we habituate to particular experiences, that promote a state of wellness and produce satisfaction and pleasure. Drugs are chemical devices for attraction that produce some sort of maternal fixation[13]. The invisible processes present in the emission of pheromones are emergent, because we humans live in crowded localities sharing more and more expanded overlapping active spaces. A bum sitting on the train at midday, stinking of beer, will most likely have his or her own active private space secure, because no one else will come near to that cloud of alcohol and sweat. We have so much olfactory information to process nowadays, the roasted coffee beans from the coffee shop and the fresh baked croissant from the bakery, that in order to cope with so much information we need to be selective and filter only that which attracts us the most. We develop dependencies on the things we like, and sadly, most of the things we like are artificial creations: artificially flavored aromas, artificially flavored food. We are junkies of tobacco, marihuana and cocaine. And they are all artificial mutations of originally natural products. It is easy to use our sense of smell to find out who is smoking a cigarette or a joint because the active spaces created by the engulfing smoke expand from the private spheres into the open environment, exposing their existence. All of these latter examples may not actually involved pheromones, but they definitely represent mechanisms, similar to those found on ants, for recognition, association and interaction of the chemical compounds produced by social entities and expelled into the open environment.

What about sexual attraction? The human body is a collection of organs that work together as a team, just like a colony of ants, producing many substances and pheromones, too. When we sweat we produce distinctive personal pheromones that send a chemical message to the exterior public sphere, triggering multiple diverse reactions on the people around us. Sex is the most intimate experience where body fluids together with sweat and pheromones are exchanged between partners. And probably the combination of all is what really makes us fall in love with each other. There are a couple of

12 See chapter 'Bivouac Mimetics'.

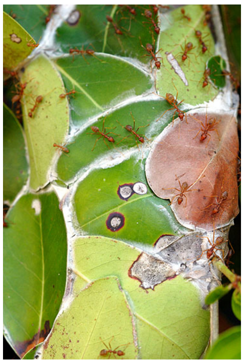
13 On the 1996 film 'Trainspotting', from director Danny Boyle, the main characters are junkies who hang out, and get the heroine, at a place called 'Mother'.

■ Figure 5-11

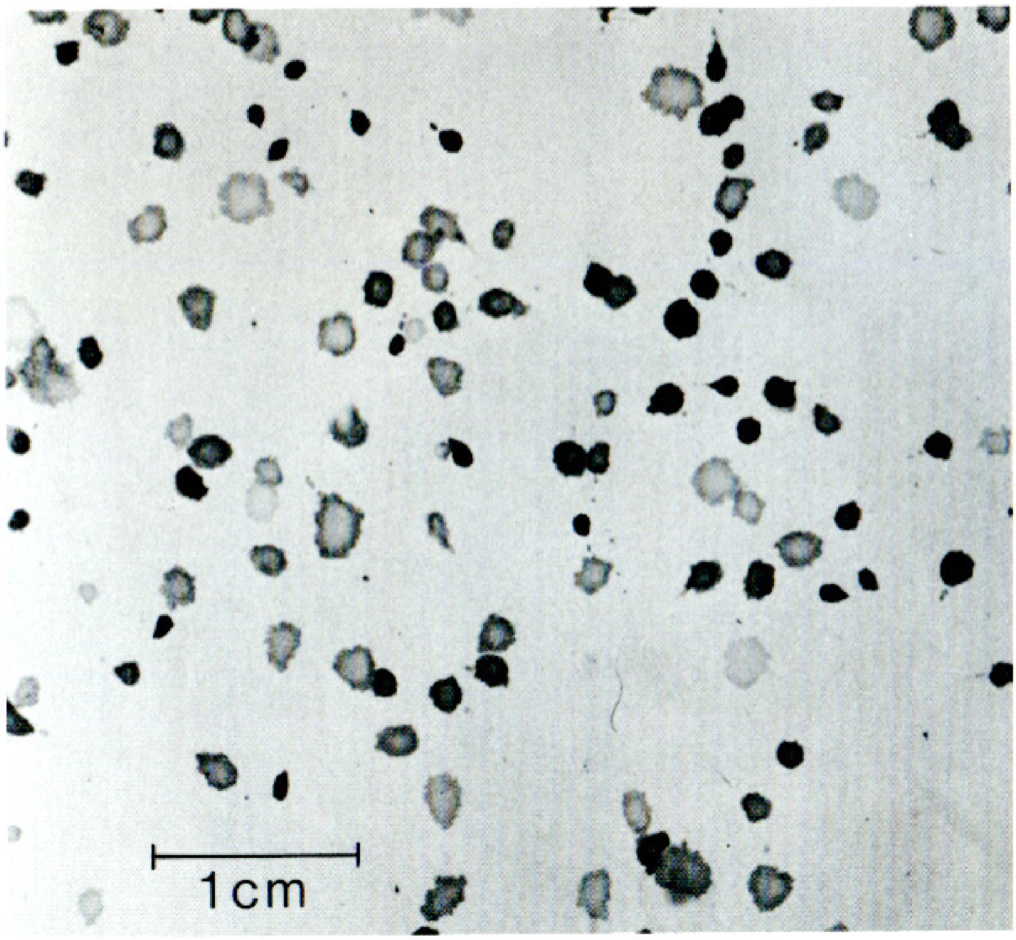


4 possible models of the defensive territorial trail system of the weaver ant Oecophylla: (a) circular territory determined by a given radius, (b) spherical territory covering the height of the tree also determined by a given radius, (c) absolute cylindrical territory covering 3 trees determined by a given height and radius, (d) relative cylindrical territory determined by 2 radiuses and 2 heights.

Figure 5-12

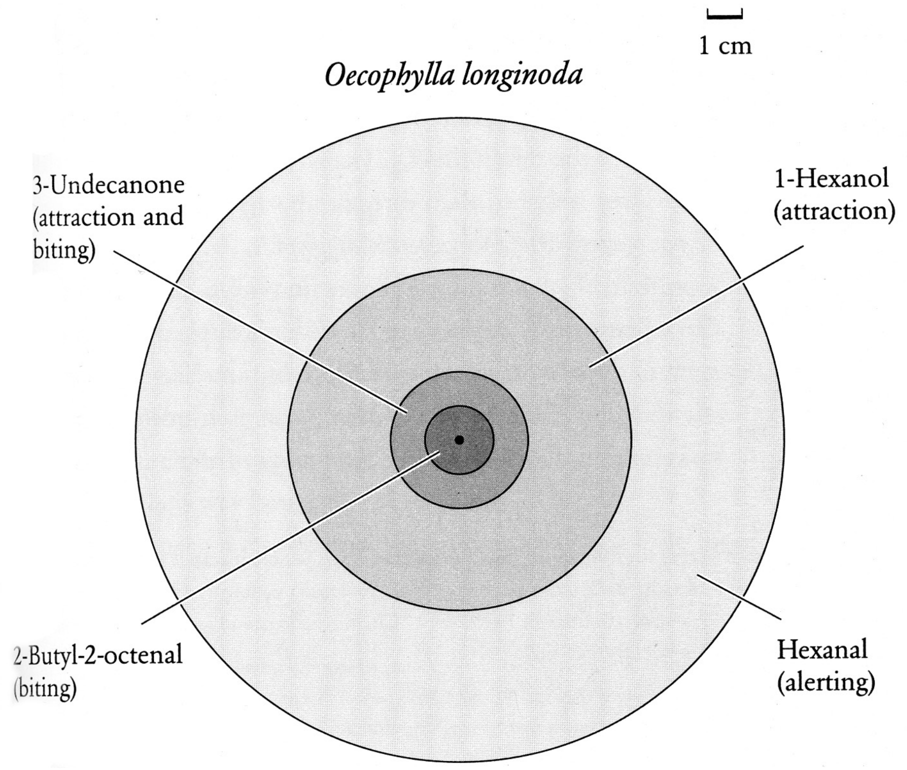


(LEFT) Oecophylla longinoda on attacking position, biting and bending the gaster to secrete poison. (CENTER) A nest of O. longinoda: the cocoon shape is achieved by team collaboration and the white edges are the natural glue produced by the larvae to patch the leaf-nest together. (RIGHT) Oecophylla smaragdina on alert position. (Photos: Alex Wild)



Chemical territorial marking (anal spots) by Oecophylla longinoda on a sheet of paper in a laboratory arena. The different coloration denotes the difference in compound concentration.

Figure 5-13



The concentric active spaces produced by a complex pheromone mixture in O. longinoda. The circles actually form overlapping hemispheres that intensify the message from the outer rim to the center, and which spread above the ground from the point source. These are mandibular gland substances for alarm recruitment in territorial defense.

studies that have proven the existence of pheromones in humans as sexual attractors: "George Preti, an organic chemist at the Monell Chemical Senses Center in Philadelphia and Winnefred Cutler of the University of Pennsylvania's psychology department, discovered that women with irregular menstrual cycles became regular when exposed to male underarm extracts. They hypothesized that male sweat contains pheromones, which mirror how pheromones affect other mammals. Another study demonstrated that the smell of androstadienone, a chemical component of male sweat, maintains higher levels of cortisol in females. The scientists suggest that the ability of this compound to influence the endocrine balance of the opposite sex makes it a human pheromonal chemosignal. Other studies have suggested that people might be using odor cues associated with the immune system to select mates who are not closely related to themselves. Using a brain imaging technique, Swedish researchers have shown that homosexual and heterosexual males' brains respond differently to two odors that may be involved in sexual arousal, and that the homosexual men respond in the same way as heterosexual women, though it could not be determined whether this was cause or effect. The study was expanded to include homosexual women; the results were consistent with previous findings meaning that homosexual women were not as responsive to male identified odors, while their response to female cues was similar to heterosexual males. According to the researchers, this research suggests a possible role for human pheromones in the biological basis of sexual orientation. In 2008, it was found using functional magnetic resonance imaging that the right orbitofrontal cortex, right fusiform cortex, and right hypothalamus respond to airborne natural human sexual sweat."[14]

Human beings as well as ants construct societies that produce emergent consequences out of the relations between its members. We like to get protection and shelter within the walls of the organized state. The mass communication system, that emerges from the interacting agents in societies, is vulnerable to any abuse and exploitation for the creation of false desires, but it also encourages activism against injustices. Popular revolutions are stimulated by a well designed system of cultural signs and symbols that target specific emotions and fears in a society. Revolutions are communicational strategies, predominantly deceiving strategies, to enter the psychological and ecological domain of others and influence their behavior. This emergent social occurrence is present in ants as well as in humans. Social agents are recruited, either brainwashed by propaganda or persuaded by a meaningful ideal, to change behaviors and assume new lifestyles. But what we don't recognize, is that the very same injustices that instantiate popular revolutions and stimulate the consolidation of rebellion, separatism or xenophobia, are indeed part of the same ecological system, where everything was born and will be re-born, where everything co-exists together. Spanish colonialism presented its friendship at first contact, but ended up revealing its genocidal hatred against those who didn't share the same beliefs. And their influence still prevails in those South American cities that were spanish colonies. Colonization may have been abolished hundred

14 From http://en.wikipedia.org/wiki/Pheromones (accessed on May, 2009): Looking for love potion number nine. Cathryn M. Delude, Boston Globe, September 2, 2003; "Smelling a single component of male sweat alters levels of cortisol in women". Wyart C, Webster WW, Chen JH, Wilson SR, McClary A, Khan RM, Sobel N (February 2007). The Journal of Neuroscience: the Official Journal of the Society for Neuroscience 27 (6): 1261–5. doi:10.1523/JNEUROSCI.4430-06.2007 PMID 17287500; "San Francisco State University study shows that synthetic pheromones in women's perfume increase intimate contact with men". San Francisco State University Office of Public Affairs. March 20 2002; "Brain response to putative pheromones in lesbian women". Berglund H, Lindström P, Savic I (May 2006). Proc. Natl. Acad. Sci. U.S.A. 103 (21): 8269–74. doi:10.1073/pnas.0600331103. PMID 16705035. PMC: 1570103; "Gay Men are found to have Different Scent of Attraction." Wade, N. NY Times, May 9, 2005; "Encoding human sexual chemosensory cues in the orbitofrontal and fusiform cortices.". Denise Chen (March 20 2008). The Journal of Neuroscience: the Official Journal of the Society for Neuroscience 25 (53): 14416-21.

years ago but traditions of ancient colonial times still prevail. Since the arrival of Columbus to America, fact is that the most probable catalyzer for the unresolved cultural differences, that emerged back then, were most likely the different body odors that both parties perceived from each other. Just like territorial ants we reject anything that smells funny. We have habituated to our favorite deodorant to the point that we reject and dislike our own body odor. A pheromone junkie is someone like you or like me, that has lost the sensibility to his or her own production of body pheromones, that bathes with exfoliating soaps, anti-aging cremes and exotic body lotions. Like parasitic ants, we have conquered the world of pheromone engineering and design the most attractive and fantastic aromas one can experience to seduce (deceive) our sexual partners. Without really knowing the emergent consequences produced by the mixture of natural body odor with artificial pheromones, we have praised the perfume industry and spend our money faking our body odor and mutating our skin, in order to please society and ourselves, too. We hide behind a curtain of artificial pheromones wearing a mask of socially accepted manners and gestures. Revolutions bring along emergent consequences. And what we have not fully acknowledged by now, is that the pheromone revolution has transformed our behaviors and turned us into domestic slaves of an institution of fake desires and deceptions.

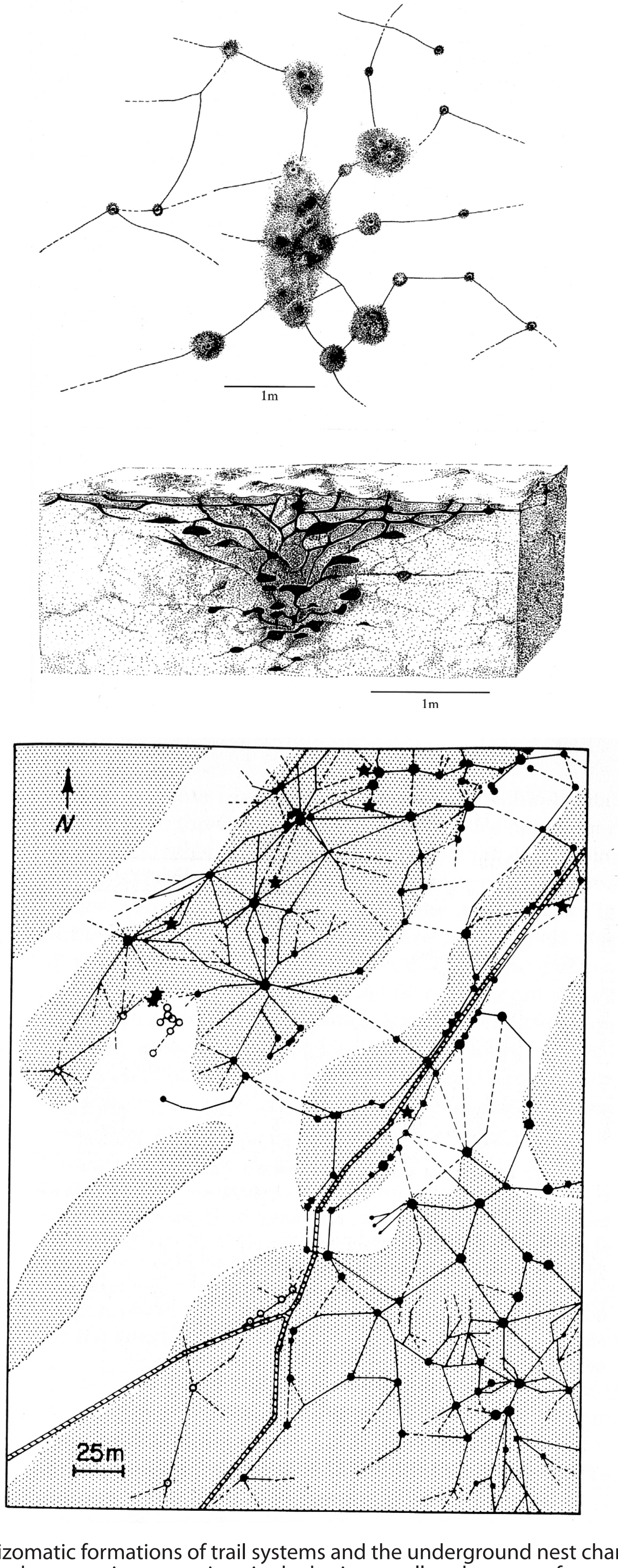
BIVOUAC MIMETICS

"the swarm raiders and the army ant syndrome"

Imagine an organic faucet embedded in a tree, it opens and just like water, 15 mm ant soldiers with 3 mm long pointy sharp mandibles burst out, running, stampeding, obliterating and destroying everything that stands in its way, always drawing a different chaotic pattern across the rainforest soil seen from above, as if they don't know exactly what to do or where to go. Chaotically scribbling their pheromones on the organic canvas of the jungle. And then after a while, after the randomly driven army force has been fully discharged from this virtual faucet embedded in a tree, that which originally appeared to be chaos diminishes, and the flanks of frenzy soldiers start orderly streaming in one direction, fractally forward, creating connections and bifurcations, vectorial highways that start making sense. It's a network of trails marked by pheromone vapor tunnels where everything gets eaten, a massive predation characterized by the march of soldiers stinging and asphyxiating a frog, or soldiers carrying back to the nest an already torn apart giant wasp. Summoned by mother nature, the army ants emerge, directed forwards along pheromone trails laid by nestmates, that excite their antennas and incite their little brains to make the decision which of the available paths to follow. And that is how a fractal is formed. Like roots that extend from the underground to the surface, the form of a trunk appears, then branches and twigs... the form of a tree, a rhizome, a connected superorganism of army ants is on the march, swarming in the deep rainforest (fig. 6-1). They are driven not by randomness, madness or casualty, but powered by the need to feed thousands and thousands of larvae back in the swarming bivouac, for me one of nature's wonders. And swarming is indeed what they do, for when the army ants raid in search for food, anything that emits an odor other than their own, excites them to attack in such a way that a positive feedback loop is transmitted along the flanks of the restless legion to attract more and more ants to the spot where the call initiated. They create a vapor envelope, an invisible pheromone tunnel emerges, inside which chemical compounds that are impregnated all over their exoskeletons, legs, antennas, external and internal glands reinforce and confirm the direction, situation and the will to keep on going together. There is no stopping force until the same ants returning home, with seized agonizing booty, drooling hemolymph between their sharp mandibles, emit the signal to other ants they encounter along the way that there is nothing left to prey on.

The system of advance and retreat, of assembling and deconstructing, used by the army ants in the tropical rainforests, is a system that listens to itself in order to know when to switch from one state to the other. A mimetic system design to create chaos and order. There has to be a negative feedback loop for every feedback loop pushing too much positive information and energy into the system. The swarm has to cool down in order to stop the ravaging ants, who are blindly excited and attracted by the strong odor trails they pick up as they run forward through the pheromone tunnel, and also worth to mention, strongly influenced by the accompanying horde of ants running with them. Imagine the civil disorder phenomena in our society known as a riot, where all the participating civilians get infected with violence and an irrational appetite for destruction. In the case of the warm swarm, a negative feedback loop has to spread the message that there is no more need to waste energies in this direction, cooling the system, transforming the excited aggressive chaos back

■ Figure 6-1



The emergent fractal, rhizomatic formations of trail systems and the underground nest chambers of harvester ants resemble the synaptic connections in the brain as well as the roots of many plants.

into order, and the unpredictable fractal march of seek and capture of the barbaric ant legion reconstructs itself, now in another direction. It's bivouac mimetics in action, the irrational behavior stimulated by peer pressure, the local influence of your neighbor to do what he or she is doing. From the banal dance and drink because all your friends are doing it, to the simple following of the crowd to the concert or the football stadium without questioning if that is the right direction. The observed behavior is socially learned, and thus replicated. The swarm raiders[1] are a very privileged species of ants that suffer, to their advantage if we may say so, from the army ant syndrome. A syndrome of multi-level proportions and multidimensional characteristics, for those under the influence of the syndrome are carried away and lose their sense of individuality. The principal feature of this syndrome, as expert entomologists have point out, is the presence of a nomadic migrational pattern, of camping or sheltering always from 2 days to no more than a week, in organic nests build by the very own bodies of the savage nomads, interlocked by their tarsal claws (fig. 6-2), protecting the queen and brood, forming a living structure, an architecture that moves, breaths and autoregulates its own temperature and humidity. This construction is alive, divides itself into organic layered chambers and blocks access to strangers by building outer protective barracks, with soldiers showing their mamut-shaped mandibles to warn intruders; living beings that compose and design a living architectural network: the bivouac (fig. 6-3). The most observed and studied ant tribes, that feature and confirm the existence of the army ant syndrome, are Ecitonini (fig. 6-4) of the New World (North-, Central-, and South-America) and Dorylini of Africa (fig. 6-5): The life cycle and complex behavior of this ant mafia is closely synchronized with the reproductive cycle of the army ant queen. As long as the queen survives, the reign of terror will endure. You get the queen killed and the art of bivouacking is lost, the force of the army gets caught in an eternal circular loop (fig. 6-6). What can we learn from the bivouac and the army ant syndrome behavior of massive predation? What does it mean to apply bivouac mimetics to our daily lives in our hierarchical human society? These ants possess tiny brains with limited decision and process capacity, so can we rely on their system and communication network to reproduce better artificial creations in the same way, for the benefit of a common society like theirs?

There are 3 characteristics that define the army ant syndrome as a whole: nomadic nesting behavior, swarm raiding or massive predation and a specialized queen caste able to lay more than 100.000 eggs in a week. There has been many discussions as to whether or not include in the army ant category other subfamilies who present some, but not all, of the 3 characteristics of the army ant syndrome. But that is concisely the point of bivouac mimetics, to apply it whenever the need for it emerges. We can apply it, when the conditions and circumstances require so, as well as other ants have already done it without really being group predators or swarm raiders. Bivouac mimetics is a group of individuals acting as a unified group. The expression bivouac mimetics comes from the open concept of social clustering, because I believe that societies push towards belongingness and togetherness, pursuing an ideal world to share only with those alike; sometimes closing the doors to strangers, nevertheless sharing a profound connection expressed in many different manners. One of these manners can be body language or facial gestures. All the possible expressions and languages that allow us to connect socially, possess somewhat certain rules of conduct, symbols and signs, familiar only to those belonging to a particular culture, nation, family, sect, fraternity, team, class, or colony. The ant bivouac is a private fortress

1 It is a distinctive name I am borrowing directly from chapter 16 of The Ants, where E.O. Wilson and Bert Hölldobler cite Wheeler, who describes the army ants as the Huns and Tartars of the insect world. Wilson Edward O. and Hölldobler Bert. The Army Ants. The Ants. Harvard University Press, 1990.

factory, accessible only to those who were born and breed in the bivouac. It stands for union, sacrifice and love. There is a natural force that brings us together and it is manifested by many different expressions that allow us to know where we are and who we are with. The demonstration of affection in public domain is restrained to a couple expressions only. We distinguish the private sphere from the public sphere and we behave accordingly. We don't get naked in public and have sex in the train, although nowadays that exceptional case is no longer a rule. The ants do the same, the closer they are to the nest the more secure and free they feel to start showing conspicuous behaviors they don't show outside when they are exposed. We learn and imitate how our elders behave, because that's where the principles of education reside. We are mimes that absorb the behavioral patterns in our surroundings. We get together to interact and mimic social behaviors we have learnt from others in a similar situation, of course, spicing it up a little bit or changing slightly the modus in our own way. We learn the respective languages and customs in order to be accepted and understood in that special social circle. We imitate our parents as we grow up, because we do what we see. Ants are born with the scent of the colony, therefore that becomes the first cybernetic step in recognizing belongingness. The nursing ants recognize the brood and the new soldiers in the fortress, mainly because they smell alike. That's where the whole process of this tiny learning machines starts, where the mimetic phenomena begins. Bivouac mimetics is about doing what the others in my social circle do, even without putting too much thought into it, just flowing with the colony, flowing with the mates. Such is the case of assisting a public concert or a football match at the stadium. We dance, cheer, sing and shout because we acknowledge joy and get injected by it if everyone around us does the same. Probably that is how you learned your first dance moves, because you saw someone else swinging the hips and you liked it. Moreover that is how fashion trends set in, you see someone with a high-tech gadget, an elegant suit or wearing an attractive combination of colors, and this image gets saved. Subconsciously, or completely unconsciously, we get impressions from other people uploaded into our library of memories to end up recalling the behaviors that can fit the situation when the time comes.

But what does it exactly mean to swarm? To my understanding, the swarm is a collective reaction to a stimulus, an action that unfolds a collective response of individuals sharing the same knowledge, when suddenly something of high magnitude appears in the same environment to attract such collective changing its actual settled state. Thus, the provocation of the attractor incites a change of states, to go from 0 to 1, from calm to aggressive, and then exponentially emerge with unforeseen consequences. When the swarming ants go hunting, we may tell for sure there is going to be death carcasses and thunderstorm in the jungle, but we don't know in which direction and to what extent the swarm raiders are going to visit this forest patch or that one, and kill this or that jungle dweller. The preferences of the swarm is what makes the swarm interesting, during the curse of actions produced by the original attractor, other attractors enter the scene also influencing the development of those already unfolded actions. And even if the ants swarm twice a day, as it's the tradition, for instance of Eciton burchelli, we cannot say that the late night raid is going to have a similar pattern as the morning raid, because there are so many decisions being taken by every member of the swarm[2] that the result is complexly unpredictable. Nevertheless attempts have been made to map the many places the swarm raiders prefer to visit (fig. 6-7). To this matter, science has relied on the collaboration of many generations of biologists because dedication,

2 From 250.000 in the case of Eciton, to 22 millions in the case of Dorylus. Wilson Edward O. and Hölldobler Bert. The Army Ants. The Ants. Harvard University Press, 1990.

■ Figure 6-2

Eciton burchelli's bivouac in Yasuni, Ecuador. (Photo: Kuaishen Auson)

Figure 6-3

Bivouac on the move. Eciton burchelli creating a living bridge to cross from one tree to the other. (Photo: Kuaishen Auson)

The bivouac can contain thousands to millions of individuals, with other insects that travel with them. In the center, the specialized soldier caste. Can you spot the staphylinid parasite (a beetle that is not an ant) in this picture? (Photo: Kuaishen Auson)

Figure 6-4

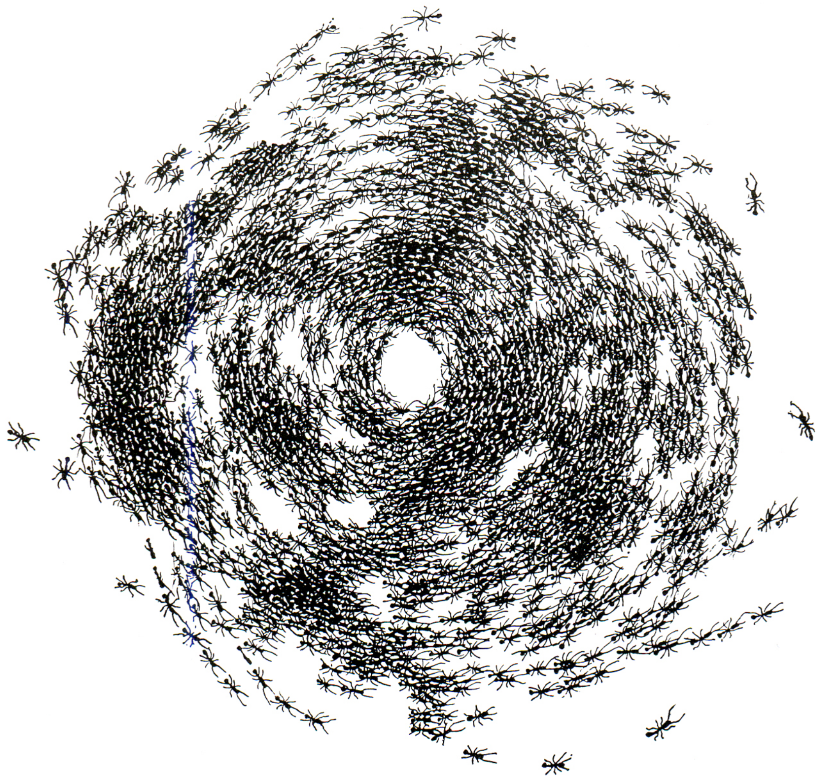
A soldier standing guard, exposing her long sharp mandibles. In the front a normal worker passing by. (Photo: Kuaishen Auson)

A soldier standing guard at the peripheries of the bivouac. Eciton burchelli soldiers are blind but highly sensitive to strange odors, thus, very aggressive to anything that comes to close to the bivouac. (Photo: Kuaishen Auson)

■ Figure 6-5

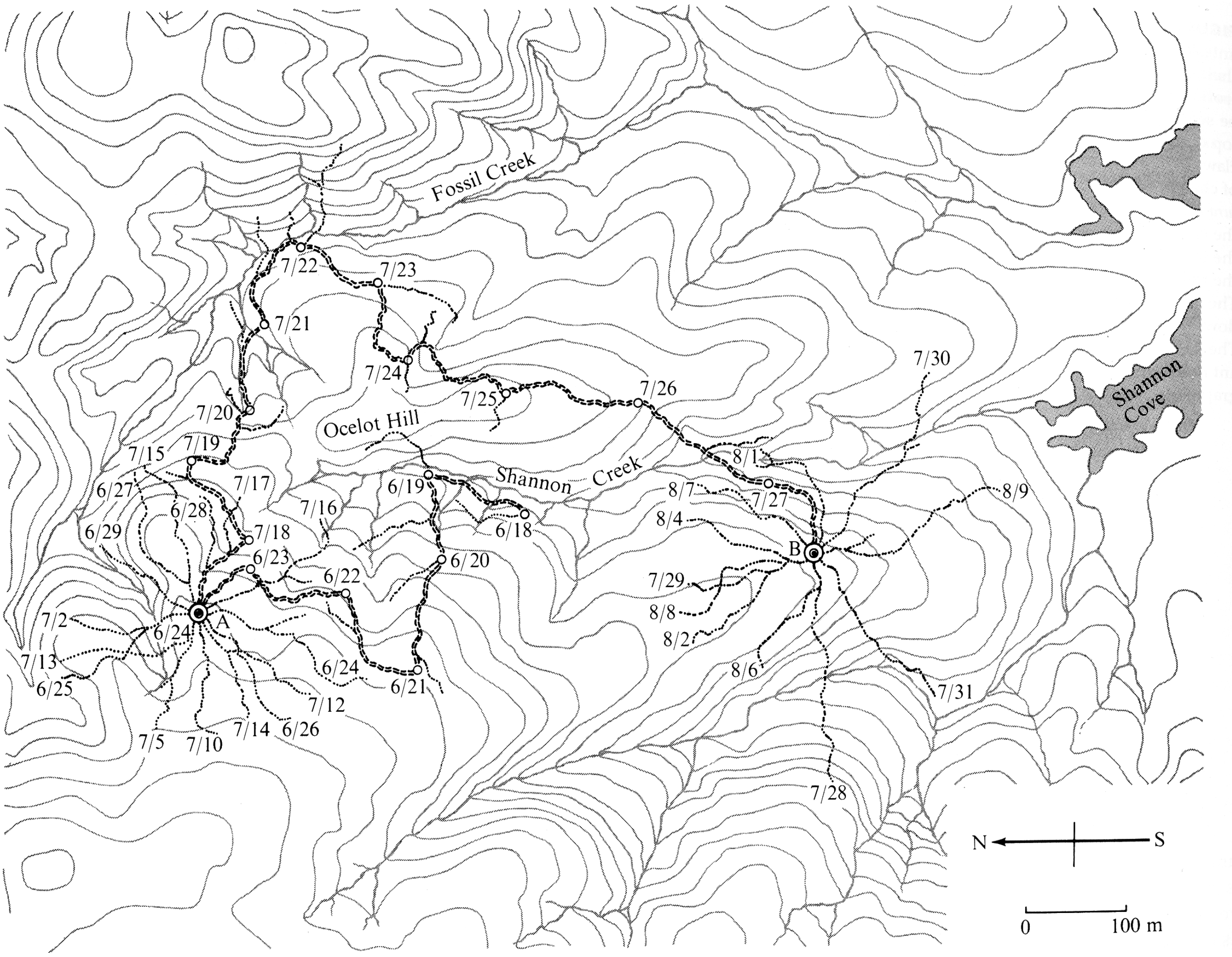
Dorylus helvolus of Africa are predatory nomadic ants that can overwhelm any kind of prey, regardless of its size and strength. Chickens and sheeps can be part of their menu. The secret lies in the millions of soldiers and an effective recruitment system. (Photo: Alex Wild)

■ Figure 6-6



The effects of a positive feedback loop, *teufelskreis*. Labidus praedator is a small army ant of the New World that spends most of the time hunting underground. Here, the queen is missing and the workers, desperately trying to find her, are attracted only to each other in an eternal loop with no regulation.

Figure 6-7



The traveling network of the swarm raiders Eciton Burchelli in Barro Colorado, Panama during 2 reproductive cycles.. (A) and (B) are the persistent bivouac sites chosen by the ants while the queen had to lay eggs, during 2 statary phases. The thick double lines represent the migration trails, the thinner lines represent the daily raids, and the smaller circles represent the temporary bivouacs.

and most of all time, is needed in order to accurately follow the army ants with successful results. To follow a legion of army ants throughout their whole life is to be practically immortal, because a colony of army ants can live up to a couple of years, or who knows maybe even a decade, but the remaining offspring survives with the new mated queen, who will be able to keep the lineage alive. The swarm raiders keep on existing for millions of years[3], and raiders is just another term denoting the efficient, yet barbaric and somehow primitive but effective, fashion of massive predation. They raid and raid without an end, of course they rest back in the bivouac but the raid continues at the break of dawn. If we take into account the strange attractors discovered by Edward Lorenz, we then realize that the fractal object representing the strange attractor is nothing more than a twisted Moebius strip looping the infinitum (fig. 6-8). M.C. Escher envisioned it and draw it with ants traveling the trails of infinity. Swarming is a collective social phenomena that suddenly manifests itself to cause strange attractors, attractors that don't have a settling point actually, for the patterns repeat themselves over and over again. The swarm raiders fan-shaped columns (fig. 6-9), formed when the bivouac starts swarming because of an attractor in the system appears, represent the visual proof that nature is an artist in its own domain, creating incredible fractals and beautiful networks that do not only truly exist, but demonstrate the existence of an interconnected living ecology, which is to say a micro-system contained in a macro-system. The swarm raid of the army ants is a fractal just like a tree or a river is a fractal. Ants are the organic pixels nature uses to render emergence.

Like crazy gipsies on the road or a punk band on a world tour, they barbarically raid everything in its trajectory regardless size, numbers or nature. Always emerging from their temporary hideout, the bivouac, the only place where they are comfortably at rest, in their essence, in a homeostatic state, yet ready to react upon the trivial appearance of strange attractors. The army ants is a race of social agents that can self-organize in huge numbers so that they have to go through a process of chaos to achieve order. They could be cunningly accredited as the keepers of the jungle's equilibrium and sanity. The ants don't have an appetite for destruction when they raid, they raid because they have mouths to feed[4], and in doing so they recycle the soil of the forest, stimulate the migration of other ants and smaller insects to new grounds because they force them to flee in panic, and eliminate competition by keeping a balanced number of predators and prey wherever they are swarming. What brings them closer together, into the bivouac mimetics stage, is a very keen sense of pheromone detection and a limited set of tactile rituals that allows them to distinguish only their own kind as equal. So there is a code of conduct that can be learned and replicated to be part of the swarm raiders. As a result the trick and trades of their communication can be mimicked by other solitary trampy insects specialized in decoding the army ants' language in order to be part of the bivouac, in order to belong and be treated as equal.

Funny fact is that this is an omnipresent phenomena in our human society. Younger generations always have role

3 In fact, there is the Gondwana theory, which proposes the idea that the army ants were already dwellers of the grounds back in the Triassic period when Africa and South America were connected as one single continent, mentioning the fact that african army ants, though different in many aspects, share the same army ant behavior of the New World army ants. Brady Sean G. Edited by Bert Hölldobler, University of Würzburg, Würzburg, Germany, and approved April 4, 2003. Evolution of the army ant syndrome: The origin and long-term evolutionary stasis of a complex of behavioral and reproductive adaptations. Center for Population Biology and Department of Entomology, University of California, Davis, CA 95616.

4 Siafu, the monster of a million mouths, is the popular name used in some parts of Africa to refer to the driver ants, Dorylus wilverthi.

models and friendship networks they want to follow. And the explosion of internet communities, like Facebook and Twitter, succumb to the temptation of the bivouac mimetics as well. We want to follow and be accepted in the bivouac, where the 'cool' people roll. Facebook and Twitter are systems where the environment is already programmed, but the content, information and events that emerge are user-generated-content, which evolves to regenerate the instance of certain private groups, to which one has to be invited in order to participate. Consequently, virtual private bivouacs arise, creating a need to be part of it, to belong and be accepted. An ecological dominance is created. In the natural world, the real ecological dominance the army ants have achieved, have earn them the respect from the rest of animals sharing the same domain. They are respected because they are indeed a powerful overwhelming army, but also because others can perceive the benefits the swarm brings with it when it raids throughout the rainforest. Insects and bird species have developed alliances and evolved complex relationships with the swarm raiders for mutual benefit. Staphylinid beetles mimic the greeting and grooming tactile rituals of Eciton burchelli to be accepted just like any other ant in the bivouac and so they stay with swarming bivouac, working with them. Some other insects, like the butterfly social parasite Maculinea rebeli, don't even leave the heart of the nest, where the queen resides, and by mimicking the cry and noises of larvae, they get to be fed as such[5]. Others raid along with the rest of the soldiers foraging for prey, and there are those brave and committed who even serve as battle companions, helping in the defense against other competing species. Moreover, the highlight, and also the best sign that a swarm raid is coming, is the presence of antbirds, which follow and accompany the swarm to catch the leftovers the raid doesn't want. These antbirds are specialized in recognizing and locating eciton burchelli bivouacs. Approximately 50 species of antbirds get up to half of their food this way by preying from the leftovers and flushed out insects the ants collect[6], but mainly from the fleeing crickets, grasshoppers and cockroaches who desperately try to escape the well-organized-raging ants. This self-organized interspecific network resembles a sustainable autonomous non-competing ecology, where even the feces of the antbirds serve as food for another insect tribe that accompanies the whole circuit, the Ithomiini, a butterfly species, which could also at the end of the day be eaten by the very same ants that generated the whole attraction scheme in the first place. One could dare to insinuate, the formula for the butterfly effect lies concealed in the bivouac.

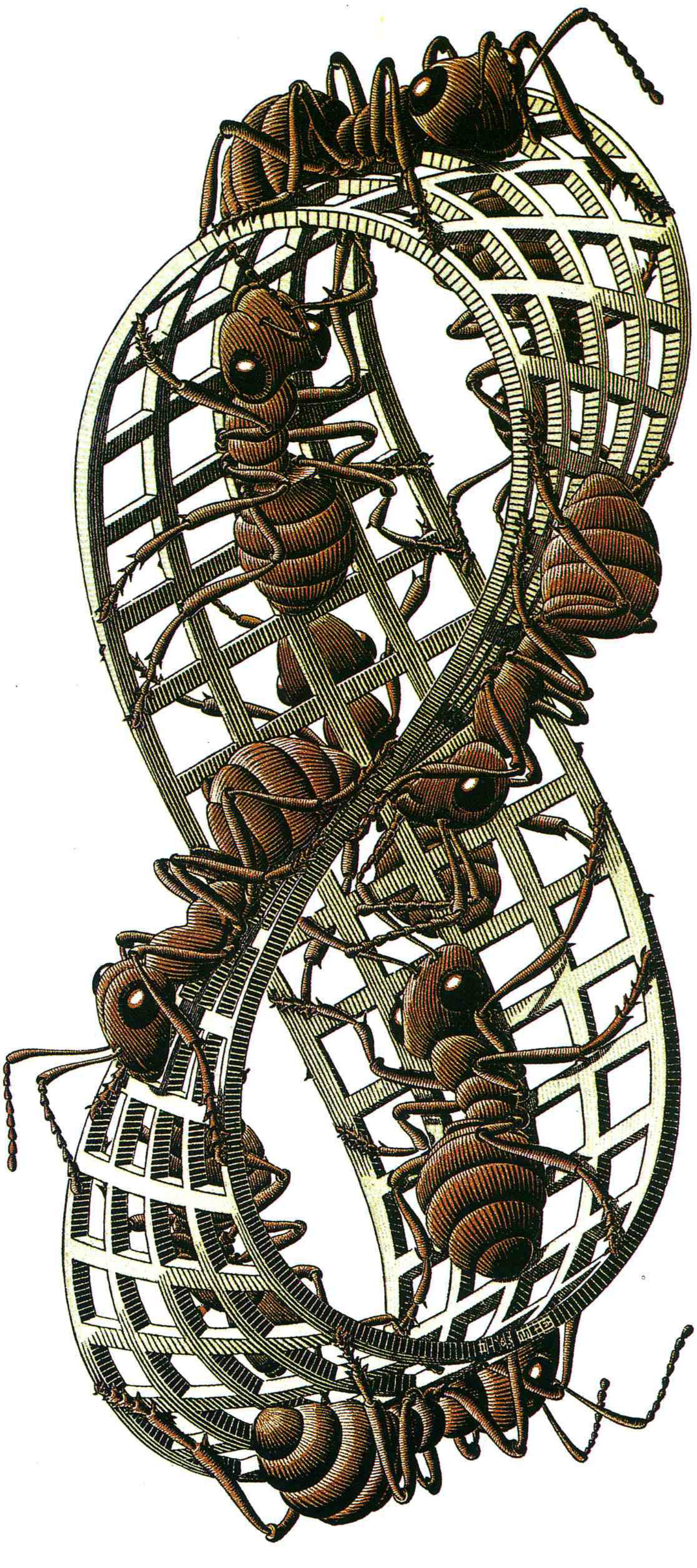
What does a water molecule, a bird, a fish and an ant have in common? just as liquid can suddenly begin to boil or a bucket of water with a hole creates a whirlpool, just like a bird flock suddenly changes its flight direction maintaining its formation, or a fish collective swims together avoiding to be eaten, an ant swarm can change abruptly its predatory direction thanks to a slight variation in the original set of simple rules. The collective intelligence in a swarm emerges unpredictably from the actions of local neighbors inside a negative feedback system. "Those rules allow thousands of relatively simple animals to form a collective brain able to make decisions and move like a single organism."[7] A homeostatic temporal state can be achieved. Every single unit can perform terribly alone, but together, just like neurons, can sum up

5 From http://www.sciencemag.org/cgi/content/abstract/323/5915/782 (accessed June, 2009).

6 Wilson Edward O. and Hölldobler Bert. The Army Ants. The Ants. Harvard University Press, 1990.

7 The New York Times. From Ants To People, An Instinct To Swarm. Published: November 13, 2007. From http://www.nytimes.com/2007/11/13/science/13traff.html (accessed April, 2009).

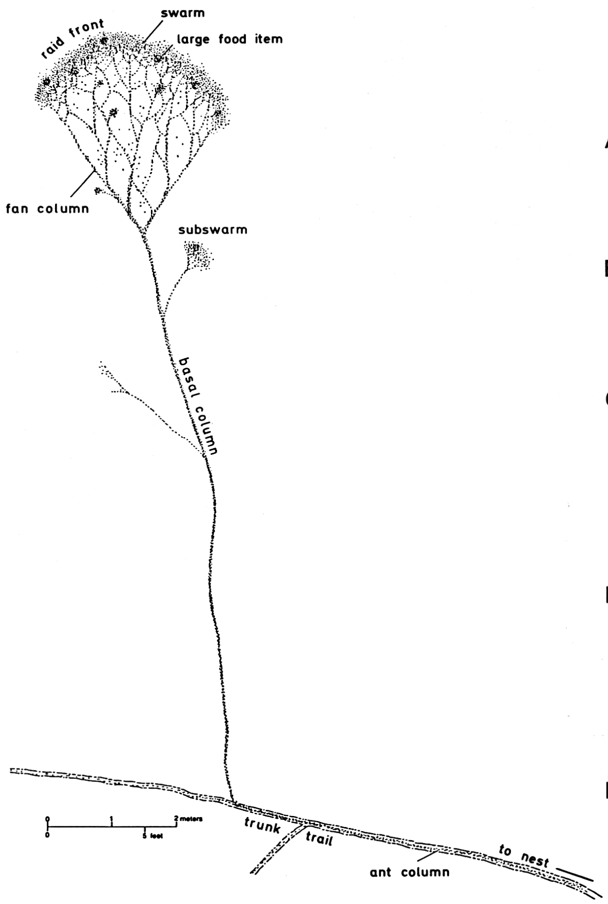
■ Figure 6-8

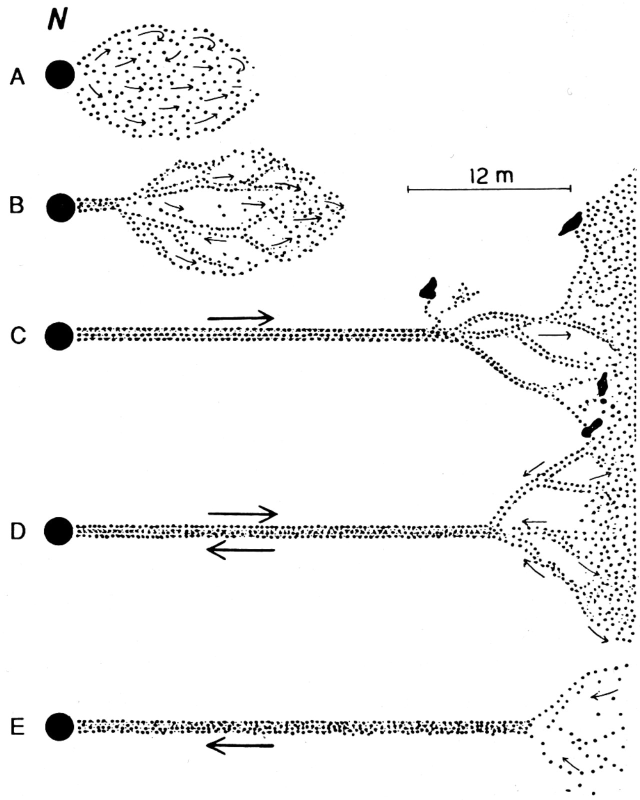


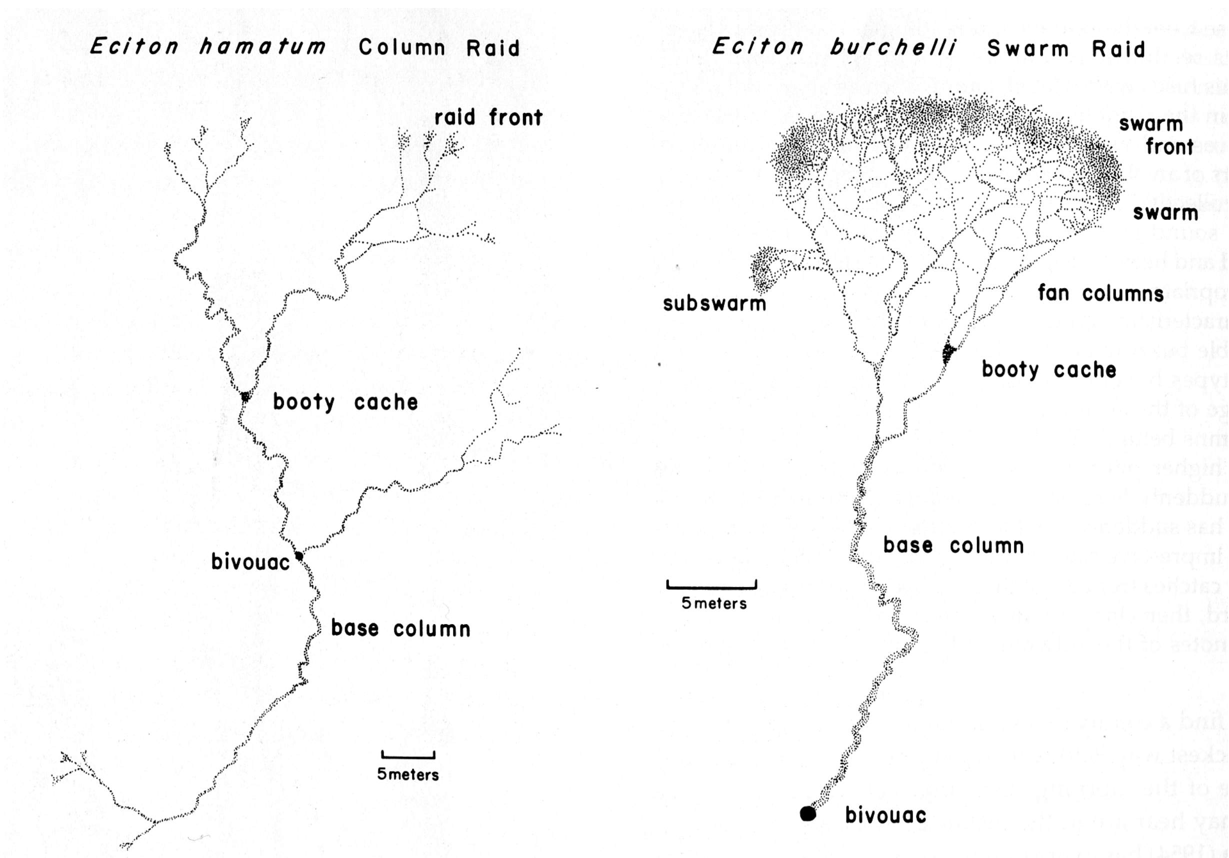
Möbius Strip II (Red Ants), 1963,

by Maurits Cornelis Escher.

Figure 6-9







(TOP, LEFT) The raiding pattern of Pheidologeton diversus resembles a young tree growing. (TOP, RIGHT) The pattern of advance (A-C) and retreat (D-E) of a swarm raid by a Dorylus colony from its bivouac site. (BOTTOM) The difference between a column raid by E. hamatum and a swarm raid by E. burchelli: the river and the tree.

and achieve greater goals. Every ant possess a simple set of rules, just like a bit is defined by 0 and 1, a raiding army ant can use its minimal knowledge to recognize and act in two ways: run back home or forage for food. Add millions of simple units with basic knowledge like this in a system, where close and constant contact is made available, and you end up having a self-organized entity. Simulating swarm intelligence is an objective the top laboratories and scientists in the world have been obsessively pursuing for a couple of decades, maybe even a bit more. The attraction to the bivouac experience and swarm intelligence is probably based on the idea that we humans, possessing bigger brains, should be able to perform more efficiently than a colony of army ants. Truth is we don't. The complexity in our brains doesn't seem to allow simple decisions.

Dr. Couzin and Dr. Naomi Leonard from Princeton University are already programming the swarm intelligence into robots. "Ultimately, flocks of robots might do a better job of collecting information in dangerous places. If you knock out some individual, the algorithm still works. The group still moves normally. The rules of the swarm may also apply to the cells inside our bodies. He is working with cancer biologists to discover the rules by which cancer cells work together to build tumors or migrate through tissues."[8] The swarm can be simulated, meaning it can be programmed based on certain conditions, which is still not as natural as in the case of the swarm raiders. Another interesting experiment is the paper presented at the Swarm Intelligence Symposium of 2003: "To gain insight into swarm algorithms, researchers can study insect societies and other natural collectives, program multi-agent software simulations or build groups of cooperating robots. In our research, we consider another resource: swarms of humans. [...] Planning is a human's preferred problem solving methodology because we are intelligent creatures with high-level communication skills. Due to the intelligence of the agents, human swarms can be quickly programmed, for subsequent observation and analysis. This paper describes human swarm experiments designed for gathering information on swarm algorithms. At these events 100 volunteers, wearing data-encoded T-shirts, work together to perform tasks of differing degrees of complexity. Researchers provide simple instructions for each task (programming the swarm), record the swarm's behavior (videotaped observation) and analyze the results (problem identification and algorithm-mining)."[9] The focus for engineers and scientists is to find the secret ingredients to the swarming formula, to the the swarm algorithm. The main problem, the way I see it, is that in order to swarm as humans, we need to have a common attractor and at least share some genetic relation in the way we socially behave, if that genetic information is not present, then at least share an ideal. For instance, Flashmobs are a form of bivouac mimetics in humans that works remarkably good. People, being provided with a very basic set of rules, create sudden collectives on public spaces to protest against war or other social injustices, but also because there is an artistic concept. These Flashmobs emerge out of the nothing and the participants share a common knowledge, performing a demonstration that manifests a statement: No Pants Subway[10], Frozen Grand Central[11], Freeze in Paris[12], The

8 The New York Times. From Ants To People, An Instinct To Swarm. Published: November 13, 2007. From http://www.nytimes.com/2007/11/13/science/13traff.html) (accessed April, 2009).

9 Palmer D.W., Kirschenbaum M., Murton J.P., Kovacina M.A., Steinberg D.H., Calabrese S.N., Zajac K.M., Hantak C.M., Schatz J.E.. John Carroll Univ. Using a collection of humans as an execution testbed for swarm algorithms. University Heights, OH, USA. Publication Date: 24-26 April 2003. From http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?tp=&arnumber=1202248&isnumber=27067 (accessed June, 2009).

Mp3 Experiment[13], Bzzzz[14], Finger Gun Fight at the Tate[15].

Bivouac mimetics can be definitely applied artistically and convey a meaningful, yet also controversial message. Spencer Tunick is a photographer whose work is based on the exposure of the naked human body. His idea, like the spirit of the swarm, depends on thousands of people willing to pose naked on public places in compromising positions to form living modular sculptures. "When I do work in a city that is somewhere repressed you'd think less people would show up, but more turned up, using participation to send a message to the government. In Chile, 10 years earlier, Pinochet was in power, killing and imprisoning artists. People participating were kicking out against the past and somehow I got caught up in that."[16]

But probably the best application there is for bivouac mimetics and the admirable behavior of the swarm raiders is on traffic control. The principles of the swarm lets the individuals of the colony move easily and fast from one place to another, and this system is replicated with a software created by the IDSIA in Lugano to aid the transport and shipment industry localize the most optimal routes for delivery[17]. Thus, a network of shared information is created where the agents moving through it are connected, because they know exactly where the others come from and where they are going.

The swarm is part of our lives just as bivouac mimetics is an inevitable social phenomena to get closer together, get to know each other, be one, and regardless nationality, race or religion, overcome with a collective empathy and consciousness the challenging obstacles of life. Bivouac mimetics is about one love, one colony, an inevitable attracting force and the achievement of a higher consciousness about the world we live in and the connections we share.

10 From http://www.youtube.com/watch?v=bXB_DcuMv_E (accessed June, 2009).

11 From http://www.youtube.com/watch?v=jwMj3PJDxuo&feature=fvst (accessed June, 2009).

12 From http://www.youtube.com/watch?v=8GfrfDmXDb0 (accessed June, 2009).

13 From http://www.youtube.com/watch?v=39Dinyl_HHU&feature=channel (accessed June, 2009).

14 From http://www.youtube.com/watch?v=__YIuDHFuAM (accessed June, 2009).

15 From http://www.youtube.com/watch?v=q7aI6zhbVtM (accessed June, 2009).

16 The Sunday Sun. Worldwide exposure. An interview to Spencer Tunick by David Whetstone. Publication Date: May 20 2005. From http://www.sundaysun.co.uk/whats-on-newcastle-north-east/arts-theatre-newcastle-north-east/2005/05/20/worldwide-exposure-79310-15538099 (accessed June, 2009).

17 Facts Magazine. Wie die Natur: Tiere bewegen sich in Massen, sind Teamarbeiter und vernetzt. Ihre Kniffe nutzen Forscher - für Roboter, Software und das Internet. By Andrea Strässle. Publication Date: 28 June 2007.

STRIDULATION AMPLIFIED

"Der Hörer und nicht der Sprecher, bestimmt die Bedeutung einer Aussage"

Listening to Beethoven, to his famous 'mondschein sonate', we humans subjectively embrace it, appreciate it, each of us with his or her own abilities, manner and imagination. The sounds, and therefore, the feelings this musical composition carries along, allows our brains to connect ideas, memories, and everything our array of senses can recall in order to endow meaning to this musical institution. Of course we are talking about music, but how we humans give meaning to what we hear, is and will still be a debate, because it is not a process we can objectively define, for each human in the world interprets music and sounds in a different way. Even among classical musicians with keen musical ear, the different musical components in the mondschein sonate can emerge as past memories concatenated out of leftovers of experiences or can emerge as colors, movements, flavors, feelings, to virtualize a recentered fictional universe. We create our own world out of the input we absorb from the cybernetic chain of events latent in the surrounding environment. There is the principle of the creative resultants, which postulates the product is not just the sum of the elements involved, but represents a new creation, something genuinely new, which could appear every time we do the same equation1. Or as heinz von foerster's reflection goes: 2 + 2 = grün. The individual notes, which are conjured up to create a musical composition, played by piano, guitar, trumpet, or any other instrument, constitute a combination of patterns, in which each individual chord has an harmonic emergent quality with the interpretation potential linked to the subject and the contextual sphere in which everything takes place. The actual interpretation relies on the listener, who becomes the receiver in charge of decoding the acoustic message.

Music is nonverbal communication and the use, or even abuse, of amplified sounds definitely belongs to the diverse array of biocommunication strategies we encounter in the world of living organisms. For example, the night bat and the moth establish a very interesting interspecific hunter-prey relationship. The bat sends ultrasound waves to find the moth and the moth evades this detection by also emitting sound waves in another frequency range that neutralize the original frequencies, so that it appears invisible to the bat's radar. We, and other social living organisms, can and must share information by any means possible, the production of sound waves is just one of many possible ways. Birds sing, monkeys shout, dolphins whistle, and some ants stridulate. Rhythms and beats, clapping, shouting, singing, drumming, and stridulating represent information codified and transmitted through air, physical objects or organic material, like water and earth. Animals and humans communicate using many of these acoustical compositions, some of them are not even perceivable to certain species, others are misinterpreted, or just regarded as plain noise. Truth is, anything on this planet is interconnected and contains potential information that just needs to be amplified or accordingly translated in order for the message to be decoded and interpreted. This flow of information is subjective because the emitter is a subject, and the receptor will become a subject when he or she interprets the emergent meaning of the acoustic message. Thus, acoustic biocommunication, an emergent product of social evolution, is an active exchange of information, a flow of interconnected and interdependent information within the network of living organisms.

When neanderthals discovered the production of sounds, and consequently the first musical forms, by means of making noise with common daily materials like rocks and sticks, they probably realized the potential aesthetic expressions embedded with every sound they produced. As primitive as it was back then, and as primitive as it is nowadays, when we realize that our complex musical compositions are indeed nothing more than the fusion of basic sounds, a colony of frequencies and acoustic wavelengths, music has its roots in the basic production of simple sounds as a biocommunication form to attract and confirm social connections. Acoustic communication is definitely an emergent product that stems from the complex society we belong to. The complex deviations, mixtures and origins of the multicultural musical genres, like jazz and salsa, and the evolution of sound production itself, are linked to the very beginning of biocommunication in social beings and the need to share and amplify ideologies to the outer spheres and upper levels. We need to share our feelings, happiness and discontent with the help of sounds, we need to shout and stridulate to the world the way we feel. In this sense, amplification as a process that allows tiny bits of information become bigger bits of information, is a natural device that allows the sharing of information far beyond the constraints of a certain social group. Amplification enhances quiet gentle messages, increasing its loudness and intensity, in order for the public, the community, the society, to perceive, interpret, and participate in the exchange of information. That is how during evolution the many social beings on this planet learned to amplify their messages for social bonding, either developing internal organs or using instruments. Ants, as insects living in societies, also possess such sound-production skill, by using a stridulatory organ, to exchange and share information for social bonding. Moreover, the process of amplification by stridulation in ants is actually a modulating method within their network of communication to reinforce messages or provoke communal attention when the case is necessary. Brokers in Wall Street shout, the leafcutter ant stridulates.

Lets take for example a very common and simple exchange of information: on one hand we have the producer of sounds, man, on the other hand we have the interpreter, a dog. Dogs have learned to establish a very primitive communication with man, just as we have learn to establish a very primitive communication with dogs. They bark and we pay attention to them, we tell them to sit and they do so. They seem to understand us, but do we know for certain that they understand the semiotics involved when we talk to them? Or they've just learned to connect our voices, our intonation, with some situation or reward from past experiences? A negotiation of perceptions enters the scene. Some animals learn, like humans, from repetition and imitation. If we raise our voice, the dog raises its ears and pays attention, usually. We cannot say for sure that the dog semantically understands that we are mad when we shout at him, but the dog definitely knows it must have done something wrong, because dogs can recognize the sonic information that travels to their ears and resonates within their sensorial system to decode anger from happiness. Dogs, very loyal animals and man's best friend, are very sensitive and empathetic. They can be taught how to communicate with us, in a very primitive way.

Now lets take an uncommon and complex exchange of information: if we shout at ants because we are angry that they are stealing our food from our picnic in the park, something that is very common in the troublesome human-ant relationship, they would not notice that we are angry, they would not even hear that we are shouting. Ants are very sensitive too, but they cannot decode that sonic information because their sensorial system is not composed by the same organs that compose the sensorial system of hearing in humans and mammals. Ants listen through the joints in their legs, where the vibrations are picked up and interpreted according to frequency, amplification and context. Furthermore, anger is transcoded as stress or alarm status in the ant kingdom. An ant colony, as a society of individuals with each individual locally exchanging emissions and receptions, generally responds to stress by reacting collectively, by amplifying their actual parallel operations, so that redundancy in the actual task performance arises. This means too much workers end up doing the same job after a short interval of time in which the alert signal extended throughout the whole system. When active workers perceive something unusual, the pattern of reaction consists of unfolding a positive feedback chain that goes through all the caste levels of division of labor in the colony to amplify the alert, which consequently increases the speed and effectiveness of workers finding the right job to do: protect the queen, bite and attack or run away and escape.

How come redundancy can benefit the colony? Because when there are too many workers performing the same task, which is the case at the beginning when positive feedback extends the alert, then the excess of ants doing one job tends to cancel out over time by moving on to the next available unattended task, so that at the end balance is restored via negative feedback mechanisms. The amplification has to be regulated, as in any communication system of living beings. The regulation exists because in the ant system there is a response for every action. They are not trivial machines, they do adapt and understand. To this extent, ants know how to regulate the colony's task allocation by balancing performance and energy invested. At the beginning it may seem ants are chaotic, saturated and overcrowded, but after a while, the system achieves knowledge of itself and manages to balance and self-organize. But it cannot achieve this goal without the amplification of messages.

Normally, this positive/negative feedback loops, present in the cybernetic ant system, are achieved by means of modal communication: the combination of semiochemical communication, tactile rituals and the acoustical communication known as stridulation. What this means is that, Hölldobler et al. 1990, communication in ants is multicomponent2, almost always, occurs as a combination of the three forms, so that each form appears in the communication structure in order to enhance, or amplify, any of the other forms already present in the exchange of information. Thus, the message is well understood and recognized from other contexts. That is more or less what myrmecologists have found throughout years of investigations, always accompanied, of course, by heated debates among experts, since ant communication's system is still lacking advanced research and field experimentation to ultimately achieve *status quo* in the science of sociobiology and its corresponding relative fields.

Fact is, flexibility or plasticity in the stridulating behavior of the species studied, specially the higher Attines like Atta and Acromyrmex, and the other ants possessing stridulatory organs like Pachychondyla, Pogonomyrmex, Messor, Aphaenogaster, Leptogenys, have demonstrated that at least these ants take advantage of modal communication, like we humans do. Gestures or caresses accompanied by tender words when we are in love, or shouting, screaming, hitting and punching when we are attacked or hurt by strangers, are just a few examples of modal communication manifested by humans and primates. These reactions, derived from stress situations or from love, the recognition and acceptation of family and friends, are also present in the behavior of the individual organisms that make up the ant colony. It is important to mention that communication by pheromone emissions has been found to be the primary form of communication in ants, whilst tactile rituals reaffirm, like human gestures, variations of that corresponding semiochemical message, and the last form of communication, stridulation, is only present when the two other forms cannot function, like when nestmates are too far away for tactile communication or trapped in such a way that the only possible communication is the production of chirping sounds by rubbing two chitin composed body parts against each other.

Stridulation is nothing more than vibration energy produced by two objects rubbing against each other, which is transmitted through soil, resonant nest walls or any organic material capable of retransmitting sound waves. The stridulatory organ is located between the third and fourth abdominal segments of only those ants that during their evolution managed to adapt it as a technological organic tool for vibratory communication. The organ is mainly composed by a scraper and a file surface that possesses a series of indentations or grooves. Hence, the resemblance with the vinyl and the turntable. These two chitin elements of the ant's exoskeleton form the stridulatory 'instrument' that outputs codified signals to the rest of the colony, informing them about the freshness of the leaves, the location of the trapped nestmate or the level of danger in the intruder. The signaling pattern varies according to ant's size, caste and species but also according to the structure of the stridulatory organ, for not every organism of the colony is born with the same physical features. Specialized soldier castes in Atta have bigger organs because they are strongly built. The stridulating frequencies oscillate from 2-5 kHz, minims of Atta cephalotes, to a maximum energy of 38-46 kHz, supersoldiers of Atta cephalotes (analysis based on personal recordings in Yasuni). It is relevant to mention that stridulation is not the only form of sound communication in ants, there is also body drumming, practiced mostly by those ants that live in carton or wooden nests, like Camponotus herculaneus. "The drumming ant strikes the substrate with mandibles and gaster while rocking her entire body violently back and forth"3.. Sound production in ants, either stridulation or body drumming, is part of their communication repertoire which serves the ants mostly for recruitment and alert messages. But recent research has found interesting behaviors not accounted before when some of the above mentioned ants are exposed only to stridulatory vibrations. Basically, when leafcutter ants are able only to stridulate, nestmates are attracted to the subject and approach her to begin tactile communication.

In human situations, a call to arms when the enemy is approaching is usually accompanied by a shout or a cry of war in order to increase the bloodlust or strengthen the will to fight in the group. In the Attini tribe the situation is exactly the same: when a scout or guard finds an intruder, then vibrations of alert are emitted with the stridulatory organ to call nestmates for reinforcement. Normally no ant that encounters enemies in the vicinities of the nest, relies on herself to defend the nest alone, she will always communicate the intrusion to the rest of the colony. If the intrusion becomes a considerable aggression, that is, an enemy raid or a bigger enemy force, then the resonance of the stridulation will increase until the alert message reaches even the entourage of the queen and the last line of defense, the supersoldiers or generals. The supersoldiers are the biggest and strongest caste of the atta and acromyrmex genus. They possess the biggest stridulating organ found in the ant kingdom and make public appearances only if necessary. The supersoldier caste is a unique evolutionary development in the advanced Attini tribe and its reason of existence for the colony have not been yet thoroughly studied. That said, the stridulating signals, this magnificent social agent produces, are perfectly perceivable by humans if one picks up one supersoldier and locates her close to the ear. She will start to stridulate instantly because she will sense the funny human sweat juicing out of our finger tips, and according to Atta's pheromonal code that means danger. Of course, one has to be careful enough not to let her chop off a piece of skin with her strong mandibles. Apparently, a state of maximum alert originated by stridulation is prominently related with the appearance of supersoldiers when the colony is under major threat or danger. Recruitment is then a guaranteed product of a stridulating ant that needs help, and the amplification of this 'call to arms' throughout the defensive network renders always effective.

Thus, the efficiency in recruitment by stridulation represents a positive feedback mechanism proportional to the danger or threat the colony is experiencing, bringing forth more defenders as the danger increases. The amplification of stridulation achieves this result, as every ant's reaction consists in passing the message by stridulating to the nearest nestmate and so forth. To cool down this reactive state of the colony, this alert state, the enemy must be completely neutralized or forced to retire. Stridulation seems to be then, roughly based on my personal observations, a faster recruiting method than chemical alert signals, at least in the case of Atta cephalotes and Atta sexdens. When the provided circumstances are not suitable for chemical amplification, stridulation induces the presence of more and more waves of defenders to the ultimate deployment of supersoldiers.

When researching leaf-cutter ants in the tropical rainforest of Ecuador, specifically in the province of Los Rios near a private farm, I encountered a supercolony of Atta cephalotes. To test the defensive reaction time, and the quantity of supersoldiers that will be recruited in the presence of danger, I arbitrarily took two endemic beetle larvae and threw them near one of the nest entrances. The beetles have a very strong odor, which stresses the Atta workers. The reaction was immediate, for the pheromone highways were crowded with transporters carrying leaves and it was around midday when the activity of the colony is usually at its peak. Some minor worker spotted the stranger first, then around 8-12 majors, without foreign affair considerations, arrived with open mandibles to viciously attack the false intruder, and after approximately 5-6 minutes of permanent biting, rolling and body scratching, the stridulating signals summoned 6 fat supersoldiers, who emerged from the nearest nest entrance and finished the job. The unfair fight lasted about 8-10 minutes. The two larvae were no match for the sharp cutting mandibles of the Atta supersoldiers, but the chitin armor of the baby beetles was hard enough to withstand a well alerted defense system, that is, until by means of stridulation amplified the supersoldier caste appeared.

Heinz von Foerster said that the listener, not the speaker, determined the meaning of an expression, and by this mean, both the listener and the speaker when facing each other instantiate an environment of conditions, a cybernetic ecology, where the two become one symbiotic organism, who once conformed tries to negotiate the meaning of its existence in a determined point of time and space. The subjectivity and objectivity, implied in a communication network, are nothing more than instances of the poetics of immersion, that each movement, gesture, message contains. Bioacoustics and Biomimetics help us approach the natural phenomena manifested by all social living beings in this planet: communication is learning by imitation and to imitate creativity is to listen and see in order to mimic a successful behaviour which produces a successful reward. We all imitate creativity from nature, we all depend on each other, and therefore, we are influenced by each other. Seeing and adapting transformations and mutations throughout the open source network of evolution is in fact evolution driven by feedback, and we can approach, embrace and imagine this evolution network through experiments within the fields of Bioacoustics and Biomimetics. To this extent, stridulation is perhaps one of the most underestimated communication mechanisms found in social and solitary insects, and it definitely needs to be revived, celebrated, amplified.

The application of cybernetics and an artistic open mind, towards the understanding and analysis of stridulation phenomena, such as acoustic and vibratory messages shared by social communitarian beings, like ants and humans, have gained increased attention in the field of artistic research. Yet the cybernetics behind the system of self-organisation and emergence in ants and other social beings, is but a mere example of what have always been the inspiration ground for the human brain to imagine, create and produce, attaining technological and engineering achievements which come from the nature that surrounds us: aerodynamical cars, thermo-regulated materials, hydrodynamical swimsuits, traffic networks, peer-to-peer file sharing, are all examples of the mutated influence and the amplification of nature on our creative minds.