

# Emergent phenomena only belong to biology

Hugues Bersini

IRIDIA – ULB  
CP 194/6  
50, av. Franklin Roosevelt  
1050 Bruxelles, Belgium  
bersini@ulb.ac.be

**Abstract.** In this philosophical paper, I discuss and illustrate the necessary three ingredients which together could allow a collective phenomenon to be labelled as “emergent”. First the phenomenon, as usual, requires a group of natural objects entering in a non-linear relationship and potentially entailing the existence of various semantic descriptions depending on the human scale of observation. Second this phenomenon has to be observed by a mechanical observer instead of a human one, which has the natural capacity for temporal and/or spatial integration. Finally, for this natural observer to detect and select the collective phenomenon, it needs to do so in rewards of the adaptive value this phenomenon is responsible for. The necessity for such a teleological characterization and the presence of natural selection drive us to defend, with many authors, the idea that emergent phenomena should only belong to biology. Following a brief philosophical plea, we present a simple and illustrative computer thought experiment in which a society of agents evolves a stigmergic collective behavior as an outcome of its greater adaptive value. The three ingredients are illustrated and discussed within this experimental context. Such an inclusion of the mechanical observer and the selection as much natural to which this phenomenon is submitted should underlie the necessary de-subjectivation that strengthens any scientific endeavor. I shall finally show why the short paths taken by ants colony, the collective flying of birds and the maximum consumption of nutrients by a cellular metabolism are strongly emergent.

## 1 Introduction

“The whole is more than the sum of its parts” is an expression that continues to feed vivid debates in many scientific circles. In a recent special issue of the famous computer journal “Communications of the ACM”, Tim Berners-Lee, the Web inventor, and his co-authors are joining the “emergent fanatics” by arguing for a still to be invented science of the Web largely inspired by system biology. They claim “*a large-scale system may have emergent properties not predictable by analyzing micro technical and/or social effects*” [16]. The scale-free topology of the Web [3] is presented as one of these emergent properties. While these days, every scientist would agree that the two scientific observers seen in figure 1 (let’s call them Mic Jim – the micro observer and Mac Jim – the macro observer) observing the same collective phenome-

non but at different spatial and temporal scales are required (for instance, Mic Jim sees and knows the updating rules of the cellular automata game of life while Mac Jim only sees the “glider” moving [25]) to qualify a phenomenon as emergent, the heart of the disagreement rests on the status of Mac Jim. What is his role, his “raison d’être”? Does his observation testify of any outside reality, or does it simply boil down to an epistemic facility, a mental compression, summarizing what really happens outside when observing the phenomenon longer and/or at a broader scale. There are many good reasons for such a mental compression. It may help to describe and to communicate anything relevant about the observed pattern in a much more direct and clear way. It may facilitate the formal description of the pattern at one level up where this phenomenon needs to be integrated with others. For instance, it is well known that temperature or entropy are macro-scale physics variables that help to characterize the evolution of the whole system, like when stating: “the temperature is constant” or “the entropy increases”. It also makes possible the simple expression of physical law such as  $\Delta S = \Delta Q/T$  or  $PV = nRT$ , summarizing much more complex underlying phenomena and making possible the variables causal interrelation (for instance, the more agitated the particles are the greater pressure they do exert on the walls).

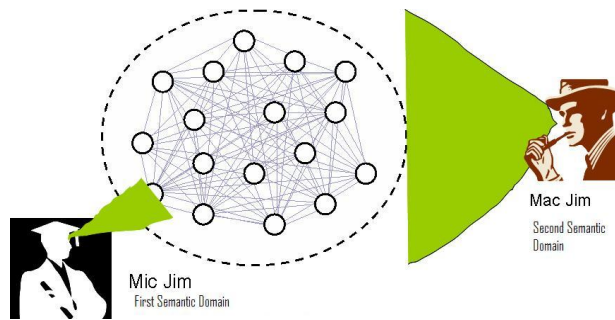


Fig. 1: Mic Jim and Mac Jim observing the same phenomenon but at different spatial scale.

In the case of the epistemic facility, Mac Jim’s status is considerably weakened since everything he sees and describes can be completely anticipated and fully recovered by Mic Jim, as a result of some spatial and temporal integration. Mic Jim takes the scientific leadership; he is the only one to have a complete and faithful understanding of the phenomenon, he can perfectly explain what is seen by his colleague but not the other way round. He could analytically integrate the behavior of the micro objects in space or time or, more generally (in the case of nonlinear interaction), substitute this integration by a software numerical one to recover his macro observation. Reductionism wins, the truth is underneath, and it is the only way good science should progress. Although two Nobel prizes of physics [1][20] have intensively advocate the need for physicists to better account for emergent phenomena, it is not clear at all how they do depart from the classical scientific reductionism and the consequent adoption of the restricted epistemic version of emergentism. Convincing arguments really lack for perceiving in emergence, as they claim, the source of a new paradigmatic shift in physics. No astronomer would ever say that the elliptic planet trajectory

is emergent although it really depends on the gravitational interaction of many celestial objects. However all the parameters of the ellipse are ground into the Newtonian gravitational forces. Just integrate the movement in time and the ellipse appears. Physics might not be the most appropriate intellectual territory to give emergence the most scientific i.e. ontological and objective “id card”.

Although certain authors [4, 5, 19] insist in keeping separated a weak version of emergence (epistemic) from a strong one (ontological), so as to stress what is really needed for the strong one, only worth of interest, there should be no reason for the weak one to deserve any further attention. Again in physics, the queen of science, Mac Jim, when watching the glider in the game of life, behaves in the same classical way as when observing an increase of entropy in an isolated system or the ellipses which planets draw in the sky. An entropy or a temperature increase appears to be more than the sum of particles, randomly and furiously agitated, but physics rightly says it is not. The planet ellipses seem to be more than the gravitation force combined to the planet inertial original velocity but physics, once again, rightly says it is not. So enough with the weak version of emergence which is nowhere innovating with respect to the scientific daily activity consisting in identifying macro-variables and connecting them by mathematical laws in order to predict the behavior of the system under study. Now, what about the strong one ? The only remaining “emergence” to care for, while remaining completely waterproof to mysticism, dualism or vitalism ? When John Searle argues that the secret of consciousness lies in the emergent properties of the brain just like liquidity out of water molecules, but is not reducible to it, he is either contradictory or adheres to the old fashioned dualism [28]. Indeed, liquidity can be predicted all the way down to the properties of water molecules whereas the subjective character of consciousness is out of reach by the neuroscience reductionist trends. The everlasting mind/body problem has nothing to gain from a better and stronger characterization of emergence. Consciousness is not to neurons what liquidity is to water molecules but rather remains as elusive as the transformation of water into wine alluding to one of those fantasies whose religion has the secret.

This paper defends that a key move needed to reconstitute its ontological status to emergence is to substitute Mac Jim by a natural (mechanical) double of it. Science strengthens by more and more discarding the part played by human observation in the characterization of the observed phenomenon. This is an epistemological crusade that, for instance, many philosophers of science have already undertaken for de-subjectivating quantum mechanics (hidden variables is one possibility, parallel universes is another). A similar process for the concept of emergence should turn out to be less challenging since none emergent phenomenon really violates common sense like quantum effects do. For the natural observer to detect a natural collective phenomenon, it needs to be selected for in rewards of its adaptive value. Since the only adaptation-based selection filter that science authorizes is the Darwinian one, it justifies why I believe in this paper (with others [9] [14] [18] to be reviewed later) that biology only and its theory of natural selection can make an emergent phenomenon to exist without any Mac Jim to detect it. Rather he is substituted by a part of the surrounding environment into which the phenomenon unfolds. Like convincingly argued in [4], emergent must always be conceived as a relational concept, in which some-

thing always emerges for something else. Finally, like famously stated by the geneticist Dobzhansky: “In biology nothing makes sense except in the light of evolution” and this is similarly true for emergence. A phenomenon will finally emerge in a system once observed and detected by a “integrating” mechanical observer for the adaptive capability it provides this system with. In the rest of the paper, I defend this idea and provide a simple illustration of it, through a robotic swarm experiments performed in my lab and a computational experiment of how and why stigmergy evolves in societies of very elementary agents.

## 2 The biological three key ingredients of emergence

The picture below (figure 2) is taken from the European Swarm-bots project, which is being coordinated in my laboratory [15]. Largely inspired by the capacity of some insect species (such as ants) to assemble in order to accomplish tasks that none of them, alone, is able to accomplish, this project is about small elementary robots that connect together to do as well. For instance, in the picture, you can see two robots that together and assembled can pass over a gap that would make any of them fall down if trying alone. One could be attempted to claim that “passing over that gap” is an emergent behavior since it requires a group of robots. However, being engineered as it is right now, we consider this not to be the case, since a human observer and engineer is required to plan, hand-code this behavior and to organize the pieces together (here the robots) so as to achieve it. A car or an airplane, although rather complex machines, are nothing as emergent since engineering is top-down while biology is bottom-up. As Dawkins metaphorically stated in response to the creationists of the 18<sup>th</sup> century, the watchmaker is blind in biology. However, I’d like to claim that the genuine biological phenomenon (the ants colony for instance), which inspires this engineering version, really is emergent. It is so because of two reasons. First any emergent phenomenon needs a natural observer able to integrate in space and time this phenomenon. Here, and as surprising as it could seem, this role is endorsed by the gap, which “observes” and “makes sense” of the phenomenon. The gap is indeed a kind of space integrator since it can distinguish the case of one robot from the case of two robots. Again, we agree with Yaneeer Bar Yam [4] that any definition of emergence requires the presence of two complementary realities: the emerging phenomenon and an environment the phenomenon emerges for, here this role being played by the “gap”. However, we feel more uncomfortable with the best example of emergence he proposes, as a string of bits including the “parity” one which constraints the other bits. This trick is used to detect errors in transfer of bits, but I really see too much of a “top-down” and engineering favor in his favorite example. If it is true that the “parity” bit acts as an observer of the remaining bits, only the human engineer endorses this final bit with the crucial role it is supposed to play.



Fig. 2: Two robots passing over a gap

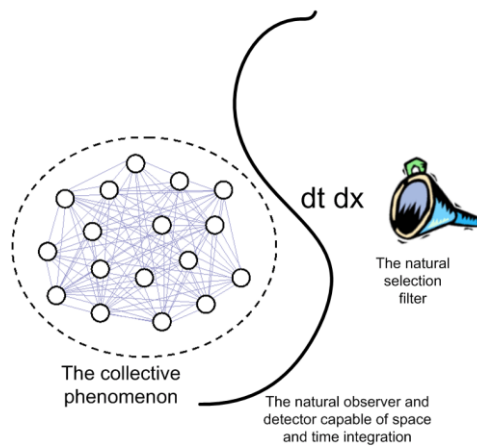


Fig. 3: The three needed ingredients for a collective phenomenon to be qualified as emergent.

The second required ingredient for a phenomenon to be qualified as emergent justifies why and within which non-human context the mechanical observer detects and makes sense of this phenomenon. In biology, natural selection is at play. The observer detects and selects the phenomenon because it provides the system in which this phenomenon is manifest with adaptive capability, often a more economical or robust way to accomplish some task. Here, the insects have to pass over the gap since falling down will simply kill them. The couple “gap/dead” (here the contextual instances of the mechanical observer and natural selection) is indispensable to justify why the insects do assemble. Without it, this collective behavior is meaningless. Obviously, no engineer would appreciate a similar destiny for its robots even if, as a reminiscence of real emergence, some evolutionary algorithms applied on a simulation of the robots (simulated robots don’t break) often help them to realize the collective task. As figure 3 illustrates, the emergence I defend appears at the crossroad of these three key epis-

temological ingredients: the collective phenomenon per se, the mechanical observer and natural selection. Any of them misses and the whole idea collapses, bringing back emergence to a weak and no longer original version of it.

I already had the opportunity in previous publications [6] to recognize my intellectual debt to authors like Jim Crutchfield [10,11] and Peter Cariani [8] in my way of naturalizing Mac Jim. The addition of natural selection in the whole picture goes in line with Maynard Smith and Szathmary's concept of "evolutionary major transitions" [22] and Peter Corning's "synergism hypothesis" [9]. This later defends the idea that "*synergistic effects of various kinds have played a major causal role in the evolutionary process, for essentially the functional payoff (mainly in economical terms) these effects were responsible for*". Indeed biology is a science located somewhere between physics, by the use of "proximate causes" to objectively describe the collective phenomenon, and engineering, by the use of "ultimate causes" to endorse this same phenomenon with an adapted functional role.

### **3 The emergence of shorter paths in insect societies**

Let's illustrate the three ingredients previously introduced by the following simulation. It is inspired by the ants colonies stigmergic strategy: the selection among many paths of the shortest one in order to link resource locations [12]. In substance, we aim at answering this simple basic question: "Why did ants once decide to communicate by laying down some signal (in the case of ants, it is called pheromones) along their way? Which observer once decided that this could be a very effective communication strategy? In the following, I describe the developed simulation in order to answer that question. On a bidimensional grid with periodical boundary conditions, a set of cells contains three possible items: an agent (for instance, an ant), a quantity of resources (food, for instance) and a quantity of signals (some pheromones). Each agent is characterized by a further positive quantity called its "vital energy". The agent is alive as long as its "vital energy" does not fall down to zero. If this energy vanishes to zero, the agent dies and disappears from the simulated environment. The quantity of resources in a cell stochastically varies with time. This stochastic variation represents different hardness of the environment. Resources are food for agents. Agents have to "consume" some resources to increase their "vital energy" and survive. Depending on the value of its "vital energy", an agent can be either "hungry" or "not hungry". With respect to its state, the agent can react differently. In the case of the presence of resources, the sated agent can decide not to consume.

A signal is the third possible item a cell can contain. The strength of this signal is represented by a positive quantity which can be increased by agents. With time, this quantity is decreased by a natural and exponential decay. When the agent deposits some signal in its cells, the signal quantity increases by a fixed amount. The behavior of an agent depends on its genotype. This genotype is evolved in time by means of a Genetic Algorithm. This genotype is divided in two parts: the "hungry" and "not hungry" parts. Each part is composed of a same number of genes. The allele of a gene

codes a possible behavior. The locus of a gene corresponds to a possible state of an agent. The state of an agent is defined by its "vital energy" and the items contained in its four-cells Von Neumann neighborhood. With respect to this state, the agent acts following the behavior coded in the corresponding gene. Six possible behaviors have been defined. They are:

- 1) "don't do anything",
- 2) "randomly move to one of the four neighborhood cells",
- 3) "consume a resource",
- 4) "go to a neighboring cell that contains a resource",
- 5) "deposit a signal in the cell", and
- 6) "move in a neighboring cell selected as a function of the signal contained in the cells".

Obviously, some actions are impossible in certain states. The possible actions are conditioned by the current state of the agent. For instance, an agent can consume resources only if its current cell contains resources. It can move to a neighboring cell with resources only if such a cell effectively exists. It can move in a selected neighboring cell only if the signals distribution in these cells make that possible, i.e. if one of these cells have the greatest or the smallest quantity of such signals. They are 6 possible cases of the signals distribution among the agent's cell and the four neighboring cells:

1. complete uniformity of the signal quantity among the five cells
2. signal quantity in the agent's cell greater than the signal quantity in the neighboring cells
3. signal quantity in the agent's cell equal to the greatest signal quantity in the neighboring cells
4. signal quantity in the agent's cell in between the greatest and the smallest quantity in the neighboring cells
5. signal quantity in the agent's cell equal to the smallest signal quantity in the neighboring cell, and
6. signal quantity in the agent's cell smaller than the signal quantity present in the neighboring cells.

The genotype of the agent includes then 2 x 8 genes: "hungry" and "not hungry" parts and in both cases: resource, not-resource, plus all the 6 cases just described. With respect to its locus (corresponding to a state of the agent), each gene provides a different number of alleles (corresponding to an action of the agent). The size of the search space is rather huge, about  $10^{11}$  possible behavioral patterns. At each time step of the simulation, the situation of all cells is synchronously updated and the action of each agent selected as a deterministic function of its current state ("vital energy", surrounding signals and resources). Every action of an agent entails a loss of "vital energy" depending on the precise action. Even doing nothing is costly. Obviously, the viability of an agent depends on its capacity to rapidly and economically find available resources to be consumed during the time of the simulation. After a simulation, the best alive agents are kept and evolved. Simulations are the way to evaluate geno-

type. We consider two kinds of simulation. A first one includes a set of homogeneous agents: they all share an identical chromosome. A second one includes a set of heterogeneous agents: they can have different chromosomes.

The evolution of agents' genotypes proceeds as follows. For each run, a population of twenty agents is generated and simulated during twenty thousand time steps. For the homogeneous case, each chromosome is the same in the twenty agents which are simulated. The fitness of an agent is given by the value of its "vital energy" at the end of a run. In the homogenous case, the fitness of the chromosome is defined by the average over the twenty agents' fitness. The used genetic operators are very classical. The five best agents are selected. They are exactly copied in the next generated population. From them, fifteen children are created following a uniform crossover and a gene mutation.

The homogeneous case is the simplest to understand. Which unique behavioral pattern allows the set of agents to live longer in average? We were rather satisfied to discover that the behavior consisting in 1) after the consumption of a resource, depositing a signal all along the way together with 2) in the absence of any resource, following the signal gradient, turned out to be the fittest and the most stable chromosome through the GA generations. A snapshot of the simulation obtained with the "best" chromosome is shown in figure 4, where the fittest strategy can be clearly seen and understood, discovering the signals left by the agents around the resources. The heterogeneous case pushed further the evolution principles. In this case, each agent with different chromosome has to struggle for life. A direct competition between each represented chromosome is at play. Indeed, the resources are not inexhaustible. If an agent does not have a competitive behavior, and even if it can find resources, the resources will be quickly consumed by fitter agents. Signals could be used by defectors, and altruistic agents would not be rewarded. In fact, the exploitation of signals is both a selfish and collaborative behavior. The agent which deposits and smells signals bounds its research of resources in the whole environment. The probability to find again a source of resources is then increased. By selection pressure, this behavior is transmitted to some children. A nearly homogeneous sub-population is then obtained such as in the homogeneous case. One can clearly see the signal trace and above all this collective cooperative strategy which really and "strongly emerges" as the result of the Darwinian competition.



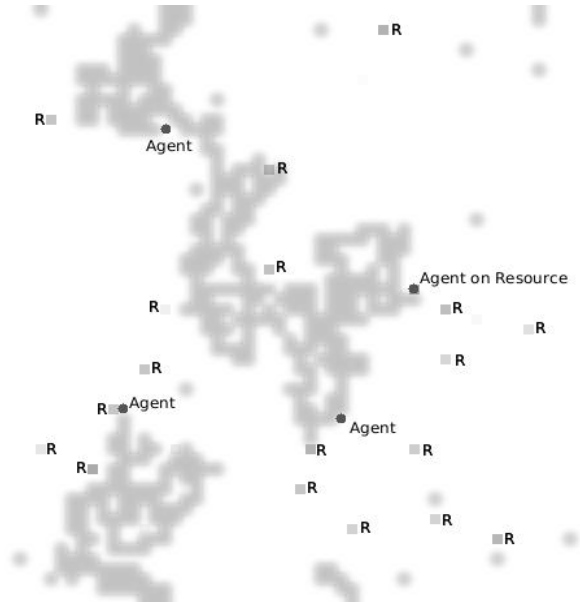


Fig.4 Snapshot of the simulation. “R” indicates a resource, “A” an agent and the grey trace is the signal left by the agents around the resources.

Therefore, here the role of the “mechanical observer” is being played by the vital energy measuring device which integrates in time the collective effect of the agents. Indeed, the presence of the signal and this stigmergic cooperation among the agents is responsible for the reduction in length of the paths and thus in the energy to be consumed to reach the resources. As required in the previous sections, the three ingredients are all present to attribute the "emergent" qualification to this stigmergic, signal-based and cooperative behavior. Figure 5 shows the fitness of the best behavior in the homogeneous case. It is hard to really distinguish among many other well fitted behaviors such as, for instance, “don’t move at all”, which can be rewarding in some cases. Figure 6 is the frequency of appearance of the actions “deposit signal” as the evolutionary algorithm progresses and successive generations of agents are evaluated (in the heterogeneous case). We can see how this action stabilizes in time, an even better indication of its adaptive value.

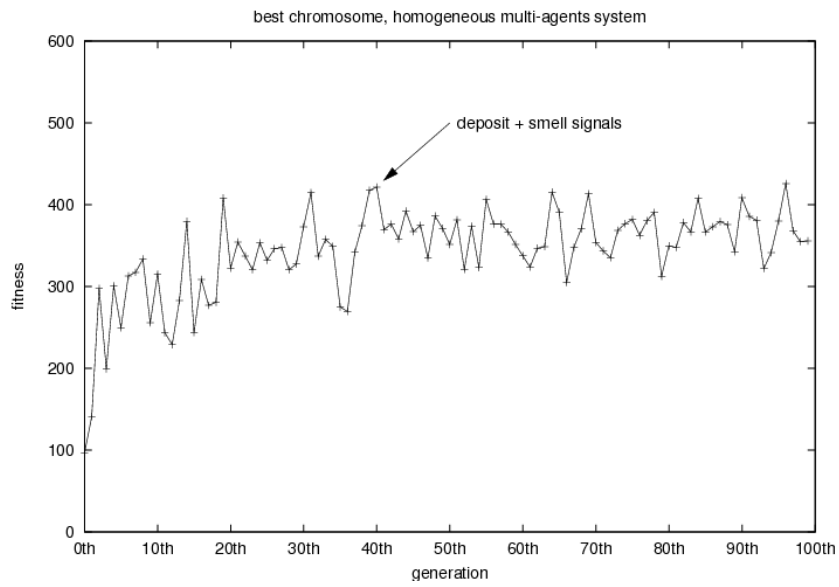


Fig. 5: The fitness value is plotted as a function of the different behavioral patterns in the homogeneous case. The best behavior is slightly better than the others. At the 40<sup>th</sup> generation, a “deposit + smell signal” behavior appears and turns out to be slightly better than the other behaviors in previous generations. This behavior remains stable during the next evolved generations.

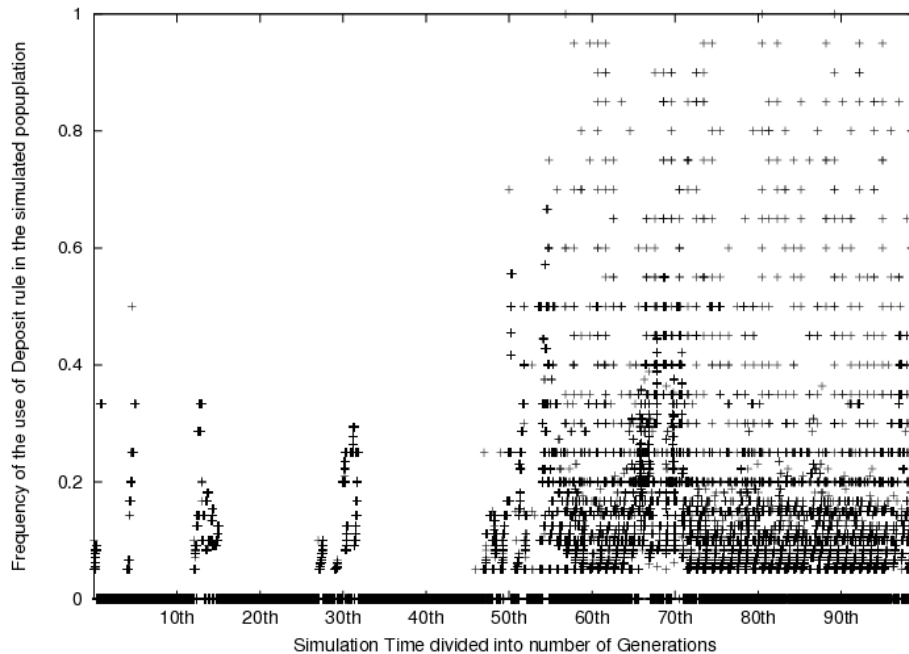


Fig. 6: This figure plots the use frequency of the action “deposit signal” as evolution progresses in time. In the case of heterogeneous multi-agents system. After about the fiftieth generation, the “deposit signal” action is always used by the best agents.

In a recent book and its chapter entitled “social gene” [21], the biologist W. Loomis relates a very similar phenomenon occurring in an even simpler bacteria called “*Distyostelium discoideum*” which is “*one of the simplest social system and yet present a wealth of social genes*”. If food lacks in the environment of these bacteria, each of them express genes for releasing the molecules cAMP (the equivalent of our previous signal) and also to produce the surface receptor of cAMP. When any cell starts releasing cAMP, surrounding cells respond by moving toward the area where there are the most cells and the concentration is the highest. Once assembled, this novel organism, composed of previous bacteria, can initiate a moving behavior, impossible before, to reach locations with more food.

#### 4 Emergence in an operational context

Three very practical uses of my vision of what is emergence can be spotted both in the science of complex systems and in the development of efficient optimization algorithms. Regarding complex systems study, one of the most active field of physics, emergence is often weakly and uninterestingly claimed to label what collectively happens in the system. For instance, in the analysis of bird flocks, the V shape done

collectively by the birds is nowhere reflected in any single bird. Each bird behavior is based on very simple rules function of its position relative to nearby birds. In the original algorithm of Reynolds called “boids” [26], the behavior of every bird obeys three simple rules such as: “avoid flying too close to the neighbors”, “copy near neighbors”, “move towards center of perceived neighbors” and thus a stunning variety of sophisticated collective patterns are explained to emerge out these rules. Some sociologists are so impressed by this alleged emergence to claim that this type of observation should give rise to a new trends of sociological studies [27]. Physicists try to model these flocking behaviors by adjusting the rules and their encoding parameters to what they experimentally observe on real birds. Again, I suspect that by matching those rules to the physical reality, and however successful they are, they still miss a key part of the story - that those rules really emerge under the filtering of natural selection - providing the birds which follow them with some adaptive advantages such as avoiding predation or saving flying energy. Another possible research protocol to uncover the right rules and the right parameters that define these rules, could be to simulate the birds in a given realistic environment, including predators, weather and other environmental aspects these simulated birds are sensible to, and then to optimize some cost functions taking account energy saving and success in escaping predation.

Another operational context is the today very popular study of cellular metabolic flux [23]. The molecular components involved in these studies and the reactions that connect them are described in a stoichiometric matrix. Thus, the null space of this matrix is computed in order to identify the equilibrium fluxes that best described the function of the metabolism. However, again this is far from enough. In order to really distinguish the most important reactions (since each reaction is catalyzed by a enzyme coded by a given gene, experimentalist can turn off the gene to evaluate the quality of their understanding) and the most important local fluxes, they need to graft on the whole study a optimization process whose presence mimics natural selection. For instance, some key metabolites should see their concentration maximized by the reaction network. Only by means of this optimization addition can the structure and the function of this metabolic network be fully recovered. The simple study of the proximate causes delivers an incomplete understanding of the phenomenon, ultimate causes are required to identify the key genes. As Palsson rightly assesses: *“The second feature that has to be taken into account in the study of biochemical network is the fact that they have a sense of purpose ... The fundamental purpose is survival... The goal seems to be to maximize ATP production from available resources. Therefore the study of objectives, that is, purpose, of biochemical reaction networks becomes a relevant and perhaps a central issue”*.

Regarding the positive impact of my vision of emergence in an optimization context, the essential part of researches in evolutionary algorithms or any optimization algorithm aims at discovering ways to accelerate the search when the problem is characterized by a huge search space. Many metaheuristics and hybridizing of them are invented and compared to travel this search space in the most effective way. One alternative approach to face the problem of the dimension of the space is to discover clever ways to reduce it, at least during some steps of the search process. It is here

that my notion of emergence and the very related one of “intrinsic emergence”, originally inspired by the developments of Crutchfield and Mitchell [10,11] turned out to be quite helpful. According to them and as further discussed in [6, 24], a macro-property which is labeled as “emergent” should supply some mechanical and non-human observer with additional functionality.

*“[...] Pattern formation is insufficient to capture the essential aspect of the emergence of coordinated behavior and global information processing... At some basic level though, pattern formation must play a role... What is distinctive about intrinsic emergence is that the patterns formed confer additional functionality which supports global information processing... During intrinsic emergence there is an increase in intrinsic computational capability, which can be capitalized on and so lends additional functionality. [...]”(Crutchfield [10])*

Indeed, this concept offers an interesting way to code macroscopically the genome of multi-agents system and, doing so, to reduce temporally the size of the search space. This implies a second search process taking place in the “space of observables” so that the “observables” of the solution space, here the emergent property, be also submitted to an evolution process, the same as the one trying to discover the best candidate in this solution space. This combination of the two evolutionary searches is the core of various enrichments of metaheuristics that I have proposed and experimented together with Christophe Philemotte in many famous combinatorial optimization problems such as the TSP [24]. For instance, for that very classical problem, like shown in figure 7, the towns were simply aggregated into regions and the metaheuristics applied to this one-level-up search space. The whole problem becomes now the discovery of the most appropriate regions and the simultaneous search in the two problem spaces but, so far, our experimental results give us many hopes to be confident in this extra plug-in for resolving very complex problems. Isn't that the way human also proceeds to resolve complex problems ? To first find a simplified useful representation of the problem that renders the solving to follow much more effective.

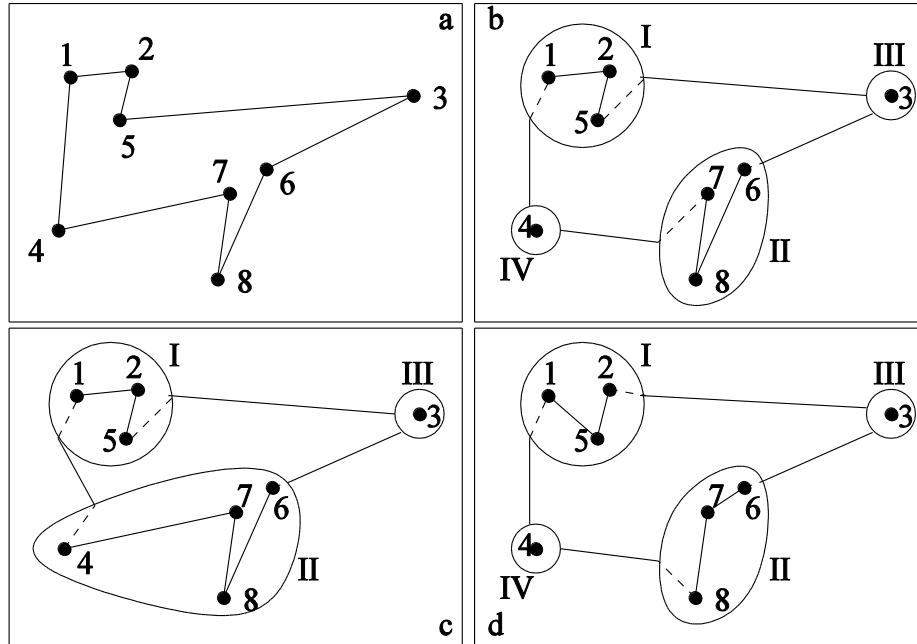


Fig.7 An instance of the TSP problem with 8 cities and different ways to aggregate these cities into regions so as to reduce the search space into the new problem of connecting the regions.

## 5 Conclusions

Among others, two biologists [14] [17] are acknowledged for the marriage they demand and celebrate between self-organization phenomena coming from physics and the natural selection too much influent and systematic in biology. For them, natural selection should boil down to an opportunistic parameterization of agents which, when interacting in a non-linear way, show a spontaneous tendency for interesting and complex collective behavior. They consider that this articulation between the two sources of order which are natural selection and physical self-organization has to be readjusted in favor of physics. Whatever road to be taken, coming from physics and viewing in this exotic natural selection a way to detect and select some of these spontaneous collective phenomena or, coming from biology, and viewing in the existence of self-organisation the missing explanation behind that kind of complex behaviours natural selection alone cannot assume, our emergence in exactly there at the meeting point of these two roads.

More recently and even more interestingly, still discussing the concept of emergence, Stuart Kauffman [18] insists in keeping separated physics from biology in the light of the teleological reading which biology imposes and which remains absent

from physics. Even if you can dissect a heart into the slightest details i.e. down to the fluid dynamics Navier-Stokes equations, something will still miss if not taking into account the fact that the primary role of the heart is not to make sound but to act as a blood pump. The collective behavior of all the parts that constitute a heart has been selected for its fundamental successful role in pumping blood.

I have insisted in this paper on naturalizing Mac Jim, the macro observer, or substituting him by a “natural double”, in order to reinforce the status of emergence. However, Mac Jim, as a human, still exists and, although completely eclipsed by Mic Jim and the way he understands the observed phenomenon, we might still try to explain and justify his existence and to conciliate in part the weak (i.e. the epistemic emergence) and the stronger form of emergence (that I made here dependent on natural selection). There are two ways. The first is obvious and not so appealing. Something can be interested both in the “eyes” of natural selection and in the human eyes. Short paths are beneficial for the viability of insects but can also easily be detected by human observer. Notice that the visual salience does not always go hand in hand with any adaptive value. Glider or planet ellipses are interesting in their own right or surprising to the eyes but don’t see themselves enriched with any adaptive value. On the other hand, some interesting biological collective behavior like network effects of gene or proteins (the robustness, the small-world [3]) endorsed with adaptive advantages and so emergent are hardly accessible to the human eyes.

However a much more promising second way to explain why Mac Jim describes a collective phenomenon in a new and simpler way, reconciling so doing the weak and strong emergence, is to accept human perceptive apparatus as being calibrated by natural selection. Not only natural selection makes our cognition eager to abstract the outside world in space and time but, even more, some authors insist in explaining the filtering mechanism of neural processes in Darwinian terms [7, 13]. The simple instantaneous process of perception and the learning in life time to perceive in a more adapted way are akin to a selectionist mechanism. The synaptic plasticity contributing to favor one neural pattern rather than another one in response to a stimulus can be interpreted in the Darwinian light. The strong version which requires the presence of a mechanical observer calibrated by natural selection slips into the weak one if the human we firmly try to discard turns out at last to be this same very well adapted mechanical observer.

## References

1. Anderson, P.W. 1972. More is different, *Science*, 177, pp. 393-396.
2. Baas, N.A. 1994. Emergence, hierarchies, and hyperstructures. In C.G. Langton (Ed.) *Artificial Life III. Sante Fe Studies in the Sciences of Complexity*, Proc. Vol. XVII. (pp. 515-537). CA: Addison-Wesley.
3. Barabasi, L-A. and R. Albert. 1999: Emergence of scaling in random networks. *Science* 286, pp. 509-512.
4. Bar Yam. Yaneer. 2005. A Mathematical Theory of Strong Emergence Using Multiscale Variety. In *Complexity* – Vol. 9 – No. 6 – pp. 15- 24.

5. Bedeau, M.A. 1997. Weak emergence. In J. Tomberlin (Ed.) *Philosophical perspectives: Mind, causation and world*, Vol. 11 (pp. 375-399), MA: Blackwell.
6. Bersini, H. 2004. Whatever emerges should be intrinsically useful. In *Proceedings of Artificial Life 9*. pp. 226-231. MIT Press.
7. Calvin, W. 1987. The Brain as a Darwin Machine . In *Nature* 330:33-34.
8. Cariani, P. 1997. Emergence of new signal-primitives in neural networks. *Intellectica*, 2, pp. 95-143.
9. Corning, P.A. 2002. The Re-Emergence of “Emergence”: A Venerable Concept in Search of a Theory – in *Complexity* 7(6): 18-30.
10. Crutchfield, J.P. 1994. Is Anything Ever New? Considering Emergence. In *Integrative Themes*. G. Cowan, D. Pines and D. Melzner (eds.) Santa Fe Institute Studies in the Sciences of Complexity XIX. Addison-Wesley, Reading , MA.
11. Crutchfield, J.P. and M. Mitchell. 1995. The evolution of emergent computation. Proceedings of the National Academy of Science, 23(92):103. van Leeuwen, J. (ed.): *Computer Science Today. Recent Trends and Developments*. Lecture Notes in Computer Science, Vol. 1000. Springer-Verlag, Berlin Heidelberg New York.
12. Dorigo, M. V. Maniezzo & A. Colomi, 1996. "Ant System: Optimization by a Colony of Cooperating Agents", *IEEE Transactions on Systems, Man, and Cybernetics–Part B*, 26 (1): 29–41.
13. Edelman, G. 1990. *Neural Darwinism*. Oxford University Press
14. Goodwin, B. 1999. *How the leopards change its spots. The Evolution of Complexity*. Princeton University Press.
15. Groß R., Bonani M., Mondada F., Dorigo M. 2006. Autonomous Self-Assembly in Swarm-Bots. in *IEEE Transactions on Robotics*, volume 22(6).
16. Hendler, J., N. Shadbolt, W. Hall, T. Berners-Lee and D. Weitzner, 2008: Web Science: An Interdisciplinary Approach to Understanding the Web – in *Communications of the ACM* – July 2008 – Vol. 31 – No 7.
17. Kaufmann, S. 1995 - *At home in the Universe : The search for laws of self-organisation* - in Oxford University Press.
18. Kaufmann, S. 2008. *Reinventing the Sacred: A New View of Science, Reason, and Religion*. [Basic Books](#)
19. Kubik, A. 2003. Toward a formalization of Emergence. In *Artificial Life 9*: pp. 41-65. MIT Press.
20. Laughlin, R. 2005. *A Different Universe: Reinventing Physics from the Bottom Down* – Basic Books.
21. Loomis, W. F. 2005 *Life as it is – Biology for the public sphere* – Cambridge University Press.
22. Maynard Smith, J. and E. Szathmary. 1995. *The Major Transitions in Evolution*, Freeman press, Oxford.
23. Palsson, Bernhard O. 2007. *Systems Biology – Properties of Reconstructed Networks* – Cambridge University Press
24. Philemotte, C., & Bersini, H. - 2007. *A gestalt genetic algorithm: less details for better search*. Paper presented at the GECCO '07: Proceedings of the 9th annual conference on Genetic and evolutionary computation, New York, NY, USA.
25. Poundstone, W. 1985 *The Recursive Universe*. Chicago: Contemporary Books.
26. Reynolds, C.W. 1987. Flocks, herds, and schools: A distributed behavioral model. *Comp. Graph.* 21(4): 25-34
27. Sawyer R. K. 2005. *Social Emergence – Societies as Complex Systems* – in Cambridge University Press
28. Searle, J. (1992). *The Rediscovery of the Mind*. Cambridge, MA, MIT Press