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The Contingent Subject for a Radical Theory of Emergence in Developmental Processes

Summary:

The author intends to give the outlines of a possible "radical theory of emergence" in development processes (biological and cognitive). Said theory should be based on two main observations: 1) development processes are emergence phenomena starting from reticular connections that concern the integrated totality of the systems being studied (internal source of the order); 2) development processes occur within structurally coupled systems whose co-evolutional structure has characteristics of irreducible uniqueness and contingency (external source of the order). The endogenous aspect and the exogenous aspect in the production of order in complex systems are here to be understood as being complementary and simultaneous. The two observations on the exo-endogenous character of development can then be generalized into a third: the crisis of the computational paradigm is read via the crisis of adaptationalist thought, sketched by biologists like Francisco Varela, by evolutionists like Stephen J. Gould and Richard Lewontin, as well as philosophers of biology like Susan Oyama. Following the latter's Development Systems Theory (DST), two possible directions are here explored to formulate an epistemological reflection on development in an emergentist and co-evolutionist key: a) a direction that tries to trace the "ontogenetic" (i.e. relevant to individual development) origins of the structural subject/object paring, which Varela defined as "embodiment" of knowledge; b) a direction that tries to trace the "phylogenic" (i.e. relevant to the biological evolution of our species) origins of this "incarnation" of the mind.

> *"This view of emergence, a general principle that in the past twenty years pervaded all of science and not just the neurosciences, reveals the fundamental importance of imagining a new way or kind of existence, the way to characterize that which is a something. It is a way of existence of which it cannot be said it does not exist ("Francisco does not exist"). I am telling something, you are reading what I am writing. But what is the nature of my existence? We do not assume that there is something substantial or a special quality located in this or that part of my brain that makes Francisco Francisco. Actually, this cognitive ego is just the result of its dynamic connections that connect every single local component, yet at the same time it cannot be identified with any particular interaction. To all practical purposes it is like saying it is here and it is not here."*
> (F. J. Varela 2000, p. 9)

This essay is inspired by the belief that Francisco Varela's last work, found in his essays between 1997 and 2000, contains several highly significant experimental and epistemological intuitions for the future of an approach to the study of cognitive and evolutionary developmental processes that we might start by describing as “anti-computationalist”. My assumption is seeking inspiration in these intuitions to outline a possible “radical theory of emergence”, based on two essential remarks:

1) Developmental processes are phenomena of emergence from reticular connections that involve the integrated totality of the systems examined (internal source of order);
2) Developmental processes occur within structurally coupled systems whose co-evolutionary dynamic presents characteristics of irreductible unicity and contingency (external source of order).

The endogenous aspect and the exogenous aspect of the production of order in complex systems should be seen as complementary and simultaneous. Developmental theories that privilege one or the other run the risk of excluding or underestimating an important part of the phenomena under observation.

To the two remarks on the exo-endogenous character of development, we feel we can add a third: the challenge to the cognitivist and computational paradigm, still quite influential in the definition of what “subject” is and what “organization” is, implies the discussion of and the challenge to selectionist and adaptationist thought. Indeed, lurking behind many discussions about knowledge and organization, there is an implicit evolutionary epistemology that deeply influences the theoretic elaboration of the evolutionistic debate and even its terminology. We suspect that if we do not go to the roots of this underlying epistemology (focused on a strong conception of the natural selection process and, especially, the phenomenon of adaptation, either biological or cognitive), we cannot build an alternative, and equally coherent, theory of developmental processes.

In that sense, I would like to suggest in the conclusive section two possible directions for formulating epistemological research and reflection on developmental processes in an emergentist and co-evolutionary spirit:

a) a direction that attempts to trace the “ontogenetic” origins (that is, relative to individual development) of the structural coupling of subject/object, that Varela called the “embodiment” of knowledge;
b) a direction that attempts to trace the “phylogenetic” origins (that is, relative to the biological evolution of our species) of this “embodiment” of the mind.

In this case also it is the simultaneous and complementary view of these two evolutionary processes that will provide us with a first vocabulary for a radical theory of emergence. To do so we shall examine a few very recent discoveries and scientific models that we feel have not yet been given sufficient attention in the international debate.

But we already have too may irons in the fire and should go back to the beginning of our discussion.

Natural selection on fundamental discrete units: a very influential “externalist” evolutionary epistemology

Let us concentrate a while on the cognitive modalities and implicit metaphors we are accustomed to using to filter knowledge about evolution and about formation processes of individual and social identities. What is a subject? What is an organization of physical elements or of intentional agents? Is there an order inscribed in nature and how did it start? Or is there no order? Are there fundamental laws of organization hidden ever since the dawning of life? Were they thought up by some Maker or did they somehow inscribe themselves in matter?

In the late twentieth century, while life sciences were beginning to explore the plurality and complexity of the processes characterizing biological and human evolution, the answer to that question (in a way the mother of all questions on the cause and the end of our history) was very simple, it was an utterly “economic” reply: the harmony of nature, in its infinite manifestations, is the result of a single great evolutionary agent, natural selection, acting on one fundamental substratum, genetic endowment.

This view is explicitly based on the idea, plainly described by the geneticist Richard Lewontin, that genetics is the inflexible, all-pervasive field of determination of biological identity, and that “the rest”, that is, environmental conditionings and more broadly the irreductible singularity of every single evolutionary history, is nothing but a marginal epiphenomenon. The aim is to apply an engineeristic, atomistic and mechanistic analysis of the genoma, seen here as a accumulation of cogwheels each one of which codifies a specific aspect of the phenotype, “instructed” each time by selection. This leads to a very binding postulate regarding rhythms and tempos of the evolutionary process, that has to be slow and gradual: an accumulation of small imperceptible steps, of slight progressive modifications.

But is that really the only way to explain the complexity of the natural world? If really organisms are merely vehicles for transferring and diffusing genes from one generation to the next, then why in countless episodes in natural history, in a winning strategy, did cooperation prevail over competition? Why, with the same genoma and the same environment, do two individuals remain radically different and unique? Why, if we repeat two evolutionary lines (or two cognitive processes), do we never get the same result? Why is evolution full of discontinuities? And above all, if the motor of evolution is natural selection, who gave the first spark for the emergence of life? Why has the mystery of the origin of life not yet been discovered? In other words, how did evolution evolve? What selected selection?

What we need above all is a more general level of epistemological interpretation. This approach (to sum it up: an almighty, demiurgical agent that forms from the outside a fundamental molecular substratum, from which each macroscopic property then descends in a straight line) conceals a very influential evolutionary epistemology that organizes not only knowledge about biological evolution (ultra-Darwinism), but even the way of conceiving the evolution of knowledge. Actually the latter matches a specular image of the cognitive process, seen as a linear elaboration of information coming from outside, that is, of “instructions” dictated by the environment, analogous to selective pressures. In that sense knowledge is reduced to an adaptive process of an instructionist type, an evolutionary performance, a mechanical solution to problems raised by the environment.

Thus the aim of the adaptive strategy will be to adequate as much as possible the cognitive pattern to external reality, to produce a good representation of it and to deduce from it efficient behaviors. But the price to pay (at least from an epistemological point of view) will be very high: the mind-nature dualism, denied by such a mechanical, computational approach, will surface in disguise, because the cognitivist paradigm will have to complete the likeness between mind and computer, drastically separating the realm of the elaboration of information and symbols (cognition software) from the realm of corporeal and emotional belonging (cognition hardware). Knowledge, to be adaptively efficient in solving problems, will have to codify them in the abstract language of computer science, will have to be “disembodied”. The mind goes back to being mechanical, but at the cost of losing its materiality, its biological naturalness: it is a machine for symbols.

So two permeant theoretic assumptions merge, the first deriving from evolutionary adaptationism and the second from the cognitivist tradition:

a) cognition is a process inscribed in natural evolution and thus has a merely adaptive role, is an extraordinary tool for solving problems raised by the environment and that is why it was “selected”;

b) cognition works like a very powerful elaborator of information and symbols, independent of its rootedness in a body that pulses, moves, acts and perceives.

As Steven Pinker (1998) recently wrote in Wired:

“Nearly everyone in the cognitive sciences field shares the notion that the brain is a kind of neural computer produced by evolution. The ones who don’t think so are highly visible, but few and hardly representative”

Among these few, hardly representative scientists of the mind we should certainly include Francisco Varela, whose main polemical objective was precisely the cognitivist divide between the computational software of the brain and its corporeal hardware. From the standpoint of our analysis, Varela’s strategy was dual: questioning the second assumption (the central dogma of cognitivism) in order to challenge the first (the central dogma of adaptionism).

The result of this strategy is a complete reversal of the computational approach: if, for the backers of the computer-mind, cognition is a machine, but a machine for symbols, a non-natural machine, for Varela cognition is the opposite, an activity embodied in its biological roots, a natural phenomenon to be studied as such, a form of “life” in becoming whose developmental processes are far from mechanical and linear. This paradigmatic and methodological reversal, that Varela called a “dynamic perspective” as opposed to a "computational" one, then offers a new image of the working of the mind as a natural, evolutionary system, an image that associates the mind and all biological phenomena under the definition of "auto-poietic" systems, that is, closely interconnected networks where each element of the system contributes to the production and the transformation of other elements of the system.

Such systems have a key characteristic: they are not indefinitely malleable by an external agent; they are autonomous, select outside stimuli, build a pertinence context of their own actions, reorganize their own inner structures by organizing and transforming the outside world. So the magic of these self-organized systems must be sought within them, the secret being the production of "emergent features", that is, features that belong to the integrated totality of the system on a certain level and cannot be deduced from the features encountered in components of a lower level. In other words, the thesis is that natural selection alone is not enough to explain the huge complexity of life, since it develops spontaneously through principles of interconnection, self-organization and emergence, that some scientists see as true "general laws of complexity" (Kauffman, 1995).

The flock principle: theories of emergent identity

A few years ago Francisco Varela wrote:

"I believe I have asked myself just one question in life. Why do virtual individuals, emergent Egos appear everywhere, creating their worlds on all levels, of mind and of body, of cells and of the transorganic? The production of these virtual identities is unceasing and new organic, mental, social realms constantly arise from it. Yet this result, extremely firm and lasting, seems to contrast the ephemeral, volubile nature of the processes from which individuals emerge. This, for me, is the essential question" (Varela, in Brockman, 1995, p. 188).

A flock of wild geese rises in the sky and, as though playing from memory a silent partition, sails in the wind following a proven course. Hundreds of geese, each in its own role, merge like a single goose, like a single organism. The flock moves toward a destination, adjusts, makes decisions, alters itself, is aware of a threat, rests, seeks shelter, follows the invisible traces of its own path. The flock is an intelligence in unison, a society of animals in resonance, a collective identity.

For over more than five centuries, astronomers have been observing with amazement and curiosity the evolutions of the great red spot on the surface of the planet Jupiter. For centuries, in the southern hemisphere of that gaseous giant a bunch of a million storms has been working toward forming a single huge oval-shaped storm. An ocean of random disturbances, of violent gaseous tempests inconceivably produces an orderly configuration, such a stable cosmic whirlwind that it can go on for centuries. Occasionally a number of local storms are becalmed and a number of others are unleashed, but the emergent order lasts. The overall form of that planetary society of hurricanes is similar to one huge hurricane, as if each element of the group contained the formal secret of the whole

Is there something in common, between the flock of geese and the great spot on Jupiter, systems so stable yet so voluble in their interconnections? What is the secret of emergent identity?

The building of simple models of random networks (whether they be genetic, neural, chemical-reaction or ecological networks) has allowed the theoretic biologist Stuart Kauffman to prove that only three parameters, that is, the number of nodes of the network, the degree of average interconnection between the nodes and step by step rules of connection, determine a very broad range of possible networks. Within this range, modulating the three parameters in computer simulations, scientists can create highly stable networks (that in a very short time stay in an orderly configuration), totally chaotic networks (that randomly waver between countless different configurations, without ever repeating the same) and especially interesting networks in which spontaneously emerge a few "islands" of recurrent order.

The main idea is that, in any type of network, when a group of elements (molecules, genes, individuals, and so on) reaches a critical threshold of diversity and interconnection, a "self-catalytic" or self-poietic network forms spontaneously, meaning a tangle of elements connected circularly by cycles of positive and negative retroactions, a network in which all the elements converge to form other elements of the network, producing evolving orderly configurations: the network "comes to life", metabolizes certain external elements, regulates and sustains itself on its own, multiplies by self-duplication, and sooner or later will produce a new "emergent feature".

Life then is not a very rare miracle of chemical combinations: it is the predictable, "necessary" result of the dynamics of self-organization true of all complex systems. Given certain minimal conditions of diversity and interconnection among the primary elements, beyond a threshold of minimal complexity life "produces itself", requiring neither a pre-existing substratum of genetic transmission nor a pre-existing principle of natural selection. The metabolic network is not built by a gradual aggregation of new components: it quickly crystallizes as an integrated whole, as a "self-catalytic group". Given these conditions and given the strength of spontaneous self-organization, the emergence of life is not in the least unpredictable, it is a certainty, an inevitable phase transition.

Each network presents a repertory of "stable states", that is, of stable behaviors to which it periodically returns. These stable states, or attractor, tend to attract the courses of the system, as if they were attraction basins of all the possible trajectories of the network. They guarantee the network's stability, because they resist disturbances and tend to maintain the overall homeostasis. A typical process of emergence of spontaneous order in a self-catalytic network is ontogenesis, that is, the development of the entire individual from the ovule fecundated owing to self-regulation and canalization dynamics of the genetic network: Kauffman's hypothesis is that from a highly complex genomic network derive about 317 possible orderly configurations, an amount very close to the actual number of cellular types in nature.

The extraordinary evolutionary properties of "living" networks depend on their ability to balance flexibility and stability: they should be neither too ordered (that is, with just one attractor that quickly leads them to equilibrium and hence to death) nor too chaotic (that is, with an infinity of unstable attractors through which the system endessly wanders, sensitive to the tiniest disturbances). The most efficient networks tend to approach a condition described as "on the edge of chaos", having, that is, parameters that bring them on the threshold of chaos yet without ever crossing it. Life emerges and evolves on the edge of chaos, in that fluid transition area between order and chaos, in which the system remains stable enough even within strong disruptive dynamics that unpredictably transform it.

Therefore natural selection would have the limited task of encouraging systems on the margins of chaos: that is, it would be a secondary "maintenance" force of the average evolutionary capacities, and no longer the primary modelling force. Evolution would tend to maintain living systems in the state of fluidity required for them to be creative enough: neither too sub-critical (that is, tending to stability) nor too supra-critical (that is, tending to the explosion of forms). So a general law of complexity is the one according to which every adaptive complex system evolves spontaneously toward the condition on the margins of chaos. Ecosystems, for instance, stay on the border between a subcritical state (typical of individual cells) and a supra-critical state (typical of the biosphere as a whole).

In that sense, there would be a "limit" condition highly favorable to life, that Per Bak, Chao Tang and Kurt Wiesenfeld called "self-organized criticality" (Bak, 1996), true for all complex systems: like a heap of sand fed by grains falling on the table, external disturbances and internal self-organization dynamics produce in complex systems a variety of changes that can range from the catastrophic landslide (the heap collapses and forms anew), to the small landslide (little landslips on the slopes of the heap), to nothing at all. The variety of forms of life in the biosphere in fact feeds itself by obeying a distribution law of this kind. What is remarkable is that the distribution law of these changes (few catastrophic landslides and lots of little ones) is exactly the same for very different systems as well: it is identical, for instance, to the distribution of extinction events that really took place in natural history. With a specification that we should not overlook: it is never possible to predict which kind of landslide will be produced by a determined grain. Complex systems prove common rules, but remain largely unpredictable.

The theory of the emergence of spontaneous order therefore strongly limits the power of natural selection in forming and giving "instructions" to living forms. The source of order is prevailingly internal, it is a spontaneous morphogenesis arising from the reticular interconnections of the system:

"Whence the order out my window? Self-organization and selection, I think. We, the expected, and we, the ad hoc. We, the children of ultimate law. We, the children of the filigrees of historical accident. What is the weave? No one yet knows. But the tapestry of life is richer than we have imagined. It is a tapestry with

threads of accidental gold, mined quixotically by the random whimsy of quantum events acting on bits of nucleotides and crafted by selection sifting. But the tapestry has an overall design, an architecture, a woven cadence and rhythm that reflect underlying law, principles of self-organization" (Kauffman, op. cit., p. 185)

This emergence is not a gradual assembly produced by selection, it is not an accumulation of changes, but a discontinuous phase transition, a bifurcation toward a new form of organization. For the cognitive sciences this emergentist approach has highly interesting implications, some of which in fact Francisco Varela recently explored.

Consciousness is a storm in the head: the discovery of the syntonization of the cortical areas

In 1999 the CNRS équipe coordinated by Francisco Varela and Eugenio Rodriguez at the Laboratory of Cognitive Neurosciences and Cerebral Visualization of the Hôpital de La Salpétrière in Paris obtained an experimental result of great relevance published in the review Nature (Rodriguez et alii 1999). For the first time an electric mapping of conscious perception was achieved, allowing to infer that the production of a mental state by the brain coincides with the synchronized activation of various cortical areas (in particular of the temporo-parietal and occipital lobes).
The hypothesis of Varela and Rodriguez was based on the idea that the connection between consciousness and attention was closer than previously believed, and that consciousness consists of the emerging, from time to time, of a coordination between cerebral areas engaged in a task of selective attention. Between attention and consciousness there would be a sort of feedback loop: attention would trigger the process of consciousness and in turn consciousness would guide the selective attention processes. So consciousness would be an emergent feature of attention, a cooperative behavior between cerebral areas synchronized by gamma oscillations (that is, high frequency waves, about 30-80 cycles per second), whose dynamic would follow the predictive models of the chaos theory. Therefore consciousness would not be the result of a strategy planned only on the level of the frontal cortex, but the emergence of an ordered configuration out of chaotic dynamics owing to the trigger offered each time by an attention task.
This emergentist and discontinuist interpretation of formation processes of neurocognitive structures explicitly refers back to René Thom's and Jean Petitot's neo-gestalt tradition as well as to the connectionist tradition introduced by the second cybernetics theoreticians. In an interesting 1999 essay on the "neuro-phenomenology of the consciousness of time", Varela insists on the importance that theories of chaos, or more precisely theories of systems with a non-linear dynamic, can have for the neurosciences (Varela, in Petitot, Varela, Roy, Pachoud, 1999).
In solving a mathematical problem or in interpreting an ambiguous figure, the brain, according to Varela, works from the synchronization of a network of active cortical sites. This harmonic sychronization is very swift and happens all the time (as Antonio Damasio had already suggested in a work in 1990). You can observe here, we feel, a further advance with respect to the classic metaphors of connectionism: actually we have a double reticular integration. The cerebral network is not just an interweaving of circuits crossed by binary messages (excitation-inhibition), it is also a global self-poietic network marked by synchronization waves between integrated areas, in turn constituted by networks of circuits:

"This is true of every cognitive activity: perception, motivation, planification or semantic. It is as though our mental life coincided with a series of waves that regularly emerge and dissolve" (Varela, 1999).

Consciousness, in the interweaving of these "shadows" of perception, would thus reveal itself in sudden storms of synchronized gamma waves. Like a well-orchestrated musical symphony, they produce an emergent ordered configuration, that researchers call "neural synchrony" or "long-range neural integration" (Lachaux, Rodriguez, Martinerie, Varela, 1999, p. 194). As Gerald M. Edelman and Giulio Tononi (Tononi, Edelman, 2000) also claim in several recent works, the neurosciences are drawing ever closer to understanding the subtle large-scale connective integration mechanisms emergent from the network of the neuronal groups.
It seems to us that this discovery, many decades after Walter Pitts' and Warren McCulloch's pioneering

works, gives a heightened interest to the connectionist choice to work on real biological systems rather than on systems of symbols and to build non-linear models to explain neuronal activity. Regarding neural dynamics, as Brian Goodwin and Ricard Solé point out in their latest book Signs of Life (2000, pp. 119-146), a precious, up-to-date synthesis of the theories of self-organized systems, if we study systems from the standpoint of their autonomy, we systematically discover principles of self-organization and emergent features, that is, global states of the system that derive from the intrinsic interdependence of all the components of the system itself, and that can be usefully described by mathematics of non-linear systems. Today the "dynamic" view suggested by Varela is applied in many cognitive science laboratories. Some recurrent phase transitions in the brain, studied as a self-organized network "on the edge of chaos" have for instance been identified and recorded in subjects involved in visual perception tasks by the équipe of Scott Kelso, a neurobiologist of the Florida Atlantic University (Kelso, 1996).
The emergent identity of living systems is therefore a bricolage of identities, an interior parliament. It does not have a privileged place of residence because it is distributed all along the branches of the network. In that sense Varela introduced the expression "Virtual Self":

"Organisms should be viewed as networks of virtual Selves. I do not have a strong identity, but a mosaic, a makeshift of different identities: a cellular one, an immunitary one, again another cognitive one, and so on, that reveal themselves in different interactions. What interests me is studying the transition from local interactions to the emergent global feature, to understand how all these Selves come together and then separate again in the dance of evolution " (Varela, in Brockman, p. 189).

If this be the case, the mind cannot be separated from its biological support and the physical and corporeal context it is immersed in. Cognition arises in a melting pot of "ecological" conditions that it conditions and by which in turn it is conditioned: cognition is located, is embodied, and embraced in a context in transformation, is a dance of self-eco-organization.
In this sense, an internalist view engaged in identifying the self-organizational laws of living and cognitive systems indeed offers the essential tools for challenging the instructionist and neo-Darwinian paradigm, but by itself is not sufficient for understanding the complexity of developmental processes. The study of formation mechanisms of the internal structures of non-linear systems has to go along with the study of the coevolution dynamics between subjects and contexts, between systems and supra-systems, between the subject as organization and the organizations that (in turn as subjects) surround it:

"The most important consequence of the mind viewed as an emergent feature is that the Self exists only in its relationship with the world. The Ego is such because it interacts, and outside of this relation it does not subsist, insofar as it does not have a place where we can find it" (ibid., p. 194)

The internal source of order and of complexity implies, as a complementary and simultaneous aspect, a binding relationship with a world, with an evolving context: outside of this relationship identity does not exist. The internal source of order implies an external source of order. This opens up a research direction that in recent years has been rich in interesting scientific contributions that, we feel, seem to confute the idea that the study of coevolutionary dynamics is just an extension on a broader scale of the same rules of self-organization and spontaneous order found in an internalist perspective. Coevolution introduces an even more irreductible degree of complexity.

Coupled landscapes: complexity, coevolution and fitness in developmental processes

Let us go back a while to Stuart Kauffman's theory. First of all, it does not underestimate the importance of the coevolutionary dimension, but instead completes it with the construction of "fitness landscapes" that (in Kauffman's version) ought to provide a good model for coevolution dynamics. You obtain a fitness landscape by projecting in a three-dimensional space fitness values randomly assigned to all the combinations of a network (if a network is made of three genes, each of them connected to the other two, we shall have eight genetic combinations, each with an assigned degree of fitness). This produces a "landscape" with fitness peaks, medium valleys and basins of low fitness. Compared to the attractors metaphor, the point

of view is reversed: an attraction basin becomes a mountain to climb.
With this simple projection we can effectively visualize the networks' features: by modulating the three parameters, we shall have monotonous landscapes with a single peak, increasingly uneven landscapes, mountainous or even "Dolomitic" landscapes. Practically speaking, fitness landscapes are spiderwebs of conflictual constraints, inside which organisms strive to reach adequate fitness (never optimal). The greater the degree of connection between the elements of the system (for instance, between genes), the more conflictual constraints increase and make the landscape rough and uneven, with lots of medium heights. When a disturbance intervenes in the system (for instance, a mutation or a recombination), the organism shifts about within the landscape, encountering a higher or lower peak and pursuing its fitness striving. Evolution moves toward the margins of chaos and thus tends to encourage rough, uneven landscapes, neither too monotonous nor too chaotic.
Adding a further connection parameter to the models, two fitness landscapes can be "coupled", simulating for instance the coevolution and interrelation dynamics between species that characterize ecosystems. Conflictual constraints increase considerably, but in this case as well we observe in the simulations a sort of spontaneous "syntonization" of the landscapes in coevolution toward a state "on the edge of chaos": they are still uneven, but not too much so.
The idea is that organisms (but also technologies, articles, cultures…) evolve in uneven landscapes following the conflictual constraints that characterize them, moving from one peak to another when there is a disturbance. The usefulness of the model can also be deduced from its capacity to "predict" some evolutionary regularities that can indeed be found in empirical reality, like for example the typical descending curves of learning we find in many fitness strategies: the more seeking high peaks increases, the more the average distance of the closest best fitness peak increases and improvements dwindle.
So we begin to see several deep "regularities" outlined in the evolution of complex systems. However, the sheerly probabilistic and conventional definition of the degree of fitness of an organism shifting about in its rough landscape may be a weak point in the model. Indeed fitness is well simulated as a local and temporary process deriving from multiple and even discordant selective pressures. It is a zigzagging course among conflictual constraints, internal and external. But what is the relationship between the organism and its fitness peak? Do fitness peaks somehow attract the courses? We can recognize a certain proneness to a degree of unevenness of the landscape, but how can a sheerly mathematical model describe the real sources of fitness? Can we really "measure" and compare a degree of fitness? What is the meaning of the fact that in the course of coevolution the same parameters of connection can change, irreversibly altering the geography of the fitness peaks?
The idea is that actually these laws of self-organization and evolution are true for all organizations, regardless of their components. Even organizations of intentional agents evolve in uneven fitness landscapes, because they, too, shift about in a space defined by the play of the conflictual constraints within them. Economy is an evolving ecosystem presenting the same laws of self-organized criticality and of syntonization toward the margins of chaos as biological systems. Even democracy, according to Kauffman, might be a natural evolutionary emergence, given by its high fitness value: it is a very high fitness peak since it guarantees excellent compromises between interests and conflictual constraints. However, the key question of fitness remains unsolved and is perhaps even more obvious in some more applicative models. Lately, an interpretation of the theory of complex fitness systems focused on this idea of "coupled fitness landscapes" has interested psychoanalysis, for instance. Stanley R. Palombo, psychoanalyst at the Washington School of Psychiatry and associate at the Santa Fe Institute, published in 1999 a proposal to redefine the psychoanalytic practice through the concepts of self-organized systems (The Emergent Ego: Complexity and Coevolution in the Psychoanalytic Process). Stuart Kauffman writes in the introduction of the book:

"Palombo bases his extension on the emerging concepts of complex adaptive systems. A microbial community some two billion years ago was a coevolving complex adaptive system trying to thrive in its own world. Analyst and patient form a coevolving complex adaptive system as well. The interpretation of the analyst do, in fact, impinge on the self-reinforcing whirlpools "attractors". In doing so, he has properly borrowed concepts from nonlinear dynamical systems" (in Palombo, p. xii)

Even if the appropriateness of this “borrowing” of concepts on such different scales is not always convincing (at times it looks like a simple analogy by assonance, not thoroughly examined), nonetheless the basic viewpoint Palombo suggests, that is, describing the analytic process as a coevolutionary landscape punctuated by attraction basins, might be worthwhile: “there is something new under the sun of psychoanalysis” (ibid., p. xv). The hybridization between Freudian psychoanalytic semantics and the syntax of the theory of self-organized systems seems inviting:

“Palombo formulates the concept of an ‘unconscious infantile attractor’, a sustained belief and feeling system that closes upon itself and is relatively impervious to perturbations. The attractor is sustained by stimuli which are liable to be misinterpreted by the patient, and act as a ‘food set’ for the attractor. Analysis proceeds as a coevolutionary process between analyst and patient in which the interpretations of the analyst lead to changes in the underlying beliefs and feelings that swirl persistently through the infantile attractor. Such changes can, hopefully, lead to the diminution of the malignant attractor and the emergence often through phase transitionlike phenomena, of new attractors. As a successful analysis proceeds, Palombo suggests, the variety of options open to the patient increases, allowing new, more adaptive responses to his life situation” (ibid., p. xiii)

The hope is that these changes might reduce the negative, paralyzing influence of the dominant infantile attractor and lead to the emergence of a number of new attractors. The patient’s fitness response may thus be directed toward a multiplicity of attractors, getting rid of the encumbrance of a single attractor. Then the solution would lie in the creation of a vaster space of possibilities of action and of “courses”, by a kind of fluidification of the system that would keep it removed from both schizoid chaos and perfect paranoid equilibrium.
The resulting therapeutic dynamic will be connotated by a largely discontinuous rhythm: the emergence of new attractors will happen at the same time as rather sudden “phase transitions”, preceded by long latency phases in which changes accumulate on a level of lower complexity. Thus, sprung from a therapeutic event, various courses of change, often unpredictable and asynchronous, will be produced, like in a bushy evolution. In a phase transition we observe a change in organization at the end of which new features of the system emerge. The homeostatic resistance of the system is broken and new courses of development open up. Particularly worthwhile, in the accounts of clinical cases Palombo presents, is the awareness of seeing at work, in interpreting the psychotherapeutic dynamic as an authentic evolutionary process, two implicit evolutionary epistemologies: an epistemology of gradualness centered on the idea that the evolution of the mind is a linear, instructive process (with action-reaction metaphors; control; problem-solution; progressive modelling; intentional manipulation); and an epistemology of the plurality of rhythms, scales and units involving all the self-organization processes (with constructive interaction metaphors; discontinuous emergence; unpredictability and non-linearity; irreversibility).

“I think of the ego as the highest level of organization of the mental contents of a mind or a psyche. Integrating disconnected contents into the ego is the business of psychoanalysis. The ego must reorganize to include its new components. The reorganized ego emerges from the integration and coordination of its component parts through a process of self-organization. These components are themselves organizations at a high level of complexity. Complexity is the state that results when many components interact to produce a collective output that is not a linear function of the input to the individual components, the whole being greater than the sum of its parts” (Palombo 1999, p. xviii)

So then psychoanalytic treatment will privilege the fitness character, rather than the defensive character of condensation mechanisms in dreams or free association. The narration of the Self will be viewed as a reconstructive, integrative process, like an activation diversifying possible strategies and opening unexplored areas of awareness, rather than like the ratification of a linear, predictable course. Compensations and definitive explanations will not be sought, but instead new possible relations. The patient modifies his image of the analyst and the analyst that of the patient, and these events in themselves already constitute thresholds of irreversibility. The patient’s associations, the contents of his dreams, his emotional states retroact, reorganize themselves and produce vaster and vaster structures.

Every interpretation that intervenes in the therapeutic process, Palombo pointedly observes, is by nature "mutative" and already potentially the beginning of new drift. The highly delicate dynamic of transfer and countertransfer relations, whose degree of complexity should never be underestimated, is viewed here as a narrow coevolutionary dynamic, a structural coupling of "uneven landscapes" that irreversibly transforms analyst and patient:

"Coevolution is the process through which interacting systems self-organize in order to adapte to one another. Psychoanalysis is a coevolutionary ecosystem in which the patient's self-knowledge is reorganized through his adaptation to the analyst's increasing knowledge of him" (ibid.)

So here the ambiguities of the notion of fitness surface again. This reciprocal fitness is in fact an endless, temporary, local, contingent task. You might think the analyst himself transforms his own self-knowledge, irreversibly, in the course of the treatment and that, after all, it is not necessary to postulate that reciprocal knowledge has somehow "grown" or progressed (compared to what?): as though sculpted by the sequence of reciprocal disturbances, between patient and analyst if anything a new "ecosytem" has fully emerged.

"What do the patient and the analyst actually do in an analysis? In the traditional view, the patient tries to say whatever comes to his mind and that the analyst tries to interpret what the patient says in order to bring about a therapeutic change. We can see now why this description is incomplete. The patient and the analyst are doing something together. They are collaborating on a task that changes each of them, leading to a convergence of results beneficial for both. They are coevolving" (ibid., p. 343)

But how cautious should we be in shifting about between such different fields of application? Can self-organization laws of a collectivity of chemical-physical components be the same as a therapeutic dyad or as a collectivity of intentional or conscious agents? Authors like the theoretic physicist Micho Kaku have no doubts on the subject, and propose unified theories in which self-organization events by phase transition are transversally true for elementary particle physics, children's intellectual growth and the French Revolution (Kaku, 1994; 1997).
Can we endlessly extend the same regularities or should we limit ourselves to just establishing a few superficial analogies, as suggestive as we like but not very meaningful? Whereas "strong" programs like sociobiology immediately engaged in the first path (like a reductionist roller conquering new territories), complexity epistemology often modestly kept to the second, exposing itself to scientific criticism of all sorts. The same criticism, by the way, attacks it when it attempts too daring syntheses!
In recent years scientists like Niles Eldredge have been exploring a middle course we might call, following Francisco Varela, the "subtle bridges" course. The idea is to experiment the efficiency of a regularity, found locally in a certain disciplinary area, in a context even very different from the first, but still locally defined: it is a sort of sample transdisciplinary exploration, an exploration of new connections from local to local. That is, there are patterns repeated in the evolution of self-organized systems, like the bushy pattern, the avalanche distribution law and convergence toward the margins of chaos, that we can attempt to find empirically in models belonging to different disciplinary areas, and that Stuart Kauffman, in his latest book Investigations (2000), calls "the candidate laws for explaining processes of co-construction".
Based on this consideration Eldredge, whose contribution to the redefinition of the Darwinian theory in a pluralist, anti-reductionist interpretation has been fundamental in recent years through the formulation of the Punctuated Equilibria Theory in 1972 (elaborated with Stephen J. Gould) and the hierarchic Theory of Evolutionary Units in the early eighties, proposes in his latest work, The Pattern of Evolution (1999), a broad, ambitious view of evolutionary processes, a vision that fruitfully bridges the gap between the study of the inanimate world and the study of the living world.
We feel an important contribution in that sense could come from a radical theory of emergence in developmental processes: a theory that, in light of what has been said up to now, should determine to go to the roots of the co-evolutionary dimension of biological and cognitive processes, fully assuming the ambiguity of the concept of fitness. To do so, we feel two complementary research directions must be integrated: the study of the ontogenetic origins of co-evolutionary dynamics and the study of the phylogenetic origins of co-evolutionary dynamics. That is the only way we can grasp the profound criticity

of the notion of fitness, hitherto barely touched on by our examination of emergence theories.

Ontogenetic origins of embodiment: we are "cascades of contingency"

The notion of studying intelligence instead of from an abstract, a priori model of intelligence, but from the observation of how intelligent life produces itself starting from the bottom, is what has inspired the most promising investigations of the past few years. We need only think of the "Artificial Life" project elaborated in recent years by Chris Langton at the Santa Fe Institute in New Mexico, or Thomas Ray's "Tierra" project, the simulation of a whole ecosystem. This alternative notion of a "reticular" intelligence, emerging from the bottom and that then retroacts on its lower levels, has already had highly relevant applications, like in the case of the construction project of self-organized mobile micro-robots (Mobot) conceived and carried out by Rodney Brooks at the MIT Artificial Intelligence Laboratory in Boston. Tiny robots interact like in a society of artificial insects, making complex, adaptive behaviors emerge from a few rules of aggregation and interaction. The Mobots' self-organized control is both internal (because each behavior, for instance walking, emerges from the interaction of a series of small independent motors, located in various parts of the "body" of the small robot-insect) and external (because each robot interacts with the others following simple connection patterns and creating coherent, purposeful collective behaviors).
Also in the case of this "embodied robotics" there is a methodological reversal: instead of making biological systems become more and more artificial (imposing on them inadequate analogies like the computer-brain one), artificial systems are made to become more and more biological so as to understand the rules of how they work. The result is that pretty soon we grow aware of the dual nature of opening and closing of intelligence, the dual internal-external origin of developmental processes: if it is true that a coherent behavior emerges from the interdependence of internal components of the system, it is out of the close structural coupling between the system and its context that such a dynamic evolves. For a robot to really become autonomous, Brooks suggests in Cambrian Intelligence (1999), it has to be "embodied" in a material, sensitive, bodily context. The loop of senso-motor co-determinations that produces intelligence has to be triggered.
This way we are not trying to merely imitate intelligence on a silicon substratum, from its abstract model (the computer-mind, in turn the result of the deep metaphors this silicon substratum induced), but we try to make evolve something that one day we might call "intelligence", aware however that it will be very different from the type of intelligence we are used to knowing in human beings. The material, contextual, and therefore mainly historical conditions are what determine the form, the style, the quality of our intelligence. So how can we artificially simulate the result of a natural evolution? As remarks, rather angrily, the imaginary Wittgenstein of John Casti's delightful The Cambridge Quintet, how could a machine ever equal a form of life immersed in language? Could we perhaps accelerate, condense and simulate a silicon evolutionary history? Maybe we could, but as long as we admit the result will not be a perfect copy of our intelligence, it will be another history: an artificial intelligence will be an alien intelligence.
Then what are the origins of order and complexity in living systems and in cognitive systems, and how many of them are there? They are of at least three kinds:

a) an "internal" origin deriving from the mechanisms of reticular emergence and self-organization of complex systems;
b) an "external" origin on a first level deriving from the action of natural selection and other adaptive processes, of a non-selective type, that we shall see later on;
c) an "external" origin on a second level deriving from the dynamics of structural coupling and co-evolution between systems belonging to different levels of complexity (such as, for instance, organisms immersed in ecosystems, intelligences immersed in learning contexts).

This multiple origin of order in living and cognitive systems corrects, in a way, some "internalist" excesses of the morphogenetic and structuralist trend of late twentieth-century biology, moreover very well represented in works by Stuart Kauffman and Brian Goodwin. Lately an important contribution in this direction came from the reflections of the epistemologist and psychologist Susan Oyama, who recently revised and reissued her work of 1985 on developmental processes, The Ontogeny of Information (Oyama, 2000a), along with a worthwhile series of essays of evolutionary epistemology, titled Evolution's Eye (Oyama 2000b).

The main objective of Oyama's controversy is the persistence of dualistic interpretations in the study of developmental processes: according to her, distinctions between biological realm and cultural realm (like between mind and nature) are based on questionable assumptions about the mechanisms that produce change in evolving systems. She has a view of intertwining and multiplicity, a view that identifies identity with the intersection and mixing of heterogeneous influences. Even the subtler distinction between an internal origin of a genetic kind and an external origin of an environmental kind reveals, in Oyama's opinion, a lingering debt to dualism. Her radical view of development even bars speaking of separate entities that "interact" in developmental processes, since interaction thus understood presupposes a previous distinction and independence of the entities concerned.

So breaking free of dualisms cannot accomodate the supremacy of one of the two poles: a system is always coupled with other systems and identifies with this irreductible interdependence. So each system is a natural-cultural, genetic-environmental "developmental system": "a heterogeneous and causally complex mix of interacting entities and influences that produces the life cycle of an organism" (Oyama, 2000b, p. 1).

Today this integrated approach to development as an "interactive emergence" is backed up by a coherent theory called Developmental Systems Theory and can be structured around a few epistemological and methodological principles:

a) giving equal importance to the different sources of transformation in developmental systems (internal and external), avoiding assigning a "causal priority" to the genetic derivation of biological features;
b) conceiving the radical interdependence, both evolutionary and developmental, between organisms and environments: their bond is not "interactive" (as between entities, nonetheless autonomous, that enter in a relationship), but "constructive", since organisms and environments take turns co-determining and co-defining each other; the geneticist Richard Lewontin recently suggested, for this phenomenon of constructive and evolutionary interdependence between hereditary characteristics and characteristics deriving from the co-evolution between populations and their environmental niches, the term "interpenetration" (Lewontin, 2000);
c) shifting attention from a view based on "genes and environment" toward a view focused on a multiplicity of entities, influences, processes and environments; "evolution's eye" extends vision and sees multiple systems interconnected by heterogeneous processes, not a universal law of natural selection on genetic raw material; for an interactionist the two typologies of causality (internal and external) are alternative, whereas for a constructivist they are complementary;
d) shifting attention from systems reductible to a fundamental level toward multiple-scale systems, multilevel coupled systems; interactive emergence produces in fact a large range of interconnected, retroactive levels;
e) shifting attention from centralized control toward interactive and distributed regulation: before the process there are no motors, but a context of complex ecological relationships from which they emerge;
f) shifting attention from transmission of information toward continuous reciprocal construction and transformation; key words like "heredity" (or "learning") allude more and more to coupled systems in evolution, systems of interagents and resources that make and unmake subjects and contexts all along the entire life span (Oyama, 2000b, pp. 2-7).

The causal relationship between ontogenesis and information is reversed. We no longer have genetic information programming and determining ontogenesis, according to the reductionist notion of presumed passive transmission of genes from one generation to the next. It is individual ontogenesis that gives pertinence to what we call "information". In today's sociobiological furor, Oyama observes, lingers an essentialist, pre-formist conception of information, that would pre-exist to its use and its expression, nearly as though it were a principle giving form to matter. The systematic and structuralist alternative, even though it is very efficient in grasping the contradictions of this essentialist attitude, is not however sufficient in itself. Actually we have to keep an eye on solutions that still privilege endogenous factors (that is, only processes of self-organization and emergence of order out of chaos) with respect to the intrinsic co-evolution between endogenous and exogenous. The discriminating element is the contingent character of developmental processes, either biological or cognitive. This is how Richard Lewontin sums up the evolution of Susan Oyama's thinking:

"In the first edition of The Ontogeny of Information Oyama characterized her construal of the causal relation between genes and environment as interactionist. That is, each unique combination of genes and environment produces a unique and a priori unpredictable outcome of development. The usual interactionist view is that there are separable genes and environmental causes, but the effects of these causes acting in combination are unique to the particular combination. But this claim of the ontologically independent status of the causes as causes, aside from their interaction in the effects produced, contradicts Oyama's central analysis of the ontogeny of information. There are no "gene actions"outside environments, and no "environmental actions" can occur in the absence of genes. The very status of environment as a contributing cause to the nature of an organism depends on the existence of a developing organism" (Lewontin, in Oyama, 2000a, p. xiv)

The radical inseparability of the two sources of development comes precisely from the co-evolution of genetic causes and environmental causes that characterizes ontogeny. Development is the primary datum, and only in their simultaneous action do the various informations (genetic, environmental…) acquire a conceptually separate existence:

"Without organisms there may be a physical world, but there are no environments. In like manner no organisms exist in the abstract without environments, although there may be naked Dna molecules lying in the dust. Organisms are the nexus of external circumstances and Dna molecules that make these physical circumstances into causes of development in the first place. They become causes only at their nexus, and they cannot exist as causes except in their simultaneous action. That is the essence of Oyama's claim that information comes into existence only in the process of ontogeny. It is this claim about causes that Oyama, in this new edition, calls 'constructivistic interactionism', but that I would characterize as dialectical in order to emphasize its radical departure from conventional notions of interaction" (Oyama 2000a, p. xv)

The epistemological split between the developmental systems theory (DST) and the classic view is, according to us, radical for two reasons: because it introduces in the definition of the developmental identity of each subject an element of strong evolutionary contingency; and by derivation, because it characterizes each developmental process by its irreductible unicity.
In an interesting epistemological essay dedicated to Stephen J. Gould's work, Susan Oyama points out that contingency characterizes both evolutionary processes in general (phylogenetic contingency) and developmental processes of each organism (ontogenetic contingency):

"I argue for a notion of development in which contingency is central and constitutive, not merely secondary alteration of more fundamental 'preprogrammed' forms" (Oyama, 2000b, p. 116)

Ontogenetic development, that might somehow seem "predictable", being the repetition of the morphogenesis of living beings belonging to the same species, is indeed characterized by a strong contingency due to the constructive play between internal constraints and external possibilities. Internal constraints are not given once and for all, but co-evolve with the environmental opportunities: the generating of new constraints opens new possibilities, that in turn generate new constraints. Disagreeing with Stuart Kauffman's "internalist" approach to complexity, Oyama points out that we cannot speak of a "necessary", "predictable" or ineluctible emergence either of life in general or of an individual organism:

"In a developmental system, interactants and processes change over ontogenetic and phylogenetic time. Some are more reliable than others: the term system should not be taken as a guarantor of absolutely faithful replication, but rather as a marker of a complex, interacting network that may arrange its own relatively accurate repetition. System implies some degree of self-organization, in which 'self' is not some privileged constituent or prime mover, but rather an entity-and-its-world, which world is extended and

heterogeneous, with indeterminate and shifting boundaries. Evolution, then, is change in these systems" (Oyama, 2000b, p. 119)

This would mean that in equal conditions (genetic and environmental), the codification process of the phenotype and the fitness process will also lead to very heterogeneous, substantially unpredictable evolutionary paths: indeed acting upon them are manifold random factors and disturbances intervening on the molecular level, as hypothetized by the "background noise" theory that Lewontin developed in recent years, capable of deviating development in different courses. Development in fact is not an elaboration of information, more or less combined, but an evolutionary drift that gives meaning to information.
Evolutionary epistemology itself gives rise to the image of a functionally unique and complex cerebral organ, in which heterogeneous evolutionary modules, maps and rhythms follow one another: this system, too, is integrated, malleable and redundant; a system that does not receive instructions to be elaborated, but anticipates experience and selects among many possible alternatives, a system that in building its own contingent course unceasingly reconstructs itself (Edelman, Tononi, 2000; Lewontin, 2000).
So the second radical consequence of the developmental systems theory is that the constructive play between internal factors and external factors, in turn disturbed by random influences, gives rise to contingent and irremediably unique identities. We are "repeated cascades of contingencies":

"The notion of repeated cascades of contingency, some more tightly constrained than others, has been central to work on developmental systems. Developmental influences interact over the life cycle to produce, maintain and alter the organism and its changing worlds" (Oyama, 2000b, p. 118)

So we have seen that behind the structural coupling, each time unique, of systems and eco-systems (in a broad sense), we have the arranging of loops of retroaction so close-set and sensitive to disturbances that it is nearly impossible to separate internal from external. We no longer have an inside and an outside interacting: we have a world of meaning, each time unique and temporary, that emerges from the structural coupling.
So we clearly see that a second dimension is lacking, indispensable to our discussion, that unfortunately has not been examined lately with the same attention. As is written in Piaget's works that inspired the entire genetic epistemology program, the senso-motor embodiment that produces intelligence is an evolutionary process to be understood in a dual perspective: it is an ontogenetic embodiment, because it is repeated at each birth in the child's individual development; it is a phylogenetic embodiment, because there will have been a time, in the evolution of the Homo sapiens species, when it appeared spontaneously, opening up to our ancestors the new gifts of speech, of myth, of art.
How did this historical-evolutionary embodiment come about? When and how did this great "leap forward", this formidable emergent feature, happen? Was it a slow, gradual process? Was it a slow functional process backed by the growing adaptive advantages of intelligence? And above all, can we imagine in the study of phylogenesis (that is, the development of our species) a process of "constuctivist interaction" analogous to the one found in ontogenesis?
While integrating this second evolutionistic point of view we will run into the central concept of fitness. Our hypothesis is that the questioning of the neo-Darwinian and cognitivist conception of fitness, within the radical and post-interactionist perspective suggested by the developmental systems theory (DST), may open up a new research direction useful for the comprehension of the complexity of developmental processes in the cognitive and evolutionary ambit.

Phylogenetic origins of embodiment: cognitive sciences put to the test of evolution

Only in the last few years, thanks to improved paleontological investigative tools and to the hybridization of experimental enquiries belonging to different disciplinary fields (for instance, between neuropathology and evolutionary biology), we have begun to get some interesting data on the natural evolution of intelligence, speech and consciousness. Certainly this research program, that we might call "natural history of the mind and of consciousness", holds in store a number of surprises for the coming years.
A highly interesting contribution was made in the nineties by the English cognitive scientist Nicholas

Humphrey, now teaching at the New School of Social Research of New York, who published in 1992 an essay, A History of the Mind: Evolution and the Birth of Consciousness, where he outlined an ambitious evolutionary reconstruction of the birth of sensorial consciousness. Humphreys' approach is entirely evolutionary, yet definitely unusual compared to conventional research on superior consciousness. Leafing through the first pages you can but be struck by the literally revolutionary impact of an evolutionary perspective (that is, wanting to really consider the natural transformations that could have led to the birth of consciousness) compared to the cognitivist approach and more widely to the traditional dichotomies of philosophies of the mind (mind-body; mental image-objective reality; etc.).
It is in this sense that we put the word "radical" next to the "theory of emergence", to highlight the importance of an evolutionistic and "naturalistic", non reductionist approach that goes to the roots of dualisms, defusing them. In other words, the evolutionistic move is a radical break with any foundationist and essentialist attempt to conceive consciousness:

"The plot of this book will be a kind of history of mental life. By 'history' I mean an evolutionary history, and evolutionary on a large scale: from the creation of the world to the appearing of man on Earth. I chose such a long time span for two reasons: to avoid preliminary axioms on the temporal origin of the mind and consciousness, and to avoid preliminary axioms on the objective reality of the physical world… By considering a longer period of time we are able to draw near a zero degree, when these phenomena were not yet phenomena. To discover, perhaps, that neither of the two is a 'given fact' but both are historical results: that subjective experience on the one hand and the material world on the other, I mean, come from the same source" (Humphrey 1992, p. 30)

The possibility the author refers to is that of conceiving a natural and non-dualistic view of cognition (seen as a biological activity within a physical system) yet that avoids the forcings introduced either by physicalist reductionism or by the cognitivist paradigm: the space for this solution is offered by evolution. We are back to the methodological reversal we started from: we are not wondering as an a priori if conscious experience is "nothing but…" a series of flows of data to elaborate, nor if it is "nothing but…" a series of electrical discharges on a neuronal level; we are pragmatically wondering what does the mind do every day, how does it evolve in the single individual, and how did it evolve in the course of natural history.
So we will realize that the natural evolution of intelligence must somehow be rooted in the primary process of contact between internal and external world, that is, in sensorial experience and reactivity, also produced (long before consciousness) by natural evolution: it all starts on the surface…

"… I feel the urge to demonstrate that the animal is a self-integrated, self-individuated 'whole'. And that, unlike other finished bodies (a raindrop, a pebble or the moon), it arranged on its own to constantly redesign its own limits, on a line that separated the 'I' from the 'non-I' and where it gambled everything: its life, its form and its substance"(ibid., p. 33).

In particular, for Humphrey, affective and sensorial processes are a cognitive channel parallel to that of objective perception, and not antecedent to it: sensation concerns events that are happening on the surface of our body (it is self-centric); perception concerns events that are happening in the external world (it is allocentric). In the case of sight, for instance, the first rudimentary visual organs must have had a function of "visual sensation" (that is, epidermically "feeling" the intensity of light and heat), and only later were reutilized for a perceptive function (that is, to identify classes of objects, colors, forms, distances in the outer world). However, the primary function did not disappear (the experience of color, for instance, still has a strong feeling of corporeal sensation) and the two cognitive channels remained active at the same time, as we see in many cases of de-coupling between sensation and perception observed in experiments on human beings and apes (blind sight, cutaneous sight, visual agnosia, etc.).
According to Humphrey, evolution would have selected a systematic control strategy for the reliability of the perceptive image: for each perception the brain would reconstruct the corresponding sensorial stimulus and send it to the sensorial center to verify its congruency with the real stimulus. If the reconstruction does not match the effective sensation it is eliminated as a perceptive "mistake". Imagination and dreams would arise from the perceptive channel (in the absence of any real sensation) and would nonetheless produce the

reconstruction of a matching sensorial stimulus in the sensorial centers of the brain. So imagination and dreams, if considered from the internal point of view of the brain, would to all effects be as “real” as sensations coming from an outer stimulus. Even conscious thoughts, ideas and beliefs would have a sensorial reference (of the auditive kind): intuitively, they would be like “images of voices” inside the head. It is easy to infer the conclusion:

“Being conscious essentially means having sensations: having mental representations, affectively charged, of what is happening to me here and now. The subject of consciousness, the “I”, is a corporeal Self. Lacking physical sensations the I would cease to exist. Sentio, ergo sum: I feel, so I am. Each sensation is located on the spatial boundary between I and non-I, and on the temporal boundary between past and future”(ibid., p. 138).

There is truly nothing deductive left in this conception of consciousness: being aware of “what it feels like to be me”, if meant as an emergent feature of evolutionary dynamics, is a problem of sensations and structural coupling of internal and external. The “natural history of consciousness” is no longer a history connected with the traditional “superior” mental functions, like perception, imagination, belief.
But if someone were to object that sensibility is usually held to be the least significant feature of intelligence, as mere passive recording of outer stimulations, Humphrey would retort with a particularly disconcerting theoretic move, on which he bases his specific evolutionary hypothesis about the birth of consciousness. He turns the classic theory of sensations upside down:

“If my finger ‘actively’ hurts, and if the finger is part of me, it might be legitimate to suppose that, on a certain level, I myself am actively involved in that hurting. Maybe it is not just a sensation I am passively receiving, maybe I am actively creating it, I am even sending messages to produce it: as though feeling a sensation were somehow comparable to an intentional activity” (ibid., p. 172).

In this evolutionary enquiry we can discover a further radicalization of Varela’s idea on the identity between perception and action. Not just perceptions, but sensations, too, traditionally viewed as the source of exogenous information par excellence, are “ways of doing”:

“The difference between my theory and that of my predecessors is that, for me, having sensations is just like performing an action: ‘feeling’ is a way of ‘doing’. Thus, even if there were no limits to how much of the world we can learn from the outside nor to how much is objectively knowable, we should not really be surprised that there are limits to how much we can do and therefore to how much we can subjectively feel” (ibid., p.281).

If sensations are not just a recording of stimuli but also a particular form of “nearly corporeal” activity, subjective and localized, introspective consciousness might have evolved like a closing of the active-passive loop primed by sensorial experience. In a living being without a central nervous system like the amoeba, sensation begins and ends on the outer membrane, like in a very short loop. In an animal equipped with a central nervous system, sensation occurs in the shape of an elongated loop of afference (from the periphery to the brain) and of efference (from the brain to the periphery), where by efference we do not mean response to the stimulus but the nearly instantaneous activation of the stimulus itself: sensations, following the old evolutionary path of the amoeba, return to the point of the stimulation. The brain does not just passively listen to the music of sensations, but conducts them like an orchestra conductor.
In the Homo sapiens species there would then be a third evolutionary level, coinciding with the first spark of introspective consciousness: sensorial efference, this nearly corporeal activity modulating sensations, instead of returning to the concerned peripheral area of the body, would gradually have returned inside the brain itself. The active/passive sensorial loop would then have closed upon itself: afference carries the stimulus to the brain and efference falls back inside the brain, positioning itself on a sort of mental map of the body.
So sensation is produced by a sensorial afference (incoming) and by a simultaneous sensorial efference (outgoing activation): the specificity of the sensorial apparatus of a conscious being is that this outgoing efference does not go and activate a part of the body but the corresponding part in the “inner model of the

body” present in the sensorial cortex of every human being (precisely, in the terminal points of the afferent sensorial nerves from the various parts of the body). Here is where the evolutionary root of the embodiment of knowledge might lie, in this deep intuition of psycho-physical unity, furthermore already fostered in many meditative and medical practices of non-Western origin: between the areas of the brain that contain sensorial nerves and matching parts of the body there would be a close connection, an active-passive continuity. In this uninterrupted psychosomatic network, a ghost sensation, acting on the inner corporeal model, and a real sensation are to all effects undistinguishable.

So sensations are not events that happen to us and that we helplessly assimilate, sensations are also cognitive activities in which we personally take part, “activities that fall back circularly upon themselves until they create the depth of the subjective instant” (ibid., p. 283). So this would be the evolutionary discontinuity that would give rise to conscious experience, that is, the closing of a sensorial feedback loop.

This falling back inside, that Humphrey suggestively calls “sensorial reverberation”, would then produce the sensation of being a body and the sensation of being a permanent subjective identity. The evolution of consciousness would be, so to say, a reorganization of the sensorial system, in which the sensations’ return reverberates inside, like an “inner eye”.

We described at some length Nicholas Humprey’s model not so much to promote his specific hypothesis on the origin of consciousness, that naturally requires further experiments and verifications (moreover extremely delicate, difficult and necessarily interdisciplinary, since it is a historical-evolutionary hypothesis). We especially wanted to point out the methodological particularity of this reasoning, that combines in such an original way: a neurophysiological view of the mind (it describes an utterly biological phenomenon that is not “resigned to the mystery of consciousness”, as Varela shrewdly remarked) (Varela, 1997); a clinical point of view (reflections on the sensorial pathologies of sight are essential); a phenomenological point of view on different states of consciousness, and above all, an evolutionary point of view. The result is a theory of consciousness full of valuable suggestions on the phylogenetic origins of “embodied” knowledge, a theory at last aware that by themselves psychology and logic are not enough to explain the complexity of our form of intelligence: “there is nothing in the world that is only, absolutely and definitively, what we have decided it is” (Varela 1997, p. 285).

Yet one question is still open: when did consciousness begin? And more precisely, was the emerging of consciousness a gradual or a sudden event? The response to this enigma, and this will be the last part of our discussion, will require raising the great question of biological fitness.

Humphrey’s option is very clear:

“Regardless of the moment and the place where it happened, the evolution of consciousness was not a gradual process. Some philosophers, refusing to acknowledge great discontinuities in nature, suggested that consciousness had emerged slowly and by degrees, from ‘less’ conscious animals to other ‘more’ conscious ones and so on. Our theory categorically excludes this. Actually, consciousness could not have arisen unless and until the activity of the retroaction loops had reached the level of reverberating activity, and a property of feedback loops is ‘all or nothing’: either reverberating activity is supported by a significant life span or it dies at birth. So we can argue that in the course of evolution, with the shortening of the sensorial loops and the heightening of their degree of faithfulness, a threshold was reached beyond which consciousness appeared out of the blue, just like there is a threshold beyond which we go from sleeping to being awake” (Humphrey 1992, p. 268).

Actually Humphrey’s model does not bar gradualism: it is a model we might define by “latency and trigger”. After a very long phase of latent physical and anatomical transformations, a threshold is reached beyond which a sudden reorganization process, an evolutionary leap, is triggered.

The surprising fact is that such a model is getting important confirmations in the field of paleoanthropology. The rise of indications typical of a symbolic and conscious intelligence seems to come about quickly in the evolutionary history of our species, in the period we call Upper Paleolithic (around 45,000-40,000 years ago), at the end of an extremely long brain expansion process begun nearly two million years before. As remarked the paleoanthropologist Ian Tattersall, whose contribution to the redefinition of the “bush” of human evolution and to the consequent challenge to the progressionist monophyletic model has been

determining in recent years, the intelligence able to produce works of art and ritual burials seems to arise all of a sudden, after a long series of anatomical transformations that had not had relevant consequences in cognitive terms. It is as if at some point intelligence "took off", as if it had suddenly acquired the required lift to rise after a long stay on the ground.
In the ramified bush of hominid forms, certainly bearers of multiple "forms of intelligence" unknown to us, a new model appears, a new way of being human. Tattersall writes in the last chapter of Becoming Human:

"What has been concisely called 'human ability' did not derive by mere extrapolation from the oldest tendencies of our evolutionary line that paleoanthropological studies have the task of elucidating. It is something more like an 'emergent feature', whereby a new combination of characteristics randomly produces an entirely unforeseen result. It is certainly the emergent nature of our control organ and of the abilities derived from it that urges man today to reflect on himself" (Tattersall, 1998, It. tr. p. 170).

But how can we explain discontinuity in the emergence of consciousness? How can we explain the "take-off" that interrupts a long period of slow, gradual growth of the brain anatomy? Tattersall suggests an interpretation, that we feel completes and very profitably integrates Humphrey's hypothesis:

"Consciousness is a product of our brain, which in turn is a product of evolution. But the features of the human brain are emergent, are the result of a series of random acquisitions (naturally based on the exceptional result of a long evolutionary history) that may have been encouraged by natural selection only after the brain was formed" (Humphrey 1992, p. 171).

In that "only after" lies the heart of an evolutionary, non adaptationist perspective that might be favorably introduced in emergentist theories, creating a "radical" model of emergence in developmental processes. Natural selection, in most cases (and certainly in the most interesting cases), intervenes after the arising of the "form", assigning to it a function, and not before. The human brain would not have evolved because indispensable for some specific biological function (that Humphrey does not clearly identify either, except broadly referring to a certain ability of "intersubjective comprehension" useful for an elaborated social behavior), but for a contingent reorganization out of a redundant anatomical structure produced by a long evolutionary history.
Brain expansion since the first Homo genus forms in East and South Africa, probably sprung from a mutation of the regulatory genes of development (an alteration called "neoteny", that is, retention of youthful characters), would not have developed "in view of" its future uses. If it is true that introspective abilities insured a great reproductive advantage granted by natural selection, then why did just one of the descent lines of primates develop them? If it is true that the evolution of consciousness and subjectivity was "built" step by step by natural selection working on the hereditary endowment, gradually amplifying the small behavioral advantages deriving from conscious experience, then why did it take so long for clear indications of the presence of a symbolic, conceptual intelligence to appear?
In the natural history of consciousness we have gradualism (anatomical) and discontinuity (functional): these two evolutionary paths are independent from the functional point of view. The first is a side effect of a genetic mutation, then fixed by natural selection and probably emphasized by competition for resources among hominid species. The second is a sudden evolutionary emergence, a functional reorganization out of the creative reutilization of structures already formed. This "evolutionary bricolage" was christened "exaptation" in 1982, by the paleontologists Stephen J. Gould and Elisabeth Vrba (Gould, Vrba, 1982). By exaptation is meant the cooptation of a biological characteristic, produced originally for some primary function in a certain context or for a side effect without any function whatsoever, for a different evolutionary use in another context. Rather than being machines for genes shaped by natural selection or kinship selection (appealing metaphor at the basis of the recent success of evolutionistic psychology), organisms often display the ability to opportunistically reorganize their own inner structural constraints and transcend themselves by transforming what they have at their disposal. The natural history of the mind may be a story of fully successful exaptations, a story of possibilities arisen rapidly instead of necessary adaptations:

“The evolution of the brain did not proceed by simply adding some new connection here and there, until it became, after eons, a great perfectly oiled machine. Opportunistic evolution enrolled, in a highly disorderly manner, old parts of the brain to perform new functions, and new structures were added, while some of the old ones were enlarged rather at random” (Gould, Vrba, 1982, p. 174).

So evolutionary bricolage, natural selection, bushy speciation and evolutionary contingency contribute, in a pluralist, anti-reductionist perspective, to the natural history of the intelligence of our species:

“Starting from a forerunner who possessed the range of necessary exaptations, modern man’s brain appeared within an old local population and through changes we still do not understand. Then natural selection was at work in that population making the variant become the norm. Later speciation intervened, establishing the historical identity of the new entity. Last, the new species won the competition with its other kin, in a process that – maybe for the first time soon after the appearing of the ancestral hominid – ended up by leaving just one hominid species: Homo sapiens. If we look at it this way, full human consciousness is just one of the results of that routine, random process of appearing and assertion of innovations that we find in the evolution of every line” (Gould, Vrba, 1982, p. 174).

The evolution of the ability for introspection, symbolic abstraction and comprehension of others’ minds must have given our species an extraordinary reproductive advantage, but this seems to be an effect rather than the cause of the process. As Niles Eldredge aptly pointed out, evolution is a complex network of relations structured on several hierarchic levels (from the macroevolutionary level of species to the microevolutionary level of genes) and transformations only come about in part for reproductive finalities (adapting to transmit selfish genes from one generation to the next): far more often the strategies of living beings are dictated by economic finalities, by requirements of locating resources, by colonizations of new habitats, by reactions to climatic changes, by competition between entire species.
Today many scientists, among whom mainly Ian Tattersall and Jeffrey Lieberman (Lieberman, 1991; Falk, 1992), are working on the hypothesis that the key primer of symbolic intelligence is somehow connected with the arising of articulate speech, in turn an exaptation connected with the elongated throat morphology (moreover lacking in the parallel branch of Neanderthalians). So the “great leap forward” of anatomically modern man, in the Upper Paleolithic, would be a combined side effect of the throat’s adaptation to dry climates and of the cerebral reorganization required for the acquisition of articulate speech.
Around 40,000 years ago, the brain of the Homo sapiens species was indeed well “exapted” for speech and symbolic reasoning. All that was missing was a stimulus, a primer, probably of a cultural or social kind. So it all happened in an evolutionary “twinkle of an eye”:

“After a couple of million years of uneven brain expansion and of other acquisitions acquired in the human line, there must have been the necessary exaptations to allow the completion of the entire building by a mutation that in genetic terms was presumably on a smaller level. Just like the keystone of an arch is only a small part of the whole structure, but is vital for its integrity, a relatively small change in the neural structure must have had this remarkable emergent effect in our brain. And this neural innovation must have been acquired within a narrow population, our progenitor, when all the peripheral essential structures – the vocal apparatus, for instance – were already available to allow its expression” (ibid., p. 206).

The high frequency of exaptation phenomena profoundly alters the notion of a “project” or “program” inscribed in nature. Evolution becomes the realm of the possible. The structures of intelligence, in this sense, would be the result of a singular evolutionary drifting, the outcome of a series of contingent, irreversible events, a late, unforeseen emergence triggered by a small change. Repeating the same evolutionary process, we would obtain two very different “forms of intelligence” (that is, two forms of life).

An ontology of possibilities: Francisco Varela’s legacy

So even the phenomenon of consciousness can and must be studied from a biological point of view, but not a reductionist one, giving up the inherent instructionist and computational idea of cognitivism and

representationism, the idea the “out there” there is a world waiting to be reliably reproduced in mental data. To succeed, rather than “theories” of the mind, we need “histories” of the mind like Tattersall’s and Humphrey’s: “the partial history of a partial aspect of the human mind, the history of how, over the last four thousand million years, the minds of animals entirely transformed the conditions of the universe in which we live” (Humphrey 1992 p. 297).
In one of his last interviews, Francisco Varela mentioned there are two levels of study that should be envisaged separately since they are irreductible:

“Yes, consciousness can be studied. It all depends on asking the question on the right level. And the right level is above all the emergent side (le côté émergent) of experience, and only later the reflexive abilities that accompany the preparation of this phenomenal data. So there are two mixed-up levels that have to be studied separately” (Varela, 1998, p. 112).

So we might think the emergence of this “superior” level from the côté of experience had been the result of an evolutionary progress dictated by adaptive necessities and fixed by natural selection for its immediate advantages. Varela’s reply, distinguishing the “dynamic” meaning of emergence from its “evolutionary” meaning, is very interesting because it presumes (as we have tried to show by the double evolutionary ontogenetic and phylogenetic track) that there are two superimposed levels of uniqueness and of production of evolutionary diversity in our subjects/organizations, that is, the level of the emergence of cognitive abilities in each individual and the level of modalities of experience in the different biological species (where there is not necessarily emergence of the reflexive level).
As we saw in discussing the hypothesis of the synchronization of cortical areas, on the level of the biological evolution of our species’ brain and its development in each individual, the intertwining of environmental and genetic influences is so subtle and intricate, interactions between the hierarchic levels of the genoma are so complex, and random interferences in the “building” process are so frequent that they make the genesis of a brain system a process each time unique, unrepeatable, irreversible.
On a second level, that of the normal workings of the mind, the emergence of consciousness might have arisen from configurations of order (authentic momentary alliances) “on the edge of chaos”, that is, from a situation of fluidity between order (the system’s homeostatic coherence, rules of connection, pre-selected neuronal maps…) and chaos (free, simultaneous connections) in which each time a unique process is set up.
Having thus posed the problem of reflexive consciousness as a second-level emergent feature, a double “filter” of evolutionary contingency rids us of the notion of a fitness advantage as the motor of a gradual evolution of reflexive faculties:

“I mistrust the adaptionist idea whereby the emergence of reflexive knowledge brought an evolutionary advantage, because it assumes that there is a parameter of optimality. What is the improvement for which it would have been selected? Lines of heredity are not guided by adaptations. There are such complex interdependences that we cannot speak of a fitness peak” (Varela 1998).

In that sense there is no single master way, but always many different solutions for similar problems of survival. So the evolutionary course does not look like a march to approach the optimum, urged by convergent selective pressures acting on fundamental discrete units (whether they be “genes” or “memes”). Instead it looks like a singular course within a context of divergent selective pressures and agents on different scales, like a small drifting vessel that, although tossed about and carried by currents, follows its own new route and finally (precisely because it did not follow its pre-ordained schedule) explores new territories.
The key indication of a complementarity between the realm of regularity, that is, of repeated constraints and mechanisms of emergence through which evolution ceaselessly overcomes itself, and the realm of history, that is, of the irreductible, contingent event that can irreversibly alter the evolutionary course, can be a frontier of research on complexity for the coming years. To reach these objectives, the philosophy of biology and the cognitive sciences must increasingly encourage the encounter between a constructivist view of ontogenesis and a constructivist view of phylogenesis (Sterelny, Griffith, 1999).

In the final words of the interview to Varela mentioned earlier, the French interviewer's curiosity grew insistent and at last the question went to the philosophic, spiritual heart behind the scientist's thought: well then, if there was no immediate evolutionary advantage, why did introspective intelligence emerge? Why the emergence of discontinuity in evolution? Why has life, in its endless crucial bifurcations, each time gone beyond itself toward new configurations, unpredictable and often highly improbable?

"Because, among all these possibilities, there was the possibility to emerge. It is an effect of the situation. It could just as well have happened as not. There is a very aleatory dimension in the world, connected with the notion of 'gentle evolution' or 'drifting' mentioned earlier. It is as though the ontology of the world were very feminine, an ontology of permissivity, an ontology of possibility. As long as it is possible, it is possible. I do not need to seek a justification in an ideal optimality. In the midst of it all, life attempts the possible, life is a bricolage" (Varela, 1998, p. 112).

That is Francisco Varela's reply, and we hope that the tide of his thought, casting subtle bridges into this "feminine" ontology of the world, will continue to spread and sow creative storms in our minds.

Translated from the Italian by Susan Wise

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