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LANDMARKS FOR AN EUSOCIAL METHODOLOGICAL INDIVIDUALISM

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It is a great pleasure to be here at Nankai University and I would like to warmly thank my colleague Francesco Di Iorio, the dean of the College of Philosophy Prof. Xinsheng Wang, and the Director Prof. Jun Hu.

My purpose is to contextualize the question of *complex methodological individualism* (CMI) in social sciences into a broader and more general scientific context including physical, biological and ethological sciences.

I. LEVELS OF REALITY

In many domains, we come across several levels of description, and at least a *micro*-level and a *macro*-level (and often also an intermediary *meso*-level). At the micro-level, there are individual entities endowed with elementary individual rules of behavior and interacting through short range very local interactions. In contrast, at the macro-level we observe global structures which can be adequately described using concepts whose content has nothing to do with micro entities. And one of the main challenge is to understand conceptually, causally, and possibly mathematically, the relations between the two levels. It is a true challenge because any sort of *semantic reductionism* is inapplicable since the concepts used for describing the two levels don't share any content. There is therefore an *antinomy* between the thesis of independence and the antithesis of the non-independence between levels.

The problem is very age-old.[1] It is extremely difficult and transversal to the classical disciplinary fields and in particular to the traditional division between natural sciences and human sciences. Let us begin with two examples from physics where it has been solved.[2]

The first, and most celebrated, example is provided by *thermodynamics*. To describe macroscopically a substance like *water*, one uses concepts such as temperature T, pression P, volume V, which do not refer directly to any atomic or molecular concept (no semantic reductionism).[3] It took a long time [4] to find the equations correlating these thermodynamical variables and to describe accurately such striking phenomena, called *critical* phenomena, as *phase transitions* (water boils at the critical value of 100° Celsius under a pression of 1 bar).[5] But after the molecular structure of water (H_2O) has been discovered in the late XVIII-th century [6], it was natural to ask for a micro-level interpretation of thermodynamical variables in terms of local behavior (vibrations) and interactions (impacts, collisions) between molecules. Already Lavoisier had introduced the hypothesis that heat was due to some molecular agitation. But it has been the genius of Ludwig Boltzmann (1871) and Willard Gibbs (1902) to achieve this revolutionary reinterpretation of thermodynamics in terms of statistical physics. The interpretation of T as the mean kinetic energy of molecules is one of the major achievements in the history of science. The micro-dynamics is incredibly complex, but some simple macro "mean field" "order parameters" *emerge*.

Another example, more recent, is provided by the geometry and the morphological dynamics of sand dunes and sandpiles. Here, the micro elementary entities are grains of sand locally interacting by rolling against each other. The micro dynamics is very complicated and the physics of dry cohesionless granular materials is a very active discipline. The macro geometric shape *emerges* from a *fractal*

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[1] It dates back to Antiquity.

[2] In true sciences, problems can be solved...

[3] T and P are intensive magnitudes, while V is an extensive magnitude.

[4] and a lot of deep experimental innovations!

[5] At the molecular level, a liquid $\rightarrow$ gaz phase transition is an incredibly dramatic revolution: all the links giving to the liquid its cohesiveness are suddenly broken and the collective state becomes a dispersed state of "atomic" independent units.

[6] Remember the chemical revolution subject to the celebrated controversy on Oxygen and the atomic composition of water between Joseph Priestley and Antoine Laurent de Lavoisier (1779).

entanglement of myriads of micro *avalanches* of different scales, and geometric macro parameters such as the slope of the dune or pile (called the "angle of repose") can be explicitly computed using non-linear equations. It is an example of a *complex spontaneous order*. The remarkable fact is that this geometric slope is a *critical* value and the complex multiscale system of sand grains has the extraordinary property of *stabilizing* on its critical state, while criticality seems to be the opposite of stability. This phenomenon called "self-organized criticality" was discovered in 1987 by Per Bak, Kurt Wiesenfeld and the Chinese physicist Chao Tang. Once again, there is no semantic reductionism: the geometrical concepts used to adequately describe the morphology of dunes have nothing to do with fractal micro-avalanches of rolling sand grains.

These two purely physical examples share some epistemological features:

(1) The two micro / macro levels are phenomenologically heterogeneous and conceptually [7] autonomous. Their relation is a relation of emergence.

(2) But they are not *causally* autonomous. The macro-level "supervenes" on the micro-level. Moreover, causality operates bottom-up from the micro to the macro level. There is no top-down reverse causality. The slope of the sandpile does not act on the physics of the sand grains. It is no longer the case in life sciences or social sciences where top-down causalities become essential.

(3) The heterogeneity of the two levels results from the immense number of elementary micro units. The local interactions between these units must be *iterated* (in a sequential or parallel mode) and the iteration of elementary rules can reach any possible complexity (it is a theorem on networks of automata).

(4) The relation of emergence between the two levels results from their *incommensurability*.

(5) An emerging macro structure can be rather simple (a temperature, a slope). But its emerging simplicity encompasses an immeasurable micro complexity.

(6) In physical situations, the system is frequently modelled by a large system of differential equations and the emerging properties are represented by *order parameters* which have often a statistical content (as in "mean field" theories).

(7) The conceptual independence of the emerging structures is *mathematically justified* by proving that the order parameters are *essentially independent* of the fine

[7] Ontologically if you consider that an ontology is a system of constitutive concepts.

grained underlying microphysics. For instance in statistical physics, Kenneth Wilson won the Nobel Prize in 1982 for having proved that critical behaviors in magnetic materials can be classified, via what is called the *renormalization group*, in *universal* classes largely independent of the atomic-molecular structures of the substrates. Without such a *proof* of invariance, emergence would have no scientific content.

Thus, reductionism posits that high level phenomena, structures and processes can be reduced, as far as their scientific explanation is concerned, to underlying lower level phenomena, structures and processes. We have just seen that it is by no means necessarily "eliminativist" and is perfectly compatible with emergence, "supervenience" or "functionalism". Functionalism means that macro structures having a functional role can exist only if they are materially implemented in an underlying material substrate, but are at the same time, as functionally meaningful structures, largely independent of the fine material structure they are implemented in.[8] Beside physical examples, another paradigmatic example is the opposition software/hardware in computer sciences (see philosophers like Hilary Putnam, Jerry Fodor, Zenon Pylyshyn, etc.). Complex systems having different levels of reality whose emergence at different scales can be proved, are countless in nature: critical phenomena, percolation, self-organized criticality, reaction-diffusion systems, far from equilibrium dissipative structures, turbulence, cellular automata, neural networks, ant colonies, swarms, stock markets, etc. The proved emerging levels are not epiphenomenal. But they are not interpretable according to a *holist realism* positing their irreducible reality. They are causally reducible but not semantically reducible.

This key point has been also emphasized by Viktor Vanberg in social sciences concerning the "invisible-hand" explanations we will comment on later[9]: conceptual descriptive adequacy is by no means sufficient to justify any emergence thesis. Emergence must be *proved* using mathematical models, that is a *computational synthesis*. And Vanberg criticized Hayek, because Hayek recognized correctly the "synthetic" and "compositive" character of emergence, but did not insist on the obligation that *synthesis* must be carried out. It is the most difficult challenge.

II. "FROM PHYSICS TO POLITICS"

[8] See e.g. Petitot, 2010.

[9] See Vanberg, 1986.

The scientific study of multiscale self-organized complex systems is a well-established interdisciplinary field which goes far beyond physics. In 1981, Paul Dumouchel and Jean-Pierre Dupuy organized an important Conference entitled "*Self-organization: from Physics to Politics*". So, let us progress towards politics through biology, psychology and ethology.

II.1. Neural functional architectures

A fascinating micro / macro example in life sciences is the relation between neurology and psychology. Activities of billions of elementary micro-neurons locally connected through *specific* systems of connections called "functional architectures" implement a macro-level of emerging psychological states and processes. I worked a lot on that and, if you are interested in some recent results, you can have a look at my book *Elements of Neurogeometry* where I present neuro-mathematical models of Phenomenology of perception (in Husserl's and Merleau-Ponty's sense) and of some well known laws of Gestalt theory.

Results depend today upon revolutionary new techniques of *in vivo* optical imaging. Emergence is proved looking at huge systems of non-linear differential equations expressing how neurons fire and emit spikes when they are (i) activated by external stimuli and (ii) connected through inhibitory and excitatory connections having specific weights and functional architectures. This specificity results from experience and learning and encodes in a radically distributed and non conceptual way the knowledge and the cognitive resources of the system. Such equations, due to Jack Cowan, H.R. Wilson, and David Hopfield, are very similar to those found in statistical physics in spin glasses theories. Their numerical study is necessary to prove emergence by a computational synthesis. It is today the issue of some of major international research programs.[10]

Emerging properties are in particular properties of *synchronization* of pools of neurons. They explain many macro-psychological facts because the *common phase* of a synchronized population can act as a *label* for further processing (what is called "binding" and "labeling hypothesis").

The idea of interpreting mathematically psychological structures in terms of complex neural networks goes back to 1940-1950 with John von Neumann, Norbert

[10] As the billion euros *Human Brain Project* aiming to simulate cortical modules of the visual cortex. It uses a computational power up to a million teraflops (a teraflop is 1000 billions operations per second).

Wiener, Warren McCulloch, Walter Pitts, and the famous Macy Conferences (1942-1953) at the origin of cybernetics, cognitive sciences and information sciences[11]. Since then, incredible progresses have being done, e.g. concerning the explanation of *categorization* or *learning*.

But in fact, as acknowledged by great neuroscientists as Gerald Edelman (Nobel 1972) or Joaquin Fuster, the great precursor was Friedrich von Hayek in *The Sensory Order*, a unique masterpiece analyzed by Bruce Caldwell, Barry Smith, and Francesco Di Iorio[12]. It goes back to the 1920s and was taken up in the 1952 book. This critique of behaviorism is essential in Hayek's intellectual path because it is a key example of a complex spontaneous order: neural cells are connected into complex, organized and specific networks which act as communicational infrastructures for complex fluxes of neural spikes ("impulses" said Hayek) and encode learning and memory. We have to take this micro neural organization as a basis for explaining our macro psychological sensory experiences. The specificity of what are now called "neural functional architectures" introduces a gap between, on the one hand, the sensorial micro transduction of the stimuli by peripheral receptor organs such as the retina, and, on the other hand, the perceived scenes endowed with their Gestalt patterns processed by the central cortical brain areas.

In *The Sensory Order After 25 Years*, Hayek's summary is very akin to the contemporary concept of functional architecture:

> "Mind thus becomes to me a continuous stream of impulses, the significance of each and every contribution of which is determined by the place in the pattern of channels through which they flow within the pattern of all available channels." (p. 291)

These initial reflections played a role of model for the further works of Hayek in economy and, after he had come into contact in the 1950's with the transdisciplinary and polymathematical sciences of complex self-organized systems (Norbert Wiener, Ludwig von Bertalanffy, John von Neumann, Warren Weaver, see above), he wrote his 1952 book.

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[11] See J.-P. Dupuy's book *The Mechanization of Mind*.

[12] They all emphasized the importance of this early contribution of Hayek to the neurophysiology of psychology.

In the Hayek's archives managed by Bruce Caldwell at the Hoover Institution of Stanford, there are interesting letters with James Gibson, the future author of *The Ecological Approach to Visual Perception* (1979), who has been "much impressed" by *The Sensory Order* (24 February 1954) and wanted to invite Hayek at Cornell for a Conference on "Fundamental Problems of Perception". In the correspondence, there are interesting remarks concerning Heinrich Klüver (1897-1979), the great neuropsychologist at Chicago and a privileged interlocutor of Hayek in psychology and neurology. Klüver was a student of Max Wertheimer and introduced Gestalt theory in the US. He arrived at Chicago in 1928 and joined the "Neurology Club" (Karl Lashley, Percival Bailey, A. Earl Walker, Ralph Gerard, Stephen Polyak, Charles Judson Herrick, and Roy Grinker). His works on Vision are now well modelled using Wilson-Cowan equations and tools of Neurogeometry.[13]

II.2. Ethology

Other fundamental examples in life sciences are found in *ethology*. In the last decades, a great deal of research and modelling have been dedicated to the collective behavior of large communities of animals: hordes, flocks of birds, fish banks, insect swarms, etc. Very complex global geometric patterns can result from very simple local rules, as simple as (i) move in the direction of your neighbors, (ii) move to the center of the group, (iii) if another animal is coming too close, move away from it.

But the models go far beyond the modelling of mere collective motions. They progressively led to the key idea of multi-agent collective, distributed, and decentralized intelligence as a new paradigm for complex problem solving, more precisely for solving problems that individual agents are unable to solve. What is now called "swarm intelligence", "distributed artificial intelligence", "ant colony optimization algorithms", etc. The idea is that an algorithm solving a complex problem can be implemented in a distributed way into the collective intelligence of a network of micro elementary agents sharing very *limited* cognitive ressources and interacting through very elementary rules. The collective intelligence is *incommensurable* with the individual intelligences and *emerge* from their *global cooperation*.

Here again, the theoretical idea can be promoted only because many natural or technical examples are available. A long time ago (1974), I wrote with Pierre

[13] See Petitot, 2008.

Rosenstiehl a paper "Automate asocial et systèmes acentrés" explaining how a typical global task as *synchronizing* a network could be *localized* into small automata connected in accordance with the network.

In nature, the most striking examples of collective intelligence are provided by social insects: bee hives, wasp nests, ant nests, termite mounds. This leads us towards politics because social insects are considered since Aristotle as "political animals" (zoôn politikon) because *they cooperate to produce public goods*. It is the key point. In his *Politics*, Aristotle considers that there are essentially two kinds of political species: humans and social insects. A lot of empirical observations and comparisons led him to a behavioral taxonomy. Animals are either solitary (felines, spiders) or social. Social species can live in small groups (primates, wolf packs) or in large groups. In the later case, they can have a gregarious behavior (herds, flocks) or a "political" one. And Aristotle claimed: "man is by nature a political animal", but he is not the only political species. What is true is that man is the only *rational* political species.

What is especially interesting in social insects, and interests me here, is that:

(i) The collective intelligence is incommensurable with the individual intelligence of the agents.

(ii) The "political" performances (i.e. collective production of public goods) result from simple but extremely efficient ethological rules selected by evolution.

(iii) The collectivity constructs global architectures, called "architectures without architects" as honeycombs with miraculous hexagonal tesselations, or immense mounds (they would be extended up to ten kms at human scale) with pillars, external walls, galleries, cellars, channels, ridges, spiral conducts for ventilation and cooling, valves, brood chambers, etc.

II.3. Stigmergy

Highly sophisticated buildings such as termite mounds are essential for the species to survive. They result from elementary spatial moves marked by pheromones. The process was called *stigmergy* in 1959 by Pierre-Paul Grassé. Stigmergy is the key concept of the theories of swarm intelligence. In constructing a mound, initially, each individual termite rolls a mudball, invests it with pheromones and deposits it randomly in some place. But the pheromones are *attractive* and act as *signs* (hence the term of "stigmergy": stigma = sign, ergon = action). So, many mudballs become deposited in the same place. This positive feedback produces high pillars that collapse beyond a

certain height, a catastrophe which triggers the *iterated* building of new pillars, etc. This spontaneous emergence of coherent activity builds gradually, without any centralized planning and control, seemingly intelligent structures.

Their mathematical models are highly non trivial.[14] It must be emphasized that, in contrast with the physical examples, the emerging macro architectures apply here a strong *top-down* "imerging" causality upon the micro individuals.

II.4. Eusociality

This very particular paradigm of sociality "invented" by evolution is called *eusociality* in ethology, a neologism coined in 1966 by Suzanne Batra. Eusociality (from Greek ευ "good" and "social"), is defined (see e.g. Wikipedia) as the highest level of organization of animal sociality and characterized by cooperative brood care, overlapping generations within a colony of adults, and a division of labor into reproductive and non-reproductive groups. The queen and reproductive males monopolize reproduction. Division of labor creates specialized behavioral groups (castes) within the society. Soldiers and workers are sterile and specialized in brood, foraging, defense, maintaining food and resources.

At the evolutionary level, in a strict neo-Darwinian gene-centered view based on the *selfish gene* principle (individuals maximize the fitness of their genes), eusociality seems rather paradoxical. How organisms can increase the transmission of their genes if they become sterile and work for their close relatives? How can we imagine *genetic* bases for cooperation and altruist behavior? The sociobiologist Bill Hamilton explained (1964) that it could be the case if a non-reproductive (sterile) individual share more genes with a close relative that it could do with its offsprings ("inclusive fitness" principle). And it is precisely the case with many species of social insects which are *haplodiploid*: males are haploid (i.e. have a single set of chromosomes from the mother) while females are diploid (i.e. have two sets of chromosomes from the mother and the father). So sisters can share up to 75% of their genomes, that is more than the 50% they can share with their offsprings.[15]

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[14] See, e.g., works by Jean-Louis Denebourg, Guy Theraulaz, Eric Bonabeau, or Bernard Manderick.

[15] For a critique of Hamilton's inclusive fitness, see Nowak, Tarnita, Wilson 2010.

II.5. Cognitive VS Eusocial complexification

The eusocial paradigm is the opposite of the dominant paradigm found in superior species of mammals, that of small "communities" which are like extended family groups. In that later case, the communal links are *accessible* to the experience of the agents. Social organization is "cognitively commensurable" and we can speak of a sort of social reflexivity. For the eusocial paradigm it is not the case. Social organization is not community-based and is cognitively inaccessible.

The key point is that there exists (at least) two evolutionary ways for complexifying intelligence. On the one hand a *"vertical" cognitive complexification* of the individual intelligences, and, on the other hand, a *"horizontal" eusocial complexification* leading to a "swarm intelligence" with two levels micro-macro. Either individual intelligence increases but the social groups remain small communities, and it is the case for evolution leading towards primates and *Homo Sapiens*; or individual intelligence remains very limited but the groups increase drastically and become eusocial, which enables a distributed collective intelligence to emerge.

II.6. Mandeville's Fable of the Bees

The "political" character of social insects and its analogy of structure with modern human open societies has a long history in Occidental thought and was recurring in the modern period. Its best known occurrence is *The Fable of the Bees* of Bernard Mandeville (1670-1733) which, according to Hayek, "asked the right question".[16] His apologue "*The Grumbling Hive: or, Knaves Turn'd Honest*" (1705), later extended and called "*The Fable of the Bees; or, Private Vices, Publick Benefits*" (1714, 1723, 1729) had a major impact.

The thesis is that a hive functions properly only when each individual bee, each with its very limited representational resources, does what it has to do in the framework of division of labor and follows strict innate rules without bothering about collective advantages or disadvantages. They are the *interactions* of the bees according to efficient selected rules, and not "moral" virtues, which produce the collective wealth, benefits and public goods of the hive. Individual bees don't have the cognitive resources enabling them to have and share any representation of the hive. In other words, Mandeville's fable on bees as Aristotelian "political animals" concerns the social value

[16] Mandeville was from a family of liberal progessive physicians of Rotterdam who emigrate in England following conflicts with the Orange Party and Calvinists.

of selfish behavior in complex societies where myriads of individuals cooperate through labor division. Indeed, "private vices" meant at that time the prevalence of self-interest, that is what we now call choice rationality and maximization of utility.

Mandeville made explicit in a provocative way the conflict arising at his time between the new born economical liberalism and the traditional Christian ethics. Since the beginning of the XVII-th century, some philosophers already tried to explain that "enlightened" self-love could be socially positive. This political, and in fact *theological*, thesis can previously be found in Blaise Pascal and Pierre Nicole (1625-1695, a Jansenist of Port-Royal [17]): society should be based upon "enlightened" self-love rather than upon charity.[18]

Mandeville inspired Adam Smith and his concept of "invisible hand" as a mechanism ensuring the "Wealth of Nations". This first formulation of self-organized spontaneous order, operates at the metaphysical, theological and political levels as a "*ruse of reason*". As claimed Pierre Nicole, to make selfish interests cooperate in an unintended way to the benefit of public welfare is "the secret plan of God", "the hidden order of God". "There is no need of virtuous individuals to get a virtuous society". Selfish individuals are able, without knowing it and willing it, to do "an admirable thing": the more the persons aim at their own interests, the more they become interdependent, and the more they compose "a superior reality *able to transcend each bet"*.[19] Thus, God's "ruse of reason" is a "ruse of passion" for men

Later, we find the same kind of "ruse of reason" in Kant (1784, *Idea for a Universal History with a Cosmopolitan Purpose*) to solve the political antinomy of the "asocial sociality" (ungesellige Geselligkeit), which is the key concept of Kant's anthropology and philosophy of history. The question is no longer to speculate on the original pre-political nature of humans as hostile wolves (Hobbes) or kind lambs (Rousseau). The problem is that human is a social species while his individual nature (ambition, domination, cupidity) is anti-social. But, by a "ruse of reason", Nature uses this Hobbesian pathology to compel humans to accept collective *rules of law*.

The *Fable of the bees* triggered a tremendous controversy (in particular with Bishop Berkeley) and was condemned in 1724 for its "diabolic attempts against religion". Even today many people judge outrageous to introduce a principle of *moral*

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[17] See his *Essais de morale*, 1671.

[18] See, e.g., Faccarello, 2006.

[19] Here, "transcendence" means incommensurability and emergence.

inversion between micro-social individual intentions and global emerging macro-social properties, to posit that intentionally selfish individuals ("rational" in the sense of the theories of rational choice) governed by their private and local self-interest can, by means of their interactions, generate, in an *unintended* way, a global social order propitious to public interest.

II.7. Hayek on Mandeville

The *moral* evaluation of Mandeville's thesis is irrelevant. Mandeville was concerned by the economy of large cities and societies, by wealth rather than by virtue. He explained that a "sympathy fusion" between individuals is not necessary to reach a spontaneous "harmony" of interests. This said, it is not yet clear if, in Mandeville, the "invisible-hand" paradox was solved by a "hidden Providence" as it was previously the case in Pierre Nicole, or already by a *natural* self-organizing mechanism as it will be in Adam Smith, or by an *artificial* legislation as it will be in a physiocrat as Helvétius or an utilitarian as Bentham.

In his *Lecture on a master mind: Dr Bernard Mandeville*, given at the British Academy on March 23-th 1966 [20], Hayek explains that Mandeville was not a moralist but an excellent physician and psychologist-psychiatrist, and that the question is not to know if the "harmony" is natural (phusis and cosmos) or artificial (nomos and taxis), but to understand that it is an emerging *unintended* spontaneous order. Mandeville already raised the issue of incommensurability of social structures with respect to reason, and of the selection of "good" social rules by cultural evolution.

III. EUSOCIALITY IN HUMANS

The evaluation of Mandeville's thought must be contextualized with respect to the different conceptions of social order trying to solve the "asocial sociality" of humans in modern open societies.

III.1. The paradigms of social order

Three conceptions of social order have long dominated political philosophy:[21]

1. The paradigm of hierarchical order and absolute power theorized from the Renaissance by Machiavelli (1469-1527), then Bodin (1529-1596) and Hobbes (1588-

[20] In *News Studies in Philosophy, Politics, Economics and the History of Ideas*.

1679). In Hobbes' *Leviathan*, the coordination problem is solved by a centralized hierarchical "vertical" power (king's scepter and bishop's crook) which *imposes* a top-down coordination by coercion. This is possible because the wealth surplus produced by global cooperation is monopolized by narrow elites enjoying exclusive privileges and able to pay for the police and the army protecting their power.

It is in reaction to this form of absolutism that many demands arose for tolerance and human rights, from Grotius (1583-1645), Bayle (1647-1706) and Locke (1632-1704) to Kant (1724-1804), Humboldt (1767-1835) and Constant (1767-1830). The "vertical" orders were challenged by more "horizontal" and "democratic" conceptions advocating like Mandeville a sort of eusociality.

2. The rational "constructivist" (in Hayek's sense) paradigm positing that an efficient order can be computed, planned, and applied.

3. The conservative paradigm of natural order, which champions a form of organicist holism and accuses individualism for "atomizing" society and destroying "natural communities" (family, corporations, churches, etc.). For example, for Saint-Simon (1760-1825, *De la physiologie appliquée à l'amélioration des institutions sociales*, 1813) and Auguste Comte (1798-1857, *Système de politique positive*, 1851) holism was a sort of "organicism", a "physiological" conception of the social reality opposing "mechanistic atomism".

III.2. An eusocial primate

Homo Sapiens is a broadminded primate situated on the "vertical" axis of cognitive evolution. Our ancestors began to live in families, small groups, clans, hordes, tribes where there existed a cognitive commensurability between individuals and the collectivity. A kind of social reflexivity was then possible and there was no *eusocial* organization. A decentralized non coercive coordination was possible because each member could control the behavior of the others.

But after the prehistoric sedentarization of "hunter-gatherers", the advent of agriculture and farming, with the apparition of great urban civilizations in Mesopotamia, Egypt, Carthage, Rome, China, large cities, new techniques (writing, accounting arithmetic, surveying geometry), currency, land and sea lines of communication, trade exchanges, etc., a fundamental break occured and an

[21] See e.g. Nemo, 2002.

"horizontal" eusocial-like complexity emerged, complexity which was completely alien to the evolutive line of *Homo Sapiens*.

I say "eusocial-like" in a cultural sense and not eusocial in biological sense. When Edward Wilson, the sociobiologist of Harvard specialist of ants (see *The Ants* 1990, written with Bert Hölldobler) and founding father of *Sociobiology* (1975) wrote *The Social Conquest of Earth: humans are eusocial apes* (2012), after having published with Martin Nowak and Corina Tarnita *The evolution of eusociality* (2010), he triggered a live debate with sociobiologists specialist of eusocial altruism such as Herbert Gintis and Bill Hamilton, or biologists and ethologists as Richard Dawkins (the author of *The Selfish Gene*, 1976), and also cognitivist psychologists such as Steven Pinker. But, in much the same way as Hayek explained that the moral debate about Mandeville was irrelevant, the biological debate about Wilson is irrelevant. Of course, *Homo Sapiens* is not an eusocial species. Human eusociality results from a cultural (and not biological) evolution.

The problem is the *mismatch* of this eusocial cultural evolution with our primate brain. Our biological inheritance is not adapted to *global* social coordination. The later, requires the introduction and the acceptation of eusocial impersonal, "objective", and external rules. But what type of rules?

Great civilizations have been mostly *imperial*, with a coercive centralized power constraining individuals to cooperate. We have seen that it was the solution theorized by Thomas Hobbes in his *Leviathan*.

III.3. Spontaneous orders and complex methodological individualism

During all his life, Hayek defended the alternative conception of *spontaneous orders*, which posits that pluralism and individual freedom are not sources of disorder, anarchy and social struggle but, on the contrary, a factor conducive to higher forms of organization. This *complex methodological individualism* (CMI) stands in sharp contrast with the other paradigms of social order and conceives social order as neither natural (permanent and universal) nor artificial (rationally construed), but pluralist and self-organized, non hierarchical and polycentric.[22] As the masters of the Scottish

[22] Evident examples of such orders are language, law or morals: they are not natural in the strict sense of the term, but they are neither artificial since nobody has ever made them.

Enlightenment David Hume (1711-1776) and Adam Ferguson (1723-1816) emphasized [23], they are the results of human actions but not of human intentions.

This conception that individuals are the basic social entities but interact in a contractual society protected by the rule of law is in general attributed to the tradition from John Locke (1632-1704) to Adam Smith (1723-1790) and the "*invisible hand*" (*Theory of Moral Sentiments*, 1759, *The Wealth of Nations*, 1776). The essential feature of the invisible hand is that it drives subjects to collective ends that do not proceed from their intentions. But as we have seen, it is also present in Pierre Nicole. And in the volume I edited with Philippe Nemo on *The History of Liberalism in Europe*[24], you will find a chapter of Gilbert Faccarello on one of the main precursors of Adam Smith with Mandeville, namely Pierre de Boisguilbert (works between 1695: *Le Détail de la France*, and 1705: *Factum de la France*).[25]

For CIM, global macro rules must be rules of a law-abiding state. The function of state is neither to uphold an "innate" order nor to impose a "rational" order, but only to secure the *institutions* enabling the emergence of an open and evolutive spontaneous order. Methodological individualism concerns mechanisms of self-organization, which cannot be rationally computed by agents. Social cohesion, cooperation, prosperity are non-intentional effects emerging from an aggregation of selfish interests.

But of course there is a major problem. It is not sufficient to refer to *empirical* examples, as remarkable they may be, as language, religion, law, money, market, etc. and to claim that they are unintended results of human actions and not the intentional outcome of a general collective will.

As we already emphasized with Viktor Vanberg, the possibility of emergence *must* be proved using mathematical modelling and computational synthesis. This is particularly non trivial because, as we have seen, the *rationality* (in the sense of the rational choice theories since William Stanley Jevons and Léon Walras) of selfish agents able to compute the maximization of their utility seems to be incompatible with global coordination. The rational economical calculus for maximizing pleasure and minimizing pain seems to be anti-social.

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[23] Ferguson. *An Essay on the History of Civil Society*.

[24] Italian translation by Francesco Di Iorio.

[25] Faccarello, 2006.

III.4. Evolutionary game theory

But there are fortunately some fundamental results, in particular concerning the emergence of *cooperation* in evolutionary game theory. See, e.g., the celebrated works of Robert Axelrod. One starts with the study of Nash equilibria for a simple cooperation game such as the one shot prisoner dilemma between two rational players. It shows that cooperation is irrational since individual rationality selects a poor defective (lose, lose) strategy even if a collective rationality would have selected a good cooperative (win, win) strategy.

But the situation changes completely when this game becomes *complex*. First, one can *iterate* the game, which implies that defection can then be punished and cooperation rewarded. In that case, one can introduce more elaborate individual strategies such as unconditional cooperation, unconditional defection, "tit for tat" (*TFT*: start with cooperation, then play what the other player played at the previous move), "vindictive" (start with cooperation and defect for ever as soon as the other player defects, defection being punished as an irreversible betrayal), etc. Moreover games can be *evolutionary* games, where polymorphic populations of individuals use different strategies and define new generations using the scores in a generalized competition: strategies with good scores increase their number of representatives while those with bad scores progressively vanish. In these models, agents are considered as "phenotypes" expressing "genotypes" identified with strategies, and simple "micro" strategies influence complex "macro" population dynamics.

Evolutionary game theory is more realist than the classical one based on individual choice rationality. It substitutes a collective selective scheme to an *inoperable* variational calculus. Moreover, it enables to understand the dynamics that drive agents towards global equilibria.

Simulations and computational synthesis prove then that anti-cooperative strategies can be eliminated, and that cooperation can win and become stable. The best strategies are nicely cooperative, rapidly reacting to defections ("retaliatory"), rapidly forgiving, and simple ("clear", without wiles). The best known is the "tit for tat" (*TFT*) strategy.

But such cooperative strategies are *fragile* with respect to *mutations*. Indeed, as far as unconditionally cooperative mutants exhibits exactly the same cooperative behavior as *TFT* in a *TFT* environment, they can therefore substitute themselves progressively and "silently" for *TFT*, without any observable effect. But then "bad"

(unconditionally defective) mutants can destabilize, invade and destroy the system. So, to be retaliatory is a condition for being *collectively stable*.

Moreover, one can, as did Karl Sigmund, Martin Nowak and Robert May, *spatialize* this evolutionary game by introducing local neighborhood relations between the agents. Simulations show that the transition between non-cooperative global states towards emerging cooperative global states has the status of a *critical phenomenon*, exactly as phase transitions in physics.[26]

III.5. Hayek and the complexity problem

Hayek was at the same time ant-holist and anti-rationalist. For him, man is not a rational chooser. His cognitive resources are very limited and drastically imperfect, he is unable to perform the economical calculus and has always a dramatically *incomplete* knowledge of economical situations. Hypothesis of perfect information are wrong. He has to choose and to act according to fallible expectations and very local and limited knowledge. It is for that reason he needs social institutions, as prices in a market, which, as emphasizes Jack Birner in *Cosmos and Taxis*, provide a "communication structure that transmits price information efficiently and rapidly".[27]

The source of complexity has to be found in the fact that, in an open society, knowledge, competencies and informations are distributed, scattered over a great number of cognitively limited and interacting agents. The systemic properties of such systems cannot be conceptually controlled. The political control of social and economic orders rests on a methodological error.

Many consequences derive from this fundamental fact.

(i) First, complexity prohibits at the same time a centralized hierarchical organization and a communal link of reciprocity characteristic of small closed communities. In modern open societies the interactions between agents is no longer ensured by consensus on shared values but by exchange of signals such as prices in a market. Market is a way of circulating information in a multi-agent system whose very complexity makes it opaque to its own agents. In a Hayekian "catallaxy" everyone

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[26] See the chapter "Formal models of the 'invisible hand'. From Hayek to evolutionary game theory", in *The History of Liberalism in Europe* I edited with Philippe Nemo. See also Petitot, 2016, where fractal structures characteristic of phase transitions are computed for models of an iterated spatialized prisoner dilemma.

[27] Birner, 2016.

cooperates with everyone else but without any shared ends. The individual aims are incommensurable with each other but mechanisms such as free trade and markets guarantee nevertheless a viable cooperation.

(ii) Complexity is an evolutionary process resulting from a selection of historico-cultural rules of behavior, practices, institutions that are impossible to master conceptually.

(iii) A third consequence of complexity is that rules that govern social exchanges and communication are abstract and formal. Social self-organized complex systems are governed by civil rights guaranteed by public laws.

III.6. Cultural evolution and emerging ethical maxims

At the cognitive level, be it individual or social, according to Hayek, the origin of the rules governing perception and action, as well as that of conventions and norms, is evolutionary. These patterns result from a cultural selection — a collective learning — which is a competitive / cooperative process having favored the individuals and groups that applied them. They are like cultural short-cuts enabling people to behave rapidly and adaptively without having to recapitulate every time all the experiences and beliefs necessary to action. For Hayek, *common-sense* is a library of tacit knowledge routines and practical schemes patterning our experience according to generic default schemes. It is necessary to act without being overwhelmed by the overflow of irrelevant informations coming from the environment. For Hayek (as for Mandeville, Hume or Ferguson), common sense norms are not repressive constraints but, on the contrary, cognitive achievements deeply adapted to the contingencies of life. Traditions express an "embodied knowledge" which is "phylogenetic" in the sense of cultural evolution, and it is therefore rational to comply with them "ontogenetically".

In much the same way as in evolutionary biology, phylogenetic a posteriori operate as ontogenetic a priori, common sense rules operate for the subjects as a priori frames. In this sense, we find in Hayek an evolutionary theory of the *self-transcendence* of behavioral rules. Like linguistic rules, they proceed from symbolic institutions whose origin is neither a rational omniscient intelligence nor a deliberative social contract. We see how Hayek articulates cognitive psychology (the "sensory order") with the sociology of complex spontaneous orders (the "catallaxy").

Of course, the very concept of cultural evolution is quite problematic. For Hayek, as for Popper, cultural evolution selects *groups* and not individuals, subjects

having to comply with rules that maximize the collective performances of their group. Among others, Robert Nadeau and Paul Dumouchel have deeply investigated this point. We can emphasize again the fact that, in the case of social insects, biological Darwinian evolution has selected "good" *eusocial* rules of collective organization, that is efficient group rules.

However, regardless of the answer to this question, what is sure is that the subjects themselves cannot understand in what *operational* sense norms of just conduct can be socially fruitful because they encode a "phylogenetic" historical evolution. Particularly so because these norms are not "moral" in the traditional sense. That's why subjects interpret them as *duties*. We must emphasize the originality of this conception:

1. As individuals cannot understand the pragmatic efficacy of norms, they accept them for *deontic* reasons. We recognize here a thesis that belongs in Kantian ethic.
2. However, norms being socially useful we recognize also an *utilitarian* conception of ethics (Jeremy Bentham, John Stuart Mill). The main difference is that the "computation" of moral maxims and actions is cognitively inaccessible for individuals.

Therefore, according to Hayek, cultural evolution implies that maxims of action can act for individuals as transcendent "categorical" imperatives [28] while they are at the same time immanent "hypothetical" (pragmatic) imperatives for cultures.[29] For cultures, maxims are caused by the viability of a social order from which individuals gain a lot. As was emphasized by John Gray, Hayekian utilitarianism is *indirect* and exemplifies the general evolutionary principle (Haeckel's law) according to which phylogenetic a posteriori operate ontogenetically as a priori. Hayek was able to reconcile, from within methodological individualism, reductionism with holism: social entities prescribe norms, rules and maxims to individuals.

It is interesting to highlight how Hayek succeeded in renewing the notion of categorical imperative as a deontological (non consequentialist) conception of actions. According to deontological theses, actions must be evaluated in a principled way independently of their consequences, while according to consequentialist theses they

[28] For Kant, a normative judgement is "categorical" when it is independent of any end. Categorical prescriptions are purely "procedural".

[29] For Kant, a normative judgement is "hypothetical" when it is conditioned by an end and prescribes means to achieve the end (consequentialism).

must be evaluated on the basis of a computation of the costs and benefits of their consequences. But as that kind of computation is intractable for a finite and limited rational mind, it is performed by cultural evolution. As was emphasized by Jean-Pierre Dupuy, cultural evolution is "utilitarian" but bears on "deontological" maxims that can be interpreted in accordance with a test of "categoricity".

IV. OBER'S ANALYSIS OF ANCIENT GREEK POLEIS (CITIES-STATES)

To conclude, I would like to highlight an historical point. Since the time I read Thucydides' *History of the Peloponnesian War*, I considered that Hayekian catallaxy had been invented by Athenians of the Classical Ancient Greece. In Chapter III, the discourse of Corinthians at Sparta [30], is striking. They describe Athenians as "addicted to innovation", "adventurous beyond their power", and "daring beyond their judgment". And insofar as, they said, "it is the law as in art, so in politics, that improvements ever prevail", "it happens that the vast experience of Athens has carried her further than you [Sparta] on the path of innovation". [31]

During the academic year 2013-2014, I was invited at Stanford and my office was next to that of Josiah Ober, one of the main specialists of Ancient Greece and of the

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[30] The Congress of the Peloponnesian Confederacy at Lacedaemon.

[31] More precisely, Corinthians describe "the great contrast between the two national characters" between Athens and Sparta as follows. "The Athenians are addicted to innovation, and their designs are characterized by swiftness alike in conception and execution. (...) They are adventurous beyond their power, and daring beyond their judgment, and in danger they are sanguine. (...) Further, there is promptitude on their side (...); they are never at home (...): for they hope by their absence to extend their acquisitions (...). They are swift to follow up a success, and slow to recoil from a reverse. Their bodies they spend ungrudgingly in their country's cause; their intellect they jealously husband to be employed in her service. A scheme unexecuted is with them a positive loss, a successful enterprise a comparative failure. The deficiency created by the miscarriage of an undertaking is soon filled up by fresh hopes; for they alone are enabled to call a thing hoped for a thing got, by the speed with which they act upon their resolutions. Thus they toil on in trouble and danger all the days of their life, with little opportunity for enjoying, being ever engaged in getting: their only idea of a holiday is to do what the occasion demands, and to them laborious occupation is less of a misfortune than the peace of a quiet life. To describe their character in a word, one might truly say that they were born into the world to take no rest themselves and to give none to others.

"(...) It is the law as in art, so in politics, that improvements ever prevail; and though fixed usages may be best for undisturbed communities, constant necessities of action must be accompanied by the constant

poleis having emerged from the Dark Ages which followed the fall of the Mycenaean civilization. We had a great deal of discussion on Athens. He was writing a book, *The Rise and Fall of Classical Greece*, which was published in 2015. Based on the compilation of massive and detailed quantitative data, it is entirely devoted to the thesis that the "efflorescence" of classical Greece, its "miracle", its unique and exceptional wealth, its creation of public goods by a *rational* collective cooperation and not by coercion, are due to the fact that the Greek system of poleis (1035 city-states) constituted an "acentered" distributed network of competitive-cooperative units associated inside leagues and federations swarming in colonies, who succeeded in inventing a political "horizontal" democratic solution to the *decentralized large scale global cooperation enigma*.

This original solution, radically opposed to the Ancient autocratic empires of Mesopotamia, Persia, or Carthage, was invented by Solon and above all, against the tyranny of Hippias son of Peisistratos by Clisthene [32], the Alcmeonide grand-uncle of Pericles. Clisthene [33] relied upon the demos to change the political institutions, to reorganize land use planning and to introduce *isonomy* (equality of law). The new rules were based on completely new conceptions of citizenship, civil rights, and just, impersonal and equitable rules of law. They elicited in the new middle classes an avalanche of unique competences and specializations, competing exchanges, technological innovations, investments and risk taking.

To understand how such particular political conditions can *motivate* rational individual agents to cooperate, Ober uses widely works of institutional economy (Douglas North (Washington University, Nobel in 1993), Daron Aemoglu (MIT), James Robinson (Harvard)), and game models of cooperative choice (Robert Axelrod).

His book is highly original, because, even if the technical term of "eusociality" is not used, the analogy with social insects as political animals in Aristotle's sense is the core of his investigation. Ober refers recurrently to the work of his Stanford colleague

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improvement of methods. Thus it happens that the vast experience of Athens has carried her further than you on the path of innovation."

[32] Kleisthenes.

[33] After being exiled by Hippias, he came back to Athens in 510 BC and eliminated his rival Isagoras in 508.

Deborah Gordon on ants. Gordon focuses on the sophisticated exchanges of *information* between individuals.[34]

For Ober, Greek "miracle" rests on the creation of "good" political rules enabling the emergence of a collective intelligence coordinating distributed highly specialized knowledge. In Ancient classical Greece, knowledge, technologies, economy, competences were highly specialized, but not politics. The power was shared between a collective self-government of "amateurs". It is the contrary of what Plato defended in *The Republic*.

In a word, even if he does not refer explicitly to Hayek, Ober describes the ecosystem of Greek poleis as *the first catallaxy* in human history. So, we can say that Hayekian catallaxy is another name for of eusocial civilizations.

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[34] It is well known for bees since Karl von Frisch in the 1920s, but it is much more recent for ants. High rates of information exchanges are necessary for eusociality.

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