Human–Environment Relationships: Culture and Pedagogy

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Human culture can be regarded as the general context where the human–environment relationships take place and develop. Interestingly, studies on human culture and cultural evolution have been enriched with some novel perspectives that appear to dovetail with recent developments in evolutionary biology. All this allows a fresh and promising understanding of the fundamentals of human-environment interaction, according to which the environment can be shown to exert a pedagogical role for humanity, and humanity can be understood as a species modifying the environment to the aim of modifying itself.

cultural evolution studies | ecological inheritance | environment | extended evolutionary synthesis | cultural exaptation | cultural neural reuse | pedagogical ecology

1. The EES and Culture-Driven Human Evolution

So-called *Extended Evolutionary Synthesis* (EES) substantially alters the overall picture of biological evolution relative to the "received view" from the Neo-Darwinian Synthesis— nowadays also called the *Standard Evolutionary Theory* (SET). According to the latter, in a very sketchy way, evolution proceeds thanks to genetic changes that determine changes in the organisms' traits, including behavioural and cognitive ones; then, natural selection "filters" the modified traits, thus favouring the spread of those genetic endowments responsible for adaptive traits. This view has also been applied to human evolution and to human *cultural* evolution specifically. Here, the picture might be summarized as follows. Key cultural innovations characterizing *Homo* evolution since about 2.5 million years ago, are mainly regarded as the eventual outcomes of genetic evolution. More precisely, the genetic endowment is seen as establishing anatomical and physiological traits (and specifically *brain* anatomy and physiology), which, in turn, are claimed to fix cognitive faculties; cultural behaviour is finally regarded as stemming from the cognitive faculties. By implication, this general view maintains that the emergence of key cultural innovations ultimately would require genetic change. Such reasoning has been applied to the emergence of complex cumulative culture exhibited by *H. sapiens*, claiming either that it depends on the genetic change bringing about the speciation event leading to our species 260,000 years ago[1][2][3][4][5][6] or that it stems from some key mutation that occurred about 50,000 years ago in some population of our species[7][8][9][10].

This picture, however, seems no longer tenable for at least two classes of reasons[11]. First, it nowadays appears in sharp contrast with the emerging view of evolution advocated by the EES. The main tenets of EES[12][13][14] (relative to SET) can be summarised as it follows:

- Genetic changes are no longer considered as the only, or most important, source of biological novelty, as such novelty can emerge also by means of *phenotypic plasticity* or other processes happening on the phenotypic, behavioural or cognitive level without involving genetic change.
- The environment is no longer regarded as having only a selecting role upon the organisms living in it, as it can also *induce* novel morphological, behavioural or cognitive traits.
- Organisms often exert powerful *niche-conctructing* activities upon their environment, thus buffering the selection factors acting upon themselves and their progeny.
- Biological, evolutionary-relevant information is no longer seen to be passed on from generation to generation only, or mainly, through genetic channels, as it can also be passed on via *epigenetic*, *behavioural* or *symbolic* means; here the notion of *ecological inheritance* (the idea that offspring inherits from parents key environmental features as modified by the parents themselves) assumes particular relevance.

These four points ground a strong form of *organism-environment complementarity* in the general case[12], and also suggest that the above-sketched view of human evolution needs to be revised.

Secondly, that picture of human evolution needs a rethink because of a number of recent archaeological and paleo-anthropological data[15][16][17][18][19]. Indeed, the distribution in time and space of the innovations' appearance suggested by those data is inconsistent with a scenario attributing the spread of modern cultural traits to concomitant genetic evolutionary processes. No concomitant rise of innovations that one might associate with a sudden shift in human cognition produced by genetic change or speciation is observed at any given moment in the past in a particular region or population. No accumulation of innovations is observed in only one single region (what should be expected, instead, if a genetic change were the cause for them). Cultural innovations seem to appear, disappear, and reappear (with different specifics) at different times, in different places, and among different human fossil species across a huge geographical area encompassing Africa, the Near East, Europe and Asia. Such complex patterns of cultural innovation seem utterly incompatible with a scenario in which key cultural innovations would require associated and directly causally related genetic changes.

A quite different scenario can thus be proposed for the emergence of key cultural innovations and for cultural evolution more generally. This scenario proposes genuinely cultural mechanisms at the basis of cultural evolution that have been labelled as "cultural exaptation" and "cultural neural reuse"[11][15]. Cultural exaptation, in analogy with biological exaptation[20], suggests that novel cultural strategies may be devised by building upon existing strategies, either putting the latter at the service of new functions or combining them in novel ways in view of new tasks. Examples of cultural exaptation are:

- The use of ochre pigments. Compounds made with ochre are powerful photoprotective means that shield the skin from harmful ultraviolet radiation[21]. There is evidence suggesting the symbolic use of iron-rich pigments on personal ornaments since at least 80,000 years ago in Africa[22][23]. One can envision a scenario in which ochre was first exploited for its photoprotective function and, in a later phase, through cultural exaptation, becoming a means, for example, through body painting, to reinforce cultural mechanisms related to intra- and inter-group self-identification, leading to the emergence of diversified symbolic material cultures. A subsequent cultural exaptation may have occurred in an already fully symbolic context when ochre was purposely employed on ornaments and clothes[15];

- The invention of systems of notation (or "Artificial Memory Systems"—AMS), up to proper writing systems. There is a number of archaeological objects (dating from 72,000 to 14,000 years ago) that constitute Artificial Memory Systems in that the marks and incisions they bear stored information significant to our ancestors[15][16][24]. Production of such "notational" marks resorted to the motor and cognitive abilities previously developed for other tasks (from butchery activities on carcasses and preys to utilitarian modification of stone or bone tools to the production of abstract but non-notational engravings)[16][25]. These abilities have been put at the service of notational function (i.e., the ability of the marks to point to, or stand for, objects or other meanings) and thus have been "culturally exapted". It can be argued that the invention of writing is a further step in the process where marks on objects (such as the incisions on clay tokens of the cuneiform writing system developed in Mesopotamia 5400 years ago) came to be associated not just with a meaning but also with the phonology of an existing spoken language[15].

The interesting point here is that the new cultural strategy emerging via cultural exaptation may back-affect the cognitive abilities of the groups introducing it. Symbolic use of ochre pigments likely affected aspects of social cognition. The invention of systems of notation affected numerical cognition[26][27]. The invention of writing systems affected the phonological processing of spoken language[28] and has had, in the course of the last few millennia, enormous impacts on human lifestyle, up to the emergence of theoretical culture as well as of modern science and technology.

Moreover, there are convincing data showing that new cultural strategies may have a direct impact on the neural substrates subserving them, contributing to create stable functional or anatomical brain networks specifically dedicated to those new strategies *without involving any heritable genetic change*. This holds true for writing systems[28][29] and systems of numerical notation[30], but likely also for much older cultural practices such as stone-tool-making[31]. This is the core idea of the notion of cultural neural reuse[32][33][34], also labelled as "neuronal recycling"[35] or "neural exploitation"[36].

2. Cultural Transmission and Pedagogy

The main and clearest examples of cultural evolution by cultural exaptation and cultural neural reuse mentioned above are literacy and arithmetic (i.e., symbolic treatment of exact quantity). Patently, acquiring such cultural abilities requires fine pedagogical means and enduring dedicated training. Humanity has developed the institution of schooling to this aim. With all likelihood, transmission strategies themselves evolve. The animal kingdom displays an array of different transmission strategies[37][38][39]; moreover, variation in transmission strategies does not seem to be entirely dependent on differences in the genetic make-up but rather to correlate with environmental and contextual features[40]. Explicit *teaching*, however, seems to be a characterizing feature of our species (at least among extant hominins), and this likely depends on the peculiarities of human cultural evolution up to exalted cumulative culture[41],[42]. The relevance of transmission strategies, and their evolution, can also be ascertained on the archaeological level[43][44]; studies have also suggested the possibility that tool-making, transmission strategies, and language as an effective communication means have co-evolved and that more effective transmission strategies may also positively affect innovation. The evolutionary relevance of transmission strategies can also be inferred from experimental studies with non-human animals that can be trained in subtle motor or cognitive tasks outside their behavioural repertoire in the wild. Striking is the case of chimpanzees that acquired numerical abilities,[45] or that of macaque monkeys that were trained to use a tool to reach for food and were also shown to undergo neural changes as a consequence of the training[46]. This suggests that an important way for hominins to support a sustained (and accelerating) pace of cultural evolution has been to "invest in pedagogy"—i.e., dedicating specific efforts in devising transmission strategies adequate to pass on cultural traits perceived as important in the group.

It is also worth mentioning (though this point cannot be deepened here) that many recent cultural innovations—from literacy to the fine arts or to smartphones and space-crafts—do not seem to have an immediate survival value. After all, *H. sapiens* has managed quite well on this planet before the emergence of such cultural innovations. This, coupled with the considerations that (i) many cultural innovations take time to show their utility, even in terms of competitive advantages and not just as immediate survival means, and (ii) that investment in the transmission of cultural novelties is often necessary before their utility is unveiled, points out that the *motivations* beneath human cultural evolution might not always be in the search for (immediate) utilitarian outcomes or payoff[47].

3. Cultural Transmission and Environmental Heredity

The notion of ecological inheritance put forward by the EES stresses that the modifications organisms cause in the environment last longer than the lifespan of those organisms, thus being inherited by their progeny. Importantly, moreover, the modified environment inherited by the progeny often plays a crucial role in the progeny's development, sometimes being also essential to ensure parent–offspring phenotypic similarity[48][49]; i.e., the fact that the offspring has traits similar to those of the parents may depend not just on the inherited genome but also, crucially, on the fact that the offspring grows and develops in the same environment of the parents, where the environment includes all the modifications caused by the parents themselves.

Now, culture—or, more precisely, the varied array of historically and geographically realized human *cultures* or traditions—has a momentous impact on the environment. Thus, the issue of ecological inheritance acquires a special relevance for the human being exactly because the human environment is always and thoroughly a cultural environment. Additionally, this point is further sharpened by the consideration of the key role pedagogy plays in human exalted cumulative culture.

Moreover, recent human history and prehistory have seen the rise of a number of *institutions*—from the "Oldowan carnivory institution" to agriculture or trade, cities or temples, up to public school systems and the United Nations. Recent research has just begun to address the topic of institutions in the light of the EES[50][51].

Institutions are very old (the Oldowan is as old as 2.6 million years), but with the so-called Neolithic Revolution[52]—characterized by the domestication of plants and animals and the consequent development of stable settings and the possibility of accumulating goods—the urge to develop institutions increased progressively. Interestingly, this parallels the increased capacity to modify the environment that domestication implies and brings with it[50][53]. Not by chance, among the proposals for the beginning of the Anthropocene[54][55]—i.e., the proposal to officially name the current geological epoch after the impact of human activities on planet Earth—there is the invention of domestication in the Neolithic Revolution[56].

It is worth stressing that, as far as the issue of institutions is concerned, a dimension of explicit long-term planning and of shared decision making emerges as an additional character of human culture and, consequently, of the human–environment relationship. Even contemporary protocols to assess and mitigate the risk of degradation of specific environments tend to include human-related and institutional factors (such as policy for land use) besides physical, chemical and biological ones. This, in turn, deepens the pedagogical role of the environment for the human being[57]: as a matter of fact, any present-day human individual is born and grows in a highly institutionalized milieu. This further strengthens the link between the human being and its environment.

This link, in the case of humanity, turns out to be so strong and peculiar (as it involves cumulative culture and "institutional planning", respectively) to hint at the possibility that the the human being actually modifies the environment *to the aim of shaping itself*. From this, a *pedagogical criterion* for human ecology can be drawn. Indeed, given the impact that a modified environment has and can have on the human populations dwelling in it, each modification imposed to the environment should be assessed (also) for its pedagogical import - i.e., for the consequences it has in the learning processes all human beings constantly undergo all life long, for the messages it passes to the people living in it, for the effects it will have on the future generations, and for the contexts it will create for all aspects of human life[58].

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