

Evolution of modern humans is a result of self-amplifying feedbacks beginning in the Miocene and continuing without interruption until now

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ABSTRACT: Humans are a part of the complex system of life. This consists of a multitude of feedbacks among all parts of living systems. In the case of human origins, many feedbacks became positive rather than homeostatic, thus producing self-amplifying effects in basic morphological and behavioural characteristics of emerging humans: erect bipedalism, social structure, tool-making, food procurement and environmental management, symbolic communication, sexuality, extended childhood, and mental capacities. These, plus many other human characteristics, changed gradually, though at varying rates, over the last 6 million years, producing directional variation in extant morphological and behavioural characteristics of what are considered modern humans. The change through time and geographic space of those characteristics is an ongoing dynamic process, thus it is futile to pose essentialist questions about the precise date and place of the modern human origins. Modernity is a process, not an endpoint.

KEY WORDS: autocatalytic, evolution, brain, hominins, human



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– look in the mirror if uncertain. With the current branching model of hominin evolution misrepresenting members of various populations such as Neanderthals and even Flores “hobbits”, as purported failures to become “moderns” (in the sense of morphology and behaviour rather than their time of existence), it is unavoidably essential that there was a direct ancestor-descendant line that, proceeding through the copulations and births in every 250,000 antecedent generations, produced modern humans from some Miocene/Pliocene ancestral population. Differential reproduction in each of those 250,000 generations enabled natural selection to enhance biological processes that underlie complex cognition of modern human individuals. Interaction of members of each generation with their surroundings and with other members of their populations influenced epigenetic processes shaping the course of individual ontogenies, especially their early parts: infancy, childhood and adolescence, and resulted in altered natural environments and social structures with which all our ancestors had to interact.

The fossil record of hominin morphologies and the corresponding archaeological records of results of hominin behaviours are all imperfect due to the vagaries of taphonomy and geological preservation. Nonetheless, where fossil or archaeological sampling has provided reasonable sample sizes of skeletal remains or artefacts, it can be seen that the evidence shows improvements in bodily characteristics or technological abilities of some hominins increasing at a double exponential rate through the last few million years. The characteristic investigated should be measured on an interval (continuous) scale.

The general form of the double exponential equation is

$$y = a^{b^x}$$

where y – a dependent variable, x – an independent variable (e.g. time), a , b , constants.

As an example, for the increase in hominin cranial capacity representing the increase in body size the equation is (Fig. 2)

$$CC = 190.0(7.50.9997^{DATE})$$

Where CC is measured in millilitres (ml) and DATE in thousands of years (ka).

The double exponential rate of increase is the basic formal characteristic of self-amplifying systems.

Double exponential regression of hominin cranial capacities found until the end of Pleistocene (N=233) on their dates has a strong fit to actual data ($r=0.92$). Variance of actual capacities around the fitted line (stdev=164) does not differ significantly from the variance of brain size among the one species of modern humans (stdev=157, $F=1.09$; Henneberg 1990).

Cranial capacity is easy to quantify, while technological advances or other traces of behaviours do not lend themselves easily to reliable quantification (Levendis et al. 2019). This evidential constraint, however, does not mean that cultural innovations are not a result of self-amplifying feedback relations. The following basic behavioural characteristics often are mentioned, as being involved in the operation of the human system of positive feedbacks (Bielicki 1969; Tobias 1981; Henneberg 1992; McKee 2017): erect bipedalism, food procurement, technologies, symbolic communication, extended childhood,

sexual behaviours, social organisation, cognitive abilities. Erect bipedalism, however acquired, became a very energetically efficient way of locomotion on the ground and in shallow waters, freeing up the upper extremities. These could be then used for transporting food, weapons/tools, raw materials and children in a position facing the carrier. Similar to trunks of proboscideans, this shift extended the range of individuals' manipulation of the environment, and added to it increased interaction between care-givers and offspring. The erect posture liberated hands that then could manipulate various objects including foodstuffs, tools/weapons, fuels and building materials even during locomotion and without use of teeth and mouths; mouth then could be used to

send voice signals improving interindividual communication. Such effects of erect bipedalism clearly enhanced food acquisition and food sharing, and facilitated development of technologies, rearing of offspring, symbolic communication that in their own way interacted with the enhanced mental abilities and social organisation. Concomitant changes in sexual behaviours improved cooperative parenting and cooperation in food acquisition (to a large extent multi-person foraging, scavenging and hunting). Changed sexual behaviours benefitted from ovulatory crypsis (Lovejoy 2009) allowing more frequent, nearly continuous, female sexual receptivity, promoting monogamous unions with males that might also contribute to cooperative parenting.

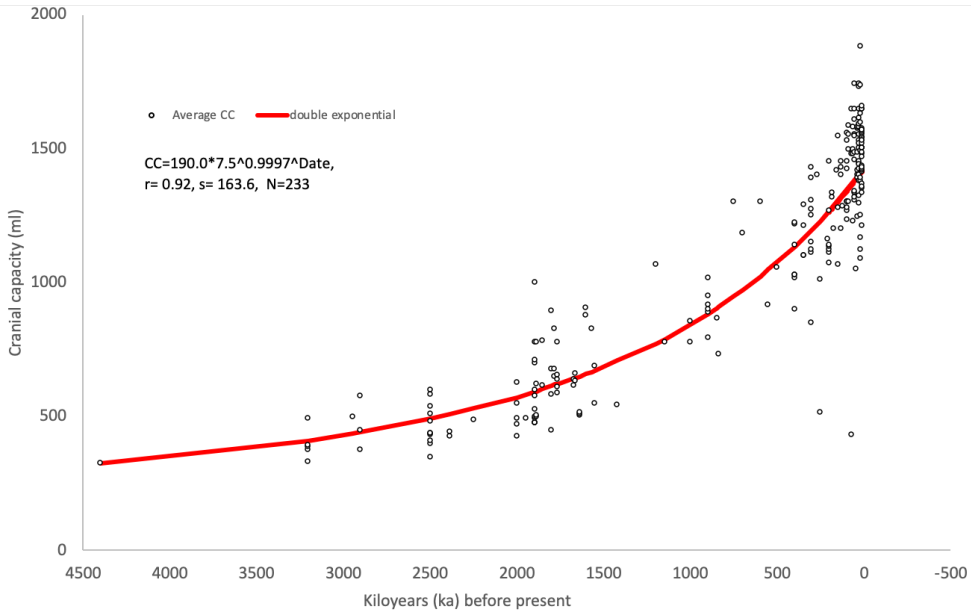


Fig. 2. Illustration of the quantitative operation of the self-amplifying feedbacks on human body size as represented by the volume of the cranial cavity. Data taken from De Miguel and Henneberg (2001) and Henneberg and De Miguel (2004) supplemented by data on new finds (Jacob et al. 2006; Berger et al. 2010; De Ruiter et al. 2019).

Collaborative parenting provided an opportunity to prolong childhood, a period of rapid and extensive learning. A prolonged childhood period enabled individuals to acquire knowledge and skills needed to use more sophisticated technologies and to participate in more intricate social structures. All these changes eventually required more learning thus demanding a further extension of the period of childhood. Improved technologies produced more efficient ways of food procurement resulting in greater access to nutrients. This interactive complex resulted in larger number of individuals being able to live together and cooperate in child rearing and food procurement but complicated social relations that had to be modified.

Improved social relations enhanced collaborative parenting and coordinated food procurement that resulted in increased group sizes requiring further development of social organisation. Such improvement was made possible by developed mental capacities and inter-individual communication (language). Improved mental abilities and more efficient (eg. symbolic) communication contributed to better social organisation that enhanced production and use of new technologies and more abundant food acquisition. Greater food abundance allowed larger group size, and so on and so on, iteratively through vast stretches of time... The scheme has many uncertain details but its general heuristic value is undeniable (Figure 3).

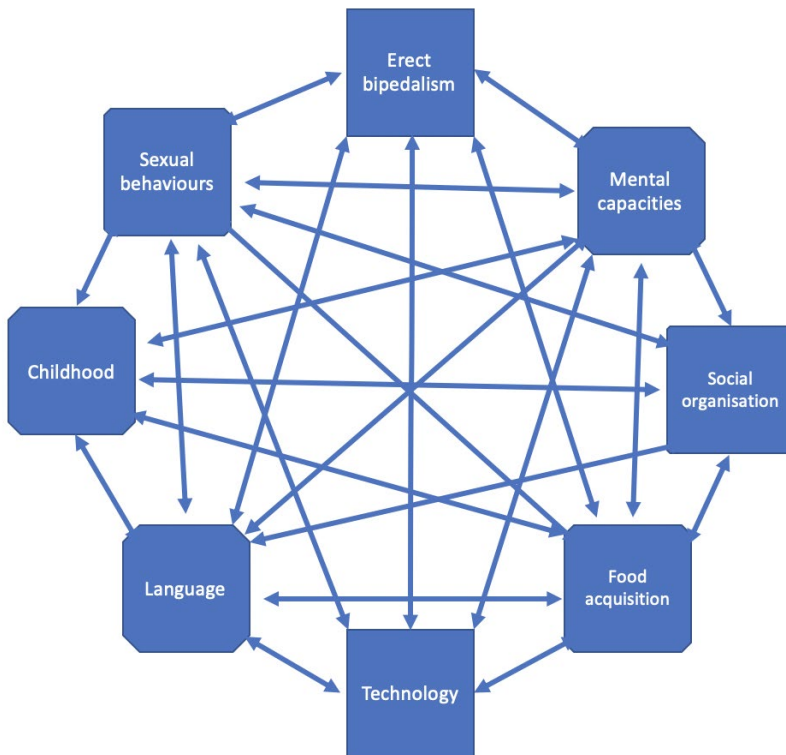


Fig. 3. A schematic representation of autocatalytic feedbacks operating during human evolution.

Evidence for the operation of this set of self-amplifying feedbacks extends far beyond the simple example of cranial capacity increase. Initial low population density of hominins, evidenced by just a few fossil finds from the Miocene and Pliocene, expanded exponentially into Pleistocene leaving fossil evidence everywhere in the Old World, even if one discounts obvious taphonomic limitations and natural vagaries of preservation. The initial scarcity of (mostly stone) artefacts of Lomekwi and of Oldovan technologies in time flourished into Acheulian industries of Lower and Middle Pleistocene and abundance of human made objects, not only technologically useful but also decorative, and into natural surfaces' alterations (e.g. "cave art") of the Upper Palaeolithic and climaxed in the management of plants, animals, soils, watercourses and building materials of the Neolithic. The abundance of human ways to manage the environment that occurred in the Neolithic, altered direction of some feedbacks so that, for example, increasing body and brain size as an effect of better food acquisition, producing collateral effects of greater protection against attacks of predators and improved hunting efficiency, later reversed towards reduction in body size (gracilisation, Debec 1960; Schwidetzky 1962) and brain size (Henneberg 1988; Henneberg and Steyn 1993) to lower metabolic costs of body mass in the situation of strong group protection and more reliable, though quantitatively limited, food supply from agricultural activities.

The mechanism described here produced, at any time it operated, a variety of morphologies and behaviours that still were capable of engaging in the set of positive feedbacks, and continued towards characteristics that we now per-

ceive as those of modern humans. The rates of morphological and behavioural changes may have varied at different periods, but continuity of change has not been interrupted in the set of our ancestral populations. Therefore, search for a single moment in time when 'modernity' appeared, or for the individual who could be the earliest holotype of modern *Homo sapiens* is a futile exercise because human variation in time and geographical space is shaped by ongoing processes, not a single act of ... creation... by forces, however natural.

Authors' contributions

Both authors contributed equally to this paper's contents.

Conflict of interest

Authors declare no conflict of interests.

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