Complexity, Compassion and Self-Organisation: Human Evolution and the Vulnerable Ape Hypothesis

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Key words: evolutionary anthropology; extended synthesis; fitness; innovation; altruism; complex adaptive systems; autopoiesis; plesionic; vulnerable ape hypothesis

Cite this as: Winder, N.P. and Winder I.C. (2015). Complexity, Compassion and Self-Organisation: Human Evolution and the Vulnerable Ape Hypothesis, Internet Archaeology 40. http://dx.doi.org/10.11141/ia.40.3

The Open Access publication costs for this article came from the COMPLEX project (EU FP7 308601) and the Department of Archaeology, University of York.

Summary

Humans are agents capable of helping others, learning new behaviours and forgetting old ones. The evolutionary approach to archaeological systems has therefore been hampered by the 'modern synthesis' - a gene-centred model of evolution as a process that eliminates those that cannot handle stress. The result has been a form of environmental determinism that explains human evolution in terms of heroic struggles and selective winnowing. Biologists committed to the modern synthesis have either dismissed agency as a delusion wrought in our bodies by natural selection, or imposed a sharp, Cartesian split between 'natural' and 'artificial' ecologies.

We revisit the seminal literature of evolutionary biology and show that the paradigmatic fault lines of 21st century anthropology can be traced back to the 19th century and beyond. Lamarck had developed a two-factor evolutionary theory - one factor an endogenous tendency to become more advanced and complex, the other an exogenous constraint that drove organisms into conformity with environment. Darwin tried to eliminate the progressive tendency and imposed linearity constraints on evolution that Thomas Henry Huxley rejected. When experimental evidence falsified Darwin's linear hypothesis, the race began to develop a new, gene-centred model of evolution. This became the modern synthesis.

The modern synthesis is now under pressure from the evidence of anthropology, sociology, palaeontology, ecology and genetics. An 'extended synthesis' is emerging. If evolution is adequately summarised by the aphorism *survival of the fittest*, then 'fitness' cannot always be defined in the heroic sense of 'better able to compete and reproduce'. The fittest organisms are often those that evade selective winnowing, even when their ability to compete and reproduce has been compromised by their genes. Characteristically human traits like language, abstraction, compassion and altruism may have arisen as coping strategies that allowed genetically vulnerable populations to negotiate new ways of being fit.

The extended synthesis allows for the possibility that great apes were agents long before they were human and that this agency enabled them to fit their environments to their own needs. This article summarises features of the extended synthesis that seem most relevant to archaeology. Some of the topics it discusses may seem abstruse and perhaps unnecessary because they amount to an acknowledgement of socio-natural complexities archaeologists have understood for decades. However, they are extremely significant in study-domains where biology and archaeology intersect. Archaeologists can no longer uncritically accept the conclusions drawn by molecular geneticists because the theoretical framework of evolutionary biology is under reconstruction.

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Figure 2: In the Modern Synthesis populations are presumed to have been organised into reproductively isolated units that evolve by divergence to create a

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Figure 4: Gene flow and biological clocks. These two trees show a hypothetical system in which three species, named A, B and C, diverge from one shared ancestor (to the top of the figure). The actual genetic history is shown on the left, with A diverging from B and C first and B and C from one another later. If this were all that had happened, the assumption of hierarchy would be justified and molecular clock methods would work straightforwardly. However, as the left side tree shows, in actual fact our system includes some subsequent gene flow between species A and B (indicated by the arrow). This would cause A and B to share some genes to the exclusion of C, and affect the way we reconstructed their relationships. The inferred evolutionary tree (on the right) would be distorted because the molecular clock would appear to run faster on some branches than others. Specifically, the B-C divergence would be pushed back into the past and the A-B divergence brought forward. The topology of the inferred tree would be a poor guide to evolutionary pathways, not because the data were incorrect, but because the hierarchic assumption would be unjustified.

1. Introduction

The central axiom of this article is that culture is a biological phenomenon - not a delusion or a by-product of brain size, but an integral feature of human ecology. Biological theories about human activity systems, if they cannot accommodate those cultural ecodynamics, are not fit for purpose. The term 'pro-social' is often used to describe animals that are born with an innate expectation that the world will contain communicative, sociable organisms from which they will need to learn complicated skills. Bees and ants, which seem to be born with their social skills hard-wired into their bodies, are not pro-social, but great apes, elephants, dogs and crows undoubtedly are.

Alongside this axiom we set a number of ideas from complex system theory. One of these is that evolutionary systems are *equilibrium-seekers*. The clouds of 'stuff' that became our solar system, for example, gradually converged into lumps to produce a quasi-evolutionary system in which lumps of stuff occasionally collided with each other, or were pounded by bodies flying in from beyond the solar system. Natural selection eliminated, shattered or relocated all the lumps that failed to keep out of the way. What remained was the stuff that had been able to hide from natural selection.

The 'stuff that could hide' was not distributed randomly in space and time - patterns had emerged that could be described in terms of planets, moons, asteroids, meteors, orbits, cycles and periods. The stuff inside the solar system was patterned and so too was the stuff from outside that occasionally entered it and left again. The external materials must have passed through similar selective mills as they crossed vast distances in space. The dynamic rapprochement between the materials inside our own solar system and the materials in its environment wrought patterns in both and, coincidentally, allowed planets and external objects to co-exist over an extended period of time.

The synergetic patterns that emerge within an evolutionary system invariably reflect processes going on in its environment and vice versa. The reflexive patterns we observe here and now are but one possibility in a vast, unbounded space of possibilities, each shaped by sequences of events and happenstance and by processes taking place outside the system at hand. System theorists often describe that possibility space in terms of attractive regions (*attractors*) and repulsive regions (*repellers*). There may also be 'basins of attraction' - regions close to a given attractor that funnel passing trajectories in.

It was briefly fashionable, in the 1980s, to write about 'chaos theory' but complex systems research is much more closely engaged with self-organising or 'self-writing', *autopoietic* systems than 80s popular science suggests (Bateson 1979; Maturana and Varela 1973). Much of the literature on autopoiesis is technically demanding, but at its heart is the idea that fitness has something to do with the ability to avoid natural selection by finding a stable attractor in which the dynamics and patterns manifest in every sub-system reflect patterns in the others. In physical systems, this synergetic fitness often has something to do with having the right physical properties or being in the right place at the right time, but in ecological and human activity systems, patterns of co-operation and selective kindness can sometimes produce surprising ways of being fit.

1.1 Synergetic and heroic models of fitness

Charles Darwin's (1859) theory of evolution used a *synergetic* or *co-evolutionary* model of fitness that characterised it in respect of an organism's 'organic and inorganic conditions of life'. When a cock-bird attracted a mate or a long-tongued insect found deep-throated flowers to pollinate, they activated dynamic multipliers that selectively rewarded success and opened new possibility spaces of future opportunities and challenges. If the co-evolution of deep-throated flowers and long-tongued moths led to an exaggeration of these traits, then conventional pollinators might be locked out and long-tongued pollinators would thrive.

During the first half of the 20th century, however, biologists re-defined evolution as a change in the gene-pool driven by natural selection (as described by Fisher 1930). This gene-centred model is often referred to as the 'modern synthesis' (Huxley 1942). Its success was due, in part, to experimental evidence that falsified the continuity assumptions Darwin had built into his theory and, in part, to the physicist Erwin Schrödinger (1944), who saw analogies between genetics and quantum theory and argued for the existence of a genetic blueprint. Watson and Crick's (1953) work on DNA seemed consistent with Schrödinger's blueprint hypothesis and the Darwinian model was set aside. In the modern synthesis, natural selection becomes a filter that punishes failure, and fitness is an attribute of a gene. The result is a *heroic* model (Landau 1991) in which genes either have what it takes to survive or are eliminated.

Darwin's enthusiasm for Herbert Spencer's phrase 'survival of the fittest' (see, for example, Chapter 4 of the sixth edition of *Origin*; Darwin 1871a) suggests that he too found heroic models attractive. Darwin often assumed that the 'conditions of life' experienced in a region would be more or less uniform. Under the assumption of uniformity one can reasonably speak of some organisms being heroically fitter than others. The differences between Darwin's theory and the modern synthesis become significant, however, when one tries to connect the two models to later developments in systems ecology. With Darwin's theory it is possible to treat fitness as the upshot of co-evolutionary processes that reward success, because selection operates on organisms in a populated neighbourhood, where co-operative behaviour can greatly enhance survival prospects. With the modern synthesis, however, there is only the heroic model. Selection does not reward success; it punishes failure. The heroes that survive are not organisms but genes. Ecological synergies are hard to model if natural selection operates on gene pools and there are no selective multipliers to reward co-operative strategies.

1.2 Symbiogenesis, constraint and evolutionary theory

Ecology and evolutionary biology parted company in the 1940s and many developments in the former have had little impact on the latter. *Symbiogenesis*, for example, the theory that multicellular organisms evolved by a creative synergy between different classes of micro-organism (Margulis 1970), implies that evolutionary synergetics and inter-species co-operation played a crucial role in the evolution of all life-forms with nucleated cells and mitochondria. The systems revolution also focused attention on synergetic processes, agency and self-organisation, developments that proved difficult to reconcile to the gene-centred model.

In order to bridge this gap, we must extend the modern synthesis in ways that accommodate two types of dynamic process. The first is a catastrophic winnowing of failures that drives rapid, directional change; the second takes place in stable attractors. Independent research on natural and human activity systems suggests that complex systems, when they become unstable, can flip from one attractor to another rather quickly, but may dwell in a stable attractor for extended periods. These 'stick-slip' or non-linear dynamics can only become manifest in situations where competitive and synergetic dynamics are both possible and systems can move from one type of dynamic to the other.

For many decades biologists and palaeoanthropologists have been trying to understand fitness in terms of competitive superiority and genes, a model that can accommodate directional change but struggles to represent co-operative synergy. Social anthropologists and archaeologists have often challenged that worldview by equating it with cultural imperialism and drawing attention to the ethical dimensions of eugenic research. This critique misfired because relatively few biologists have imperialistic ambitions and most are frankly baffled by the suggestion that they have. They often dismiss critique as the product of cultural relativism and/or professional jealousy (see, for example, Wilson 1998, chapter 9). The strongest reason for embracing gene-centred, competitive models of natural selection is that competitive constraints, where they occur, would reduce systemic complexity and present the scientist with a tractable research problem.

In general, disciplines tend to preserve simplistic theories as long as the corresponding problem-lode holds out. Often they hold onto them a little longer, while pressure builds for reform, power struggles are resolved and scientific institutions are restructured (Kuhn 1962). Archaeology and social anthropology ran out of problems that could be solved by the heroic model rather early, but the reserves of tractable problems were rather richer in zoology and microbiology. Recurrent arguments about the modern synthesis itself (Gould1982; Tattersall 2000; Foley 2001), sociobiology (responding to Wilson 1975), dual inheritance (Boyd and Richersen 1982) and studies of human uniqueness (Cartmill *et al*. 1986; Cartmill 1990) all suggest a paradigmatic tension between the heroic and synergetic models in biological anthropology - a tension that centres on the interface of ecology and evolution.

There is now growing evidence of a paradigmatic realignment in mainstream biology, where the modern synthesis is increasingly presented as a 'special' theory that has been generalised to situations where the evidence doesn't line up. We need a more general, *extended synthesis* (Pigliucci and Muller 2010) that gives proper weight to agency, co-operation, emergence, trait-mosaics, non-adaptive change, epigenetics and reticulated evolution (Jablonka and Lamb 2005; Arnold 2009; Kivell *et al*. 2011; Nei and Nozawa 2011). At least two special issues of scientific journals have reviewed the changing state of the art (Noble *et al.* 2013; Vane-Wright 2014, see also the following, more philosophical discussion). It is not necessary to re-state the case for an extended synthesis here.

This article about complexity, compassion and self-organisation in human activity systems has been written for two purposes. The first is to brief archaeologists about the extent and nature of the paradigmatic revolution in evolutionary biology. We believe that many of the most challenging barriers to integrating the humanities and biology are weakening, and a window of opportunity has opened for co-operative research that did not exist a decade ago. Every prehistorian, whether or not they wish to be involved in this integrative revolution, should be aware of these developments because they change the way we interpret the results of genetic studies in archaeology. Our second reason for writing is to formulate an alternative model of human evolution as a self-organising process, shaped by agency, co-operation and compassion. This article will look for the antecedents of the extended synthesis in early evolutionary literature. The paradigmatic fault lines of evolutionary anthropology can be traced back to the 19th and early 20th centuries. By revisiting older work we can sidestep many of the technicalities of molecular science and focus on the complex relationship between synergetic and heroic processes.

2. Early Evolutionary Theories and Darwin's Goldilocks Problem

Jean-Baptiste de Lamarck's (1830; 1914) evolutionary theory suggested a dialectic tension between the need to adapt to local circumstances and an endogenous tendency to become more advanced that was part of the alchemy of protoplasm, as it were. The endogenous predisposition drove successive generations up a ladder of ever-increasing complexity. Adaptation to local circumstances created side-branches, local deviations and evolutionary culs-de-sac. Darwin's theory eliminated the progressive tendency and explained the whole process in terms of adaptive dynamics. Darwinian organisms were agents in the weak sense that they over-produced young, which were obliged to 'struggle for existence'. There was no endogenous drive to complexify. Morphological and physiological attributes varied between organisms, and that variation, Darwin told us, was heritable.

Darwin was writing before the disciplines of genetics and ecology came into being and we must use words anachronistically to describe his work. Twentieth-century biologists used the word 'trait' to describe a heritable attribute. If we map this term onto Darwin's thesis, we can say that some types of organism (defined in terms of their traits) were better able to attract mates and more likely to thrive. The types that survived and bred were, in effect, selected by nature to transmit their traits to the rising generation. Natural selection was sufficient to explain any complexification that occurred so there was no need to invoke an endogenous tendency to become more complex. Darwin's theory of 'descent with modification under natural selection' could not work if survival were a lottery, or if variability were not heritable, or if traits were selectively neutral. His later work, as we will see, softened the last assumption, but the trait concept and natural selection remained key ideas.

Darwin needed to convince readers that the struggle for existence could never winnow populations so thoroughly that the survivors had no reserves of heritable diversity. He argued that heritable variability was omnipresent and that natural selection could multiply even tiny differences in a way that would separate the fittest from the rest. This argument placed Darwin in a bind that Stephen Jay Gould (2002) described as '*Goldilockean*'. If the wellsprings of heritable diversity were to flow too strongly, then the stream of new traits could easily become a driver of evolutionary change comparable to Lamarck's progressive factor. If supplies of heritable diversity were to run dry, however, natural selection would have nothing to work with. The flow-rate had to be 'just right'.

Darwin solved his Goldilocks problem by asserting that *natura non facit saltum* - nature does not make jumps. Evolution was slow and continuous. There need not be much variation, certainly not enough to drive change adventitiously, because the tiniest variability between individuals could activate selective multipliers and be bulked up over countless millennia. *Non facit saltum* was a fudge that ensured the wellsprings of heritable diversity never ran dry or burst the banks of scientific materialism. If readers of *Origin* rejected the *non facit saltum* assumption, Darwin explained, then they must necessarily reject his theory. Thomas Henry Huxley (1863; 1864) saw *non facit saltum* as an unnecessary weakness and formulated an alternative *salutatory* model that allowed for a stick-slip dynamic.

2.1 Saltation, emergence and non-linear dynamics

Hugo De Vries rediscovered the Mendelian model of genetic inheritance in the late 19th century. Early 20th-century genetic research (Morgan 1916; De Vries 1917) suggested that heritable traits were discrete. There were dominance-relations that could silence the expression of genes and polymorphisms that could protect deleterious gene-combinations from extinction. Many biologists saw this as a death-blow for the Darwinian model. The experimental evidence suggested: 1) that small-scale variability was often not heritable and 2) that heritable variation was quantised, so saltatory dynamics were probable.

The modern synthesis provided an empirically defensible alternative to Darwin's model, but struggled to accommodate later developments in systems ecology, many of which revolved around the concept of emergence. For a discussion of the relationship between emergence and the extended synthesis see Pigliucci (2014). Again, we will use language anachronistically to tease out what, to us, appear to be the key ideas.

In 1923 C. Lloyd Morgan, one of Thomas Henry Huxley's students, wrote a book titled *Emergent Evolution*. Morgan borrowed the word 'emergence' from the 19th-century philosopher George Henry Lewes (1875, vol. II. Prob. V. ch. iii, 369). Lewes distinguished two broad types of logical relationship. The first, following John Stuart Mill (1843, Bk. III. ch. vi. § 2), Lewes called *resultant*; the second he called *emergent*. We illustrate the difference by example.

Imagine an experiment in which a scientist uses a catapult to launch a small glider. A strong impulse moves the glider a long way and exposes it to wind currents longer than a weak impulse, but it seems intuitively obvious that the long flight can be decomposed, as it were, into a sequence of short flights, which could be executed to much the same effect. There would be some statistical discrepancies between the outcomes, but the whole and the aggregate of the parts would be broadly equivalent. Resultant systems like this one are *time-*

symmetric; their behaviour can be explained *ex post* and predicted *ex ante* because it can be decomposed into small steps and extrapolated, step-wise into the future.

Now imagine a scientist making many of these experiments, in one of which a dog chases the glider, picks it up and runs away. The scientist tries to retrieve the plane and the dog takes evasive action. Two things have happened: first, the outcome of this particular experiment clearly belongs to a different ontological class. The scientist/glider system has self-organised into a completely new type of dynamic. Second, that symmetry-breaking event means that the whole is no longer decomposable into the sum of its parts. The common-sense assumption of resultance (we would now say 'linearity') must be set aside. Lewes called these non-linear systems *emergent*. C. Lloyd Morgan used this distinction to explore a number of contentious ideas in evolutionary theory, including the question of agency among animals and the relationship between science and theology.

Emergent phenomena have two important properties: first they are time-asymmetric - past system behaviour is a poor guide to future dynamics; second, they represent a shift from one attractor to another. These two manifestations of emergence often correspond to different space-time perspectives. The winning numbers in a lottery, for example, are unpredictably emergent in the sense that they cannot be predicted *ex ante*. Viewed *ex post*, however, the effects of the symmetry-breaking event on those who possessed the winning ticket can be explained in terms of a self-organising transition.

2.2 Changing perspective to push emergence into the background

It is easy to push both features of emergence into the background by standing outside the system; viewing it from a distance. From the lottery organiser's perspective, for example, the symmetry-breaking event requires no explanation.

Lotteries sell very large numbers of tickets. On this scale, laws of large numbers stabilise probability distributions and allow the company to budget for wins and make a dependable profit. From this aggregate perspective the dynamics of the lottery system are broadly linear and time-symmetric. Its future behaviour can be predicted subject to some statistical uncertainty.

The emergence concept is a perennial source of misunderstanding between natural and human scientists. Many natural systems operate on scales that make it hard to imagine ourselves standing inside them, monitoring events as they unfold, or reviewing the narrative chain in memory. Some of these systems display patterns of reorganisation called 'metastability' that share many of the features we associate with ecological systems. When the power-button on the side of a laser pointer is pressed, for example, the system experiences a rapid shift between attractors, producing a very coherent light source. Similarly, when a dormant cress seed is planted and watered, the germination process begins rather quickly as the seed flips from the dormant attractor to the growing plant. In both cases there is a step-change as the system moves from one type of dynamic to another, but the change is predictable. If the battery isn't flat and the seeds are viable, we know what will happen.

It is sometimes helpful to distinguish surprising non-linearities from predictable ones. Systemic surprises are not merely *metastable* - capable of self-organising flips from one attractor to another - they are *innovative* in the sense that the course of history is changed by unfamiliar patterns of behaviour and events (Winder 2007). Søren Kierkegaard observed (see note[1]) that we make sense of our lives backwards but must live them forwards. This is so because our knowledge-state changes as we shift from the *ex ante* to the *ex post* perspective. Innovative, symmetry-breaking dynamics come to feel more like metastable system-flips as our knowledge state develops and we view those events from a distance.

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[1] What Kierkegaard actually said was: Det er ganske sandt, hvad Philosophien siger, at Livet maa forstaaes baglænds. Men derover glemmer man den anden Sætning, at det maa leves forlænds
which translates: It is well true, what philosophers say, that life must be understood backwards. But one should not forget the second sentence, that it must be lived forwards. 1843 (http://sks.dk/JJ/txt.xml, JJ:167)

In a metastable system, all the attractors are potentially knowable, *ex ante*. Under the assumption of metastability, an Upper Pleistocene hunter could have predicted the existence of dairy farming and a 19th-century curate could deduce that his church might one day be converted into a shopping mall. In an innovative system, however, the attractors are by-products of agency, co-operation and, in human activity systems, of shared beliefs. They could not be anticipated, even in theory, because the ability to do so would imply the existence of knowledge we do not yet have.

The difference between innovation and metastability is not 'out there' in the material universe; it is a perceptual structure that can be switched by changing mental perspective. When Einstein wrote to Franklin Roosevelt about the possibility of building an atomic bomb, for example, he was drawing attention to the fact that some atomic systems seemed to be metastable and could be bounced out of their stable attractors and transformed into huge amounts of energy. However the Manhattan Project initiated to develop the atomic bomb could never have been conceived in a world where humans had no knowledge of nuclear physics. It may seem obvious that physical matter is metastable and can be transformed into energy, and that the technology needed to do this was a mid-20th-century innovation, but the distinction is surprisingly difficult to objectify. The difference has to do with whether one locates scientists within the systems they are studying, or not.

2.3 Using system concepts to revisit Darwin's theory

We now have some of the key concepts needed to describe Darwin's model. The *non facit saltum* axiom implies that Darwinian systems are resultant in the sense that any trajectory can be decomposed into smaller steps that have similar aggregate effects. However, Darwin believed that these continuous trajectories could produce surprising outcomes. Using language anachronistically we can say that Darwin was comfortable with time-asymmetry and innovation, but not with non-linearity. The systemic surprise had to emerge gradually.

Unlike Lamarck, whose evolutionary theory was broadly philosophical, Darwin devoted a lot of space in *Origin* to evidence-based description. He was aware that the fossil evidence did not line up. Georges Cuvier (1825), for example, had assembled a mass of empirical evidence that geological epochs were punctuated by rapid collapse and the emergence of a new type of ecosystem with a new fauna and flora (discussed by Huxley1875-1889). Darwin played the taphonomic gambit familiar to any archaeologist. The fossil record was incomplete and patchy; the absence of evidence for missing links and linearity was not evidence of absence.

Darwin's commitment to *non facit saltum* may have been motivated by a fear of political theory. Darwin was a Whig, a scientist and a gentleman. Like all of his class, he would have been aware of, and appalled by, the French Reign of Terror. He would also have been uncomfortably aware of the Tory view that the Enlightenment and revolution were all of a piece, and that educating the masses was a recipe for insurrection. By insisting that the new system emerge from the old gradually, he was ensuring that his book could not be attacked as a pretext for revolution. By suggesting that natural selection could generate novelty, he acknowledged the possibility of gradual reform.

3. Plesionic Science and Reflexivity

Origin was the first book written by a reputable 'man of science' that treated interaction between purposeful neighbours in a physical neighbourhood as a worthwhile research focus. The work was shaped by Darwin's own small-scale observations, his work as a field naturalist cataloguing and describing new species and Wallace's seminal contributions to biogeography. These ideas - agency, conflict, co-operation and space-time pattern on many scales - are so deeply embedded in the culture of 21st century science that each discipline has its own words to describe them. We will use the word *plesionic*, from the

Greek *plesion* meaning 'neighbour', as an indicative term to describe this research focus.

Although Darwin's work was seminal in the sense that there are few plesionic texts in mainstream science before the 1860s, biologists were uncomfortable with the idea that non-human organisms were agents and kept Darwin's plesionic ideas beyond the pale of mainstream science. Darwin became a semi-mythic figure, often credited with ideas that owed more to Alfred Russel Wallace, Herbert Spencer, Karl Marx, mid-20th-century political theorists and, of course, the modern synthesis. The Cold War systems revolution and the many post-modern rebuttals of social engineering brought plesionic ideas into the ecological and anthropological mainstream, but traumatic memories of 'social Darwinism' were fresh and the plesionic dimension of Darwin's work was overlooked. *Origin* and *Descent* are no longer required reading and Darwin's direct influence on 21st century plesionic discourse has been limited.

It is now well understood that our species has evolved a range of empathic and linguistic faculties that fitted them for life in highly co-operative social units, which Darwin called 'tribes'. A Darwinian 'tribe' seems to be something more than an extended family unit; it is a primitive institution, common to all 'savages' that Darwin assumed would have a leader and some sort of mythic identity. Membership of a tribe would carry obligations and confer benefits.

Leaving aside the contextually loaded use of terms like 'savage', 'tribe' and 'leader', few anthropologists would now dispute Darwin's belief that early humans were pro-social and capable of altruism and that this pro-social tendency has a biological basis. The ability to acquire language and complex co-operative skills, for example, implies an innate expectation that the neighbourhoods we are born into will contain agents trying to communicate with us. Our species is so sensitive to agency that we recognise it even in situations where there are no agents. Synergetic multipliers have accentuated this predisposition to the point where most societies have protocols for communicating with these 'virtual agents'. Institutions like banks, polities and religious orders emerged as synergetic by-products of this cognitive predisposition.

A bank, a church or a government is not a convincing agent, nor is it capable of operating as a conventional plesionic system (see Figure 1), but the fact that we humans recognise, name and interact with institutions *as if* they were agents is ecologically significant (Winder N.P and Winder I.C. 2013, § 7). It would be perverse, in the plesionic sciences, to dismiss conflicts between institutions and individuals as 'delusions', when their ecological impacts are so profound. A person with a poor credit rating, for example, could argue with some justice that financial institutions were not agents and credit ratings were not 'real', but socially constructed. Nonetheless, the effect of that socially constructed consensus will constrain that person's freedom of action and, under certain circumstances, can reduce life-expectancy and destroy personal health.

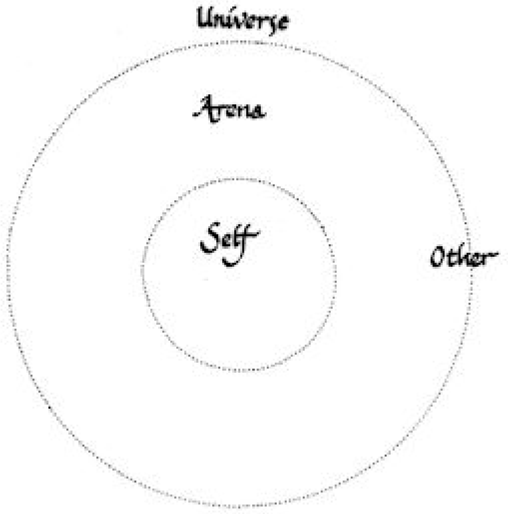


Figure 1: A plesionic system is an interval of space-time (an arena) containing, among other things, a group of one or more agents (self) working together to understand and possibly influence an interval of space-time that contains, among other things, some plesionic systems (other). A wolf feeding her cubs is a plesionic system, so too is the pack she runs with, the researchers who work on the wolves (at least when they are co-located), the herdspeople trying to keep wolves at bay (at least while they are co-located) and the committee that funded the research team. Some plesionic systems (wolves, say, or individual humans) are persistent, others are transient artefacts of purpose and role-playing. An institution like a bank or a religious community is incapable of coming together to act as a coherent unit. We humans have evolved the ability to interact with them as if they were 'virtual agents' and developed complex protocols and legal codes that regulate our interaction with them.

Research on human/environment interaction is invariably *reflexive* - the research community and the objects of research both have the same ontological structure; each 'reflects' the patterns manifest in the other. A research team, for example, is a group of one or more biological organisms trying to understand, and possibly influence, a group of one or more organisms. Reflexive systems tend to be inter-connected in a complex, fractalic way. The team may be studying early hominins, for example, but trying to influence peers, mobilise funding from research councils, engage effectively with the press and participate in university politics. This fractal network of reflexive systems means that it is not always possible to be sure what their research is really about (Winder N.P. and Winder I.C. 2013, section 1: §9).

3.1 Predictions - uncertain or meaningless?

All reflexive research can be interpreted from many perspectives, but most reflexive research is not plesionic. It operates on statistically stable populations, where laws of large numbers obtain, dynamics are presumed linear and prediction is at least locally possible. Many social science disciplines, for example, study and are funded by institutions that have little to do with plesionic complexity. To qualify as plesionic, a research programme must deal with patterns of interaction among purposeful neighbours in a physical neighbourhood. This usually involves studying space-time patterns on two or more scales and finding a dynamic balance between synergetic and constraint-based modes of explanation. Archaeology, anthropology, sociology, economics, geography, environmental science and political science have each produced many texts that could be described as 'plesionic' because they deal with interactions between neighbours in populated neighbourhoods. In practice, however, it is easy to evade plesionic complexity by stepping up a level of aggregation and working with statistically large populations of agents coping with institutional or ecological constraints in a stable attractor.

Herbert Spencer's (1864) *First Principles*, for example, deals primarily with institutional constraints, conflict and the heroic model. Political Marxism (Marx 1867) works in a similar way, ignoring agency and focusing on constraint and conflict in large populations. By downplaying the role of symmetry-breaking events, small-scale synergies and multiplier effects, Spencer and the political Marxists could argue that the ontology of nations and power-relations was stable and the past was a good guide to the future. Human affairs seemed time-symmetric and prediction was possible, subject to some statistical uncertainties that could be ignored at a first level of approximation.

It is relatively easy, in a reflexive study domain, to translate familiar patterns into an *ex post* narrative and then re-present that narrative as a causal structure that can be used to make predictions *ex ante*. Those predictions can be strengthened by synergetic multipliers that re-shape human activity systems - perhaps by changing policies or being used to justify the use of institutional power to enforce compliance. The result can be a dangerous self-fulfilling prophecy. This is not a theoretical risk. Archaeologists, biologists, sociologists and economists have, on occasion, been complicit in genocide. The social science wars and revolutions of the 20th century, for example, were often justified with reference to scientific authorities who had backgrounded plesionic complexity by up-scaling their own research.

The consensuses that crystallised around Spencerian liberalism and Marxian dialectic, for example, pitched the world into a series of heroic struggles that killed on an industrial scale. Ernst Schumacher (1973, 31) famously wrote that: 'The greatest danger invariably arises from the ruthless application, on a vast scale, of partial knowledge'. To this we would add that re-framing a plausible *ex post* narrative as a causal mechanism is a particularly risky strategy.

The contrast between Marx, Spencer and Darwin in this respect is striking. Darwin's *Descent of Man* (1871b) was an *ex post* explanation of human evolution in which agency was a significant and pervasive feature. Marx and Spencer, on the other hand, were predicting the future, downplaying the role of agency and emphasising the generality of their insights. Plesionic texts tend to be very sensitive to time-asymmetry and the unreliability of *ex ante* prediction. The difference is not that between certainty and uncertainty - all predictions are uncertain - it is that between meaningful and meaningless predictions.

A prediction of the mean annual temperature of Britain in 2050, for example, is uncertain but not meaningless because the land mass and the concept of temperature are unlikely to be changed much by human agency. To predict the GDP of Britain in 2050, however, would be meaningless because political and economic institutions can be re-shaped and even destroyed by socially constructed emergents and multipliers.

The dynamics of any human activity system are critically dependent on patterns of belief, habit and socially constructed consensus. If beliefs about virtual agents change, then institutional structures can become vulnerable very quickly. The result is often a power struggle between conservative and reforming factions that can destabilise whole ecosystems. We humans can innovate, changing the course of human evolution by changing our minds (van der Leeuw and Torrence 1989; van der Leeuw and Redman 2002). The ability to do this accentuates the time-asymmetry of human affairs, often generating cascades of innovations, each with emergent side-effects that cause collateral damage and trigger new responses. We have become 'apes in skyscrapers' (Dupré 2014, 310) whose co-evolutionary ecology cannot be understood without reference to agency, habit, purposeful action and belief (Corning 2014).

4. Darwin's Multi-scale Approach to Human Evolution

There are significant scale-disparities in Darwin's theory. Viewed from the micro-scale of demographic events, for example, species and genera are long-lived, almost static structures. Species, when they change, do so on the meso-scale, where laws of large numbers apply and Darwin's principle of *non facit saltum* ensures that they will do so in a continuous, almost linear way. Natural selection is manifest at this meso-scale as a selective field - comparable to a magnetic or gravitational field - that shapes and re-shapes the destinies of populations. These selective fields go out of focus as one zooms in on the micro-perspective of demographic events, because laws of large numbers collapse and time-asymmetry becomes significant. Sometimes individuals get lucky against the odds. Sometimes their luck slides the other way. Those small-scale deviations between observed and expected behaviours are often damped out by synergetic 'friction' (i.e. conflict and competition). Occasionally, however, they may create co-operative opportunities that are amplified synergetically.

These three perspectives form a recurrent theme in evolutionary anthropology and we need some terms to describe them. Historians of the *Annales* school, following Fernand Braudel (1980), refer to them as event-time (*histoire événementielle*); conjuncture and deep time (*longue durée*). Archaeologists interested in the longue durée often favour a 'culture history' approach that uses the methods of typology, seriation and description to describe system ontology. The processual focus would shift attention to the meso-scale or conjuncture (Binford's 'middle range') because this is the level at which laws of large numbers kick in, processes stabilise and prediction is locally meaningful. Events form a small-scale narrative chain of the sort that often appeals to post-processualists. Some of these events do little more than add human interest to the work, but others can trigger cascades of synergetic reorganisation that sweep established processes and typologies aside.

In a metastable system, symmetry-breaking events bounce dynamic systems from one pre-existing attractor to another and all that changes is the processual conjuncture. In an innovative system, however, conceptual taxonomies change too and this becomes manifest as a behavioural and cultural 'revolution' that sweeps old categories away and changes the system's deep-time structure. These innovations can be explained, *ex post*, with the wisdom of hindsight, but could not possibly have been predicted, *ex ante*.

Darwin's theory required, rather implausibly, that changes at all three levels (demographic event, conjuncture and deep-time) be smooth and continuous. By the time Darwin was writing *Descent of Man*, he and Alfred Russel Wallace were beginning to disagree about human evolution. Wallace believed evolution was driven by selective winnowing that eliminated failures and adapted the population to local circumstances. He also believed in the existence of a universal intelligence that exempted some humans and higher life-forms from the struggle for existence (Wallace 1914). Wallace drew a sharp line between natural and artificial selection. Natural dynamics were shaped by the heroic struggle for existence and the selective constraints that punished failure. Synergetic dynamics, including human agency, were supernatural phenomena.

Wallace's universal intelligence was no divine patriarch, but a necessary corollary of his ideas about human intelligence and the constraining nature of natural laws. If humans were agents, then that agency required a supernatural explanation. Henri Bergson (1907), reacting against Darwinian atheism, developed a similar argument in his book *Creative Evolution*. *Descent* was Darwin's principal contribution to anthropology. In it, he felt obliged to back away from some of his earlier arguments. He acknowledged, for example, that too much emphasis had been placed on natural selection. By now he had adopted Spencer's phrase 'survival of the fittest' as a punchy alternative to formulations like 'descent with modification under natural selection' and wrote:

> '...I now admit ... that in the earlier editions of my *Origin of Species* I probably attributed too much to the action of natural selection or the survival of the fittest. I have altered the fifth edition of the Origin so as to confine my remarks to adaptive changes of structure. I had not formerly sufficiently considered the existence of many structures which appear to be, as far as we can judge, neither beneficial nor injurious; and this I believe to be one of the greatest oversights as yet detected in my work.' (Darwin 1871a, Vol. 1, 152).

This passage is significant because it strengthened Darwin's thesis that the wellsprings of heritable diversity would never dry up. He no longer had to argue that any variability, however small, would be heritable. If some traits were not selected, there would be an untapped pool of heritable variation that could underpin new ways of becoming fit at some time in the future. The word *exaptation* is sometimes used to describe this phenomenon (after Gould and Vrba 1982). Some of these non-selected traits may have exapted organisms to life-ways that only came into being after patterns of plesionic interaction had activated synergetic multipliers.

Where Wallace had solved the problem of human agency by making a Cartesian distinction between natural and supernatural domains, Darwin (1871b, Vol. 1, 163-65) solved it by writing about natural selection operating at the level of the 'tribe', and about peer-pressure - particularly sensitivity to 'praise and blame' within the community. Darwin did not need nebulous god-agents to explain higher cognition, co-operation and agency. Humans that sacrificed immediate gain for the well-being of the tribe, though they appeared to have lost fitness at an individual level, would have gained compensating benefits by being embedded in a more cohesive and viable tribe. (For a 21st century take on these ideas, see Nesse 2007 and Tognetti *et al*. 2012.)

4.1 Selection on two levels

It is important to understand, as one reads the group-selection arguments in *Descent*, that group-selection is not presented as an alternative to the model in *Origin* that has the individual as the locus of selective action. Rather, it introduces a second selective field that shapes the destinies of 'tribes'. It is also important to remember that a Darwinian 'tribe' is not just a mob of great apes moving through the landscape. Tribes are institutional structures that exist in the minds of affiliates by negotiation and common consent. The interplay between these two Darwinian systems, one ideational and the other corporeal, was sufficient, Darwin believed, to explain the emergence of pro-social altruism. For Darwin, the tribe seems to be a hybrid construct - partly a physical community of co-operating organisms and partly an abstract sense of identity, obligation and belonging.

The model Darwin presents in *Descent* and the later editions of *Origin* has a complex structure. Natural selection had become a bridging concept that not only linked dynamics on three space-time scales (event, conjuncture and deep-time) but could occur simultaneously in two separate contexts. There was one three-level system governing the fates of individuals and another governing the fates of tribes. Altruism, which can only be valorised at the event-level as patterns of co-operation between neighbours, influences the fitness of the social unit as a whole and this communal fitness (or the lack of it) feeds back to modify the selective landscape that shapes the destinies of individuals.

Darwin clearly believed that the selective field that shaped the evolution of tribes, and the selective field that underpinned descent with modification at the individual level must have reinforced each other to act as a synergetic multiplier. The upshot of this two-level interaction was the emergence of a new species - a smart, sociable, altruistic ape. However, it is equally possible, indeed likely, that the traits that would enhance the tribe's fitness would so severely compromise the fitness of carriers that the two selection pressures would cancel each other out. Stable, cohesive tribes containing self-sacrificing altruists could only have emerged in circumstances where the two dynamic systems reinforced each other. There had to be a congruence of selective interests at the levels of the tribe and the individual.

Had these two types of dynamic been locked into a double-bind, with group selection favouring tribes that contained altruists and individual-based selection punishing altruism, then the evolutionary system would have become trapped in a stable attractor that would have prevented directional change. In cybernetics, the difference is often described as that between positive and negative feedback loops. Negative feedback is more likely to act homeostatically, preventing irreversible change and maintaining stable attractors. Positive feedback is more likely to become manifest as a synergetic multiplier that drives directional change. In *Descent*, Darwin implies that the two selective dynamics must have reinforced each other to create a positive feedback loop.

4.2 *Caveat lector*

It is easy to read *Origin* and satisfy oneself that co-dynamic interaction across two space-time scales (event and conjuncture) generates emergent, species-like patterns on a third, deep-time scale. It is also easy to establish that *non facit saltum* seems to imply almost-linear dynamics and time-asymmetry. *Descent* explicitly couples two of these three-level Darwinian systems, each with a different space-time signature, and uses them to explain the emergence of co-operative and compassionate behaviour. But we have no reason to believe Darwin would have found our account of selective fields, cross-scale lock-in, negative feedback and emergence helpful. He was certainly not interested in circumstances where evolution could become gridlocked by cross-scale lock-in and negative feedback, and resisted all attempts to persuade him to relax those continuity assumptions and admit the possibility of stick-slip dynamics.

Thomas Henry Huxley, who by this time was convinced that *non facit saltum* had been a mistake, would probably have been more alive to the possibility that multi-scale dynamics could become grid-locked in a way that would generate a saltatory dynamic, but Huxley was no theoretical biologist. He was scathing in his rebuttal of theory, describing logical consequences as 'scarecrows for fools and signposts for wise men' (Huxley 1874). His approach to evolutionary dynamics was empirical.

Darwin and Huxley did not anticipate developments in 20th-century complexity theory, but they had operationalised all the concepts needed to describe situations where pairs of evolutionary systems, each with its own hierarchy of three-level dynamics, could either interfere with each other to create a gridlock of cross-scale constraints or reinforce each other to emerge as a new species of dynamic system. However, it took biologists the better part of 100 years to put all these pieces together and get the model past the paradigmatic veto and into publication (Eldredge and Gould 1972; Gould and Eldredge 1977). Once such a model is in place, it becomes possible to explore the scope for locally linear, equilibrium-seeking dynamics punctuated by symmetry-breaking events and synergetic multipliers that allow new types of system dynamics to emerge in that characteristic, non-linear way.

5. Fit Genes Hide

Our species produces a substantial proportion of individuals with disabling and seemingly maladaptive traits. Natural selection, the ruthless elimination of unwanted infants and genocidal cleansing have not changed this. The heroic model of evolution as a crucible that burns away the dross of humanity and purifies the race has been tested thoroughly and refuted. Evolution doesn't work that way.

It is possible to argue that some high-functioning but apparently maladaptive traits might have contributed to group fitness in the heroic sense (see, for example, Nettle 2005; Spikins 2009; Hagen 2011; Nesse 2011; Nettle and Bateson 2012), but hard to explain the emergence of challenging behaviours and chronic dependence among primates that did not already possess advanced cognitive skills and high levels of altruism. Organic evolution remains the simplest natural explanation for the empirical evidence of contemporary anthropology, but the modern synthesis is frankly implausible. It requires us to argue that our ancestors became better equipped for survival and reproduction than more conventional chimpanzees because they produced hairless, helpless, congenitally macrocephalous infants.

In human populations, genetic evolution seems to be an equilibrium-seeking process that creates resilient complexes of checks and balances that protect deleterious genes from selective winnowing. One of the earliest illustrations of this is the textbook example of sickle-cell anaemia. The sickle trait is autosomal recessive, and is only expressed when the infant receives a copy of the allele from both parents. When expressed, sickle cell anaemia is very debilitating, and shortens life expectancy significantly. Individuals that carry one copy of the sickle gene and one normal gene are generally healthy and better able to resist malaria than those with two copies of the normal gene (Allison 1954). In populations where the allele is rare, the sickling trait is unlikely to be expressed and so will be able to hide from natural selection.

Another textbook example of inheritance patterns that seems to buffer populations from irreversible change is polymorphism. In the snail *Cepaea nemoralis*, for example, colour and banding patterns are governed by a handful of alleles. Different colour and banding morphs are better able to avoid predation on different types of vegetation, but the whole spectrum of traits can be reconstructed from the genes of survivors even in situations where some forms have been eliminated by predators. This means that even when environments change quite substantially from generation to generation, the snail population survives by re-assembling all the critical morphs.

These well-documented examples suggest that some of the 'fittest' genes are those that swim in large gene pools buffered against irreversible change by laws of large numbers. They hide behind dominance relations or become incorporated into stable polymorphisms. In situations where they are expressed, the fittest genes are those that code for some benign trait that does not undermine the carrier's viability or destabilise the attractor that sustains it. Possibly the fittest genes of all are those that code for nothing or mitigate the destabilising effects of deleterious genes. They may slip into the 'junk' DNA of a really successful host species or hitch a ride across species barriers with a virus - ideally one that never kills its host. Fit genes certainly do not go head-to-head with other alleles in a competition that only allows the strongest to win through. Genes maintain their fitness by hiding from natural selection.

5.1 Equilibrium-seeking dynamics

The success of this evolutionary strategy is clear. Even profoundly disabling traits may be hard to eliminate from the human gene pool by natural selection alone. At the time of writing, genetic engineering holds the strongest prospect of effecting irreversible change on the human gene pool, though it is unclear whether gene-focused therapy will eliminate maladaptive traits altogether, or provide better palliative care that will hide them from natural selection more effectively.

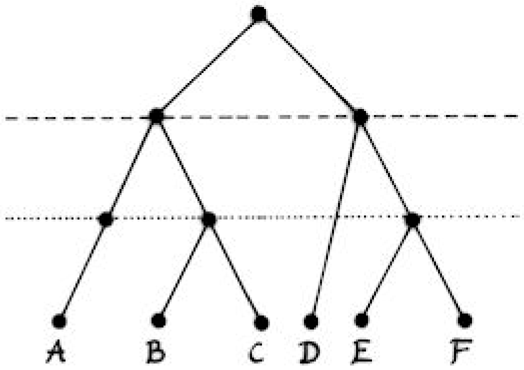
If we were to generalise this equilibrium-seeking model of fitness from genes to organisms, then the fittest offspring would be those that could cope with the challenges their parents' genes and their environment threw at them. The fittest parents would be those that facilitated these coping strategies in their own infants. Our upright stance, browless skulls, short arms, weak teeth, hairless bodies, extended period of infant dependence and feet so straightened that they can neither grasp nor climb effectively may not have been adaptive in the heroic sense of the word. Some of these traits could instead have arisen through symmetry-breaking events that flushed unexpressed genes out of hiding, triggering a dramatic loss of fitness.

These upwellings of genetic diversity would accelerate selective winnowing, flipping the system from a synergetic to a heroic dynamic that would further destabilise the gene-pool. This epic tale of tragic death and heroic survival would continue up to the point where viable coping strategies emerged. Only then could synergetic multipliers come into play that would allow organisms to negotiate new ways of being fit. A new dynamic attractor would have been located, with a new processual conjuncture, deep-time structure and ontology.

5.2 Reticulated evolution

The palaeoanthropological evidence, reviewed in detail elsewhere (Winder and Winder 2014) is not consistent with the model of evolution as a process of divergence between reproductively closed populations. Indeed, if a clear hierarchy could have been characterised, the problems of human origins would have been solved long ago. Rather, the fossil evidence suggests a patchily distributed, genetically open population of great apes organised into close-knit pro-social units.

Modern primates sometimes have complicated sex lives. Hybrids between species and, on occasions, between genera have been observed, both in captivity and within wild populations. It is easy to see how these traits, complemented with matings between close kin, would facilitate survival among tiny populations driven through demographic bottlenecks. These are situations where conventional mating strategies and barriers to hybridisation would lead to extinction. In order to survive, individuals must mate with close kin or, on occasion, with members of another species. The result would be a braided stream or *heterarchy* of crossing and re-crossing lineages in which a mosaic of morphological and physiological traits were manifest (see Figures 2 and 3 & Winder and Winder 2014). Darwin's solution to the Goldilocks problem would not work in these circumstances because upwellings of hidden traits would destabilise established attractors.



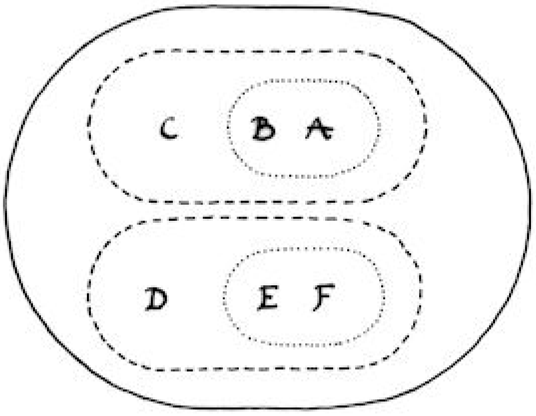
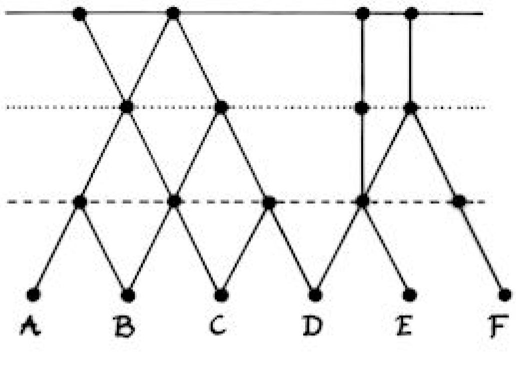


Figure 2a: In the Modern Synthesis populations are presumed to have been organised into reproductively isolated units that evolve by divergence to create a strict Linnaean hierarchy of forms (a).
Figure 2b: The Venn diagram (b) represents the classification obtained by analysing the hierarchic structure.



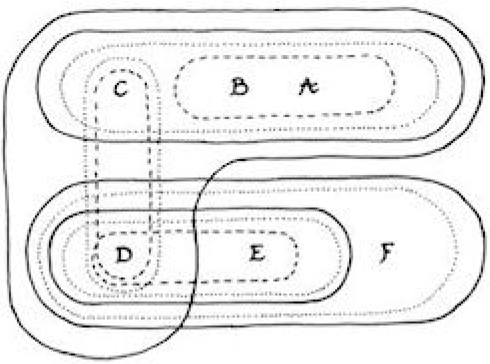


Figure 3a: The evidence for primates suggests a network or heterarchy (a) of divergent and re-crossing lineages.
Figure 3b: Note how the classification (b) contains complex, cross-cutting boundaries.

The effect of these upwellings would be to create a meta-selection pressure that favoured plesionic systems able to acquire coping strategies. Strong dominance/recessive relations and modifier genes that could prevent the expression of deleterious traits are common biomolecular coping strategies. However, behavioural flexibility, social learning and the ability to innovate may also have been significant. There is a growing body of archaeological and primatological evidence (Hublin 2009; Spikins *et al*. 2010) consistent with the hypothesis that populations which were a little smarter and more compassionate would be able to mitigate the effects of natural selection faster and discover new ways of becoming synergetically fit again.

The last 6-7 million years have seen more positive selection in the chimpanzee line than our own (Bakewell *et al*. 2007), a result consistent with the hypothesis that chimpanzee lineages did not acquire the flexible, co-operative strategies needed to hide deleterious genes from selective winnowing. Our ancestral lineages seem to have formed a braided stream of crossing and re-crossing flows. These flows would have converged and deepened into a small number of recognisable species, many of them capable of flexible social learning, pro-social, empathic, and compassionate.

5.3 Molecular clocks and reticulated evolution

Many of the methods of molecular biology, including techniques for studying cladistics (patterns of evolutionary relationships) and the molecular clocks used to estimate the time elapsed since two populations diverged, are critically dependent on a hierarchic model of evolution. A genetically closed ancestral population is presumed to have diverged repeatedly, creating a hierarchy of well-defined ancestral lineages (see Figure 2).

Molecular clock methods, for example, assume that mutations accumulate at a more or less steady rate and that lineages that have diverged will never again reconverge. Under these assumptions it is a relatively simple matter to get a rough estimate of the time that has elapsed since two lineages diverged. You just count the differences between the two species' genomes, divide by two and then work out, with reference to the 'background rate' of mutation (how many mutations, on average, per generation), how long it would have taken to reach the current state.

The molecular clock method can only work if the mutations that occur accumulate. In situations where heroic selection pressures are extreme, deleterious mutations will tend to disappear from the genome. The effect of this would be to slow the molecular clock down at times when the system was changing rapidly and speed it up again when the system entered a stable attractor. Natural selection could offset this speeding up and slowing down, of course, but there is a complex co-dynamic feedback to be considered between factors that generate mutations and those that eliminate them.

As if this were not complicated enough, there is now evidence that mutations, far from occurring at random, are clumped in 'hotspots' in the genome and occur at rather different rates in different species. In *E. coli*, the model organism for much genetic research, scientists have found that across some ~2600 genes neutral mutation rates can vary by a factor of 10 or more (Martincorena *et al*. 2012). Primates seem to have hotspots and coldspots in their genomes too (Bailey and Eichler 2006) and it is reasonable to conceive of the system in terms of many molecular clocks, each ticking at a different rate. Moreover, if mutations are concentrated at hotspots, it seems reasonable to expect that the same mutation could have happened many times in different populations and, on occasion, could have reversed itself by counter-mutation.

The evidence suggesting reticulated evolution implies that hominin populations were probably vulnerable to periodic crashes, demographic bottlenecks that would have flushed deleterious traits out of hiding and hybridisation events that would move genes between separate lineages. Under these circumstances the molecular clock could speed up, slow down and even run backwards. Figure 4 shows an illustrative example, a tree connecting three species in which lateral gene flow caused by hybridisation drives the molecular clock backwards.

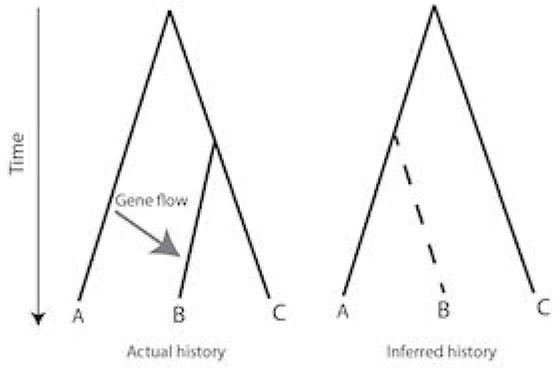


Figure 4: Gene flow and biological clocks. These two trees show a hypothetical system in which three species, named A, B and C, diverge from one shared ancestor (to the top of the figure). The actual genetic history is shown on the left, with A diverging from B and C first and B and C from one another later. If this were all that had happened, the assumption of hierarchy would be justified and molecular clock methods would work straightforwardly. However, as the left side tree shows, in actual fact our system includes some subsequent gene flow between species A and B (indicated by the arrow). This would cause A and B to share some genes to the exclusion of C, and affect the way we reconstructed their relationships. The inferred evolutionary tree (on the right) would be distorted because the molecular clock would appear to run faster on some branches than others. Specifically, the B-C divergence would be pushed back into the past and the A-B divergence brought forward. The topology of the inferred tree would be a poor guide to evolutionary pathways, not because the data were incorrect, but because the hierarchic assumption would be unjustified.

5.4 Refugial landscapes

Many evolutionary anthropologists and archaeologists have found themselves thinking in terms of refugial landscapes - places where great apes can find relief from predation and/or access to critical resources. It has been argued, for example, that complex, tectonically active and broken landscapes may have been key refugia for early hominin populations and an important bridging environment between forests and open landscapes (Winder *et al*. 2013). Refugial landscapes are thought to have become important again in the evolution of *Homo* during the successive glaciations and deglaciations that dominated the Eurasian Pleistocene (Stewart and Stringer 2012). These authors in fact propose that a process of interglacial expansion across Eurasia by *H. heidelbergensis*, followed by glacial contraction into several refugia, some in Africa and others perhaps in Europe and/or the Levant, might have been responsible for the divergence of Neanderthals, humans and (potentially) the Denisovans. This would suggest that their divergence is not solely the result of constraint-based (heroic) selection, but might also involve founder effects and the random flushing out and accumulation of mutations in small populations.

Of course, these glacial refugia are different geographically and environmentally from those proposed for earlier African species, but their use would have produced similar demographic and genetic signatures in both groups, just as they have done in various other species (Stewart *et al*. 2010). The evidence for reticulate evolution and disrupted molecular clocks just summarised would be fully consistent with one or more extended periods of low-density presence in refugia, where populations were perturbed over centuries, possibly even millennia, by many waves of immigrants and by expansive radiation when conditions were favourable. If gene flow occurred between successive waves (as the new DNA data on Neanderthals and Denisovans seems to suggest; see Winder and Winder 2014 for a review), then populations would have remained genetically vulnerable and unstable over long periods. Cascades of physical, behavioural, genetic and ecological emergents would be likely and some of the organisms and communities that emerged would have been able to leave the refugia and colonise new habitats.

6. Causality in the Hard Sciences

The modern synthesis of evolutionary biology uses a classical model of causality as constraint. Populations develop as they do because failures are either suppressed or eliminated by natural selection. The result is a negative feedback loop; a trial-and-error dynamic that means the only mechanism available to generate novelty is chance mutation. Darwin understood that that evolution could not have occurred without a complementary positive feedback system; a 'trial-and-success' dynamic (Lorenz 1977) capable of generating new patterns and amplifying them to create new attractors. Purposeful action and selective co-operation were key features of Darwin's theory. The modern synthesis struggles to accommodate concepts like agency and emergence, not because they are difficult to understand, but because of an informal consensus that the purpose of scientific research on human evolution is to make the past seem predictable. Innovations are irreducibly unpredictable.

In mathematical systems-modelling, the words 'validation' and 'verification' are used in ways that clarify this expectation. To *validate* a computer model, for example, would be to ensure that it actually simulates the causal mechanism the scientist has in mind. With complex, multi-agent models, validation is a non-trivial task because these operate at or near the theoretical limits of computability. Once the model has been validated, the next step is to *verify* it empirically by using it to 'predict the past', as it were.

Verification is relatively straightforward in situations where one is simulating the workings of a well-designed system that has been created for a specific purpose. The concept of verification becomes a philosophical minefield, however, when one is studying ecosystems where social learning, habits and purposeful co-operation shape system dynamics. Accidents of history and geography and expedient, small-scale patterns of co-operation can generate new patterns of learning and forgetting that change the course of history in an utterly unpredictable way. These self-organising events can be explained *ex post*, but not predicted *ex ante* because they are contingent on knowledge we do not yet have and habits we have not yet begun to acquire.

Any systems model that slavishly predicted the same historical trajectory every time we ran it could reasonably be said to have been *invalidated* - it has been over-constrained in a way that forces it to simulate one historical trajectory (the history that actually happened) when we have strong reason to believe this time-series was one of an unbounded set of possible histories, many of which we cannot even imagine.

Plesionic complexity places scientific anthropologists in a difficult bind. Either they repudiate conventional, constraint-driven models of causality and abandon hard-science method, or they push plesionic complexity beyond the scientific pale. There is scant help for them in pop-science literature about chaos and fractals or critical humanism because so much of that literature treats narrative explanation as if it were a causal mechanism. Butterflies do not cause hurricanes. If they did, scientists could predict hurricanes by monitoring butterflies and prevent hurricanes by controlling butterfly behaviour. In the same way, individual human beings do not cause genocidal wars or social exclusion. Institutional constraints and power-relations constrain human agency in ways that cause both the social exclusion *and* the tenor of contemporary discourse.

6.1 'Anti-cause' and innovation

Individual humans are a little like loose hairs on the mad dogs that are institutional conjunctures. Some drop out and are sucked into the vacuum cleaner of posterity. Some hang on and are damned or feted with the rest of their generation. The social constraints that drive these systems can reasonably be described and modelled in causal terms. Although there might seem to be some selective winnowing in effect that might eliminate certain types, each generation seems to re-create the full range of ideational morphs and predispositions. As with those polymorphic snails being preyed on by birds, there may be very real suffering and premature death, but no irreversible evolutionary change.

There is, however, one key respect in which the 'shaggy-dog' metaphor fails. Sometimes institutional constraints are weakened enough to allow an influential few to 'think the unthinkable' and shape opinion. Symmetry-breaking events can occur that activate synergetic multipliers, sweeping old causal constraints aside and allowing new dynamic patterns to evolve. These events cannot be said to *cause* the new synergetic conjuncture because no-one could have predicted how things would turn out. It only becomes clear with hindsight that they and the mythic histories woven around them played a pivotal role in shaping the emergent dynamic.

Causal constraints exist *de facto*. Their effect is to make system dynamics locally predictable, subject to some estimative uncertainty. However plesionic complexity also exists. In intervals of space-time where institutional constraints are weakened, time-symmetries can be broken, reorganising system dynamics from the bottom-up. The central thesis of this article has been that anthropologists need evolutionary models that can accommodate and, if possible, explain the dynamic balance between causal constraints and 'anti-causal' emergents in human activity systems.

Darwin's model of human evolution implies that 'tribes' can evolve by descent with modification. Whether he was aware of it or not, the tribe concept as developed in *Descent* was a hybrid structure - part plesionic system and part institution - a 'virtual agent' demanding fealty and constraining human action. This institutional model contrasts strikingly with 20th-century 'dual inheritance' theories, which suggest that it is not tribes, but behavioural memes or culturally embedded traditions that emerge, hijack human bodies and use them to colonise space and time. Stephen Shennan's variation of the dual inheritance model, for example, suggests that material culture traditions evolve by descent with modification (Shennan 2000).

One of the problems Shennan acknowledges with the dual inheritance model is that of knowing how qualitatively new, founder-cultures come into being. The Darwinian model resolves that problem by allowing that stable institutions constrain human actions and that these constraints are reflected, albeit imperfectly, in human behaviour. Unlike material culture traditions or behavioural memes, which are etic categories imposed on a study population by the scientific observer, institutions are emic structures that exist in the minds of the populations under study. We may not know what prehistoric institutions were called or how they were operationalised, but we have good ethnographic reason to believe they existed.

Those named institutions would have acquired spokespeople and rules of good conduct. They would have competed for affiliates and found ways of attracting or coercing individuals into compliance. They might even have entered into co-operative alliances that created a stable trade-off between the costs and benefits of institutional affiliation. If that trade-off were to evaporate, then individuals would abandon the institution, and its ability to constrain human behaviour would be compromised. Institutional collapse would unlock the adaptive potential of individual humans, allowing new traditions, institutions and behaviour patterns to emerge anti-causally.

7. The Vulnerable Ape Hypothesis

Ancestral human populations were exapted to social learning, collective forgetting and patterns of interaction with the virtual agents we have been calling institutions. They must also have acquired the range of genetic dominance-relations and stable polymorphisms needed to protect rare deleterious genes from expression, at least in statistically stable gene pools. The most serious genetic vulnerability would have arisen when previously isolated populations came together and exchanged genes. The situation would have been genetically analogous to that which we observe in cultivation, where small, genetically diverse founder populations give rise to a range of morphological 'sports' and hybrids. Hugo De Vries (1917) called these sports 'mutations', but the modern synthesis limits the word to *de novo* copying errors in the genetic code. De Vries' 'mutations' were saltations - sports arising as a consequence of genetic bottlenecks, hybridisation, hot-spots in the genome where mutations tend to occur, and polymorphism.

Our cognitive skills, flexible learning and compassionate impulses arose as part of a package of coping strategies that enabled these 'sportive' populations to co-exist with genetic risk. There is no need to posit a gradual selective constraint that weeded out the less smart and less compassionate. In this genetically sportive community saltatory leaps could activate synergetic multipliers and come to predominate within a few generations. After a period of isolation and restabilisation, the next bottleneck or influx of immigrants could produce further emergents, driving cascades of rapid evolutionary change.

The model of early human evolution we have developed here could, with some justice, be described as the 'vulnerable ape' hypothesis. It suggests that many of our characteristically human traits arose as by-products of hereditary disability and genetic risk. The only reason our hairless bodies, short arms, straight feet, macrocephalous offspring with long periods of infantile dependence and strong predispositions to neurotic and depressive illness are not described as disabilities is that opinion-shaping institutions now present them as normal, or even heroically superior to the ancestral condition. Individuals who deviate from this ideal - infants who struggle to acquire language, have boundless reserves of energy, limited self-awareness and little interest in the mind-games of conventional education - are considered 'disabled'.

Our human ability to construct distinctions of this sort and to empower or exclude neighbours as circumstances change was not *caused* by genetic challenges in the extreme past any more than airborne dust-grains cause snowflakes. Institutional power-relations arose as emergent by-products of a complex package of cognitive and behavioural coping strategies that opened up a range of possible futures and closed some possibilities down.

The vulnerable ape hypothesis suggests that the early prehistory of our species would have produced a fossil record that cannot be resolved into a clear, divergent hierarchy of coherent demes and clades. Rather, we should expect a mosaic of trait combinations that generates a network of divergent, parallel and convergent lineages. The fossil evidence is indeed consistent with this interpretation. Moreover, the archaeological evidence suggests that disabled individuals do indeed occur in the archaeological record and that their close neighbours sometimes protected them from the effects of natural selection (reviewed in great detail by Spikins*et al*. 2010). We believe the archaeology of compassion and co-operation to be an important open area of research for 21st century archaeology (Spikins 2015) and see this article as a contribution to that research initiative.

8. Postscript: Archaeology and Future Studies

Archaeology provides many opportunities for studying innovation and cultural evolution. The results of this work are potentially useful to scientists working on contemporary society and future studies. The purpose of future studies research, in a nutshell, is to provide guidance to those whose task is to change the course of history without disrupting the fabric of contemporary society. It is therefore important to understand how historical systems evolve. Archaeologists, if they are willing to master the technicalities needed to communicate across disciplinary boundaries, can contribute meaningfully to this work. This article, for example, is one of a short series of publications arising through collaboration between two international, trans-disciplinary research projects. One of these, DISPERSE, is a pure archaeology project dealing with landscapes and human/landscape interaction in early prehistory. The other, COMPLEX, is a project searching for pathways to a low-carbon economy in Europe that happens to be led by an archaeologist. COMPLEX is not an isolated phenomenon; it belongs to a growing corpus of 'future studies' research on both sides of the Atlantic influenced by archaeological perspectives.

The cross-fertilisation between archaeology and future studies has been explored in a range of papers, reviews in the 'grey literature' of policy-relevant science and books; see, for example, Winder 1999; van der Leeuw and Redman 2002;

Redman and Kinzig 2003; Bodley 2012). Archaeologists bring an important, deep-time perspective to future studies. Those trained in the systems approaches to socio-natural science have a clear understanding of human/environment interaction and long-term environmental change. We also tend to be aware of the difference between *ex post* (backward-looking) and *ex ante* (forward-looking) time perspectives and time-asymmetry. These historiographic insights have many practical applications.

One of the great advantages of integrating insights from pure and applied research is that academics, if they are so minded, can raise awareness of problems that are not yet hot political issues. Bertrand Russell did this rather neatly when he wrote: 'A stable social system is necessary, but every stable social system hitherto devised has hampered the development of exceptional artistic or intellectual merit. How much murder and anarchy are we prepared to endure for the sake of great achievements such as those of the Renaissance? In the past, a great deal; in our own time, much less.' Russell (1961, 490).

There is no doubt that human creativity has been a two-edged sword. Compassionate impulses that worked reasonably well on a human scale are increasingly defeated by the constraints and conflicts of interest that characterise modern institutions. The compassionate ape has become the genocidal ape, whose actions have entrained planetary life-support systems. So profound has this reorganisation been, that many scientists believe humans have wrought irreversible changes in the atmosphere, biosphere and lithosphere. We have entered a new geological period, the *Anthropocene*, with a new possibility space of attractors. Here Russell reminds us that human creativity is also a source of joy and fulfilment. If the price of protecting planetary life-support systems from collapse were that our descendants would evolve into mindless automata with the innovative competence of an ant or a naked mole-rat, how many intellectuals would willingly pay?

The problem we face, then, is that of reorganising human affairs in a way that protects planetary life-support systems without compromising human creativity and cultural diversity. As Russell (1961, 490) mildly observed: 'No solution of this problem has yet been found, although increase of social organisation is making it continually more important.' In order to solve the problem, we need to understand what sorts of attractors our cognitive skills have exapted us to colonise, and to characterise the patterns of intra- and inter-species co-operation likely to bring desired attractors into being.

In an earlier paper on primate/landscape interaction in the Plio-Pleistocene period, for example, we observed that anatomically modern humans have become co-operative resilience feeders, perturbing stable, unproductive ecosystems in a way that drives them to the edge of their basins of attraction so they can exploit the fluxes of energy and resources released as those ecosystems run back into the attractor (Winder I.C. and Winder N.P. 2013). This can be a risky strategy because the perturbations increase selective stress within the ecosystem that can trigger a rapid, 'heroic' dynamic that destroys the attractor completely.

There is scope for equivocation about when our species became resilience-feeders. It is possible to argue that these behaviours are as old as the genus *Homo*, but unquestionable that the resilience-feeding strategy became much more intensive at the end of the Palaeolithic period. The evidence of resilience-feeding behaviours in the Neolithic, for example, is unequivocal. Agriculturalists in many regions of the world cleared climax vegetation and modified the distribution of plant and animal resources in ways that created qualitatively new ecological attractors. In arid and semi-arid regions, some of those agro-ecosystems collapsed as a result of deforestation, desertification and salinisation, but the Neolithic attractors were resilient enough to support substantial demographic growth.

Shennan *et al*. (2013) have amassed a large body of evidence for demographic change in the European Neolithic that suggests a cyclical pattern. Instead of the gradual 'wave of advance' across Europe that archaeologists once envisioned, Shennan's group has found evidence that suggests boom-bust cycles that cannot be explained exogenously in terms of environmental vicissitudes. These demographic cycles were not sufficiently deep to re-shape human gene pools in Neolithic Europe. The interpretation of these data is provisional, but they may imply endogenous, culturally mediated phoenix-cycles of institutional collapse and renaissance, comparable to those we have described in our work on the ecodynamics of modern science (Winder N.P. and Winder I.C. 2013).

By the end of the Neolithic our innovative competence had become a destabilising force in its own right as humans began to live in deeply stratified urban units with complex institutional structures, writing and craft specialisation. One of the most significant differences between these urban civilizations and earlier agricultural attractors is that humans had begun to domesticate (i.e. enslave) other humans on a very large scale. Over the millennia, successive innovation-cascades have increased the carrying capacity of the planet from hundreds of thousands to billions, whence the global impact of human activity systems.

The demographies of ancient hominins and modern humans are strikingly dissimilar. There are now billions of humans on earth, organised into large, stable ethnic groups connected by a network of low-level gene exchange. Much of our gene pool has been silenced by natural selection. Modern populations no longer depend on refugial landscapes or face the challenge posed by those genetic bottlenecks. Human gene pools have stagnated to the point where profoundly disabling traits are protected from extinction by laws of large numbers, dominance relations, polymorphisms and behavioural flexibility. There is relatively little evidence of irreversible genetic flow over the last few millennia and none at all in modern populations. Although our gene pools are evolutionarily inert, our institutional structures are more powerful and influential than ever. Institutions have emerged that protect themselves from destabilising innovations by coercing individuals into compliance and vetoing the results of research that suggests the course of history can, and should, be changed.

Modern urban societies provide a vast range of *a priori* improbable attractors. Anthropologists studying in the history of evolutionary ideas are sustained by taxes taken from people who make plastic whistles for Christmas crackers, priests, real-estate agents and popular musicians. Our species has experienced so many symmetry-breaking events since the end of the Pleistocene that few of us are now capable of getting our own food, clothes and shelter or, indeed, have any need of these skills. Our ability to innovate - to change the course of evolutionary history by changing the way we think - has become the principal driver of human evolution. The challenge for future studies in the 21st century will be to extend our understanding of cultural ecodynamics in ways that accommodate that wondrous complexity.

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Acknowledgements

We are grateful to Penny Spikins and Andy Needham and Denis Noble for advice and encouragement, to Geoff Bailey for comments on an earlier draft and to anonymous reviewers for helpful suggestions. We also thank Heather Winder for proofreading assistance. We would like to acknowledge the European Union for funding under contracts 308601 (FP7 COMPLEX project) and 269586 (ERC DISPERSE project). Figure 1 first appeared in Winder N.P. and Winder I.C.(2013), while Figures 2 and 3 originally appeared in Winder and Winder (2014).