

ARTICLE**Grappling with gene-culture co-evolution**

Michael J. Hogan

Dr. Mike Hogan is a Lecturer in Psychology at the National University of Ireland, Galway. Correspondence regarding this article may be addressed to him by email to michael.hogan@nuigalway.ie.

Understandably, few people think their own species is weird. Somehow being a very recently evolved species that has exploded like none other seems as right and natural to most as when we still believed that God created us in his image. A little scientific theorizing is necessary to convince us that the existence of human culture is a deep evolutionary mystery on a par with the origins of life itself.

Richerson and Boyd (2005¹, p.126)

Human beings strive to understand. Understanding helps us to survive, adapt, and flourish. A central theme in the history of philosophical and religious thought has been the call to 'know thyself' and to 'understand thy nature'. Since the dawn of recorded culture, each new generation has heard echoes of this call. Long before the birth of western philosophy, religion, and science, the *I Ching* opened with the warning: *The creative is successful; this is beneficial if correct.*

With the potential to be beneficial if correct, science tells us that we can learn to know ourselves by studying ourselves as a part of Nature. Our scientific revolution would not have occurred but for the courage of Renaissance thinkers. The Renaissance paved the way for democratic conformism by transforming the courage to accept fate into *active wrestling* with fate. In this way, science and religion came into conflict. With new courage, the post-Renaissance philosophers noted how the universe continues the creative process, which first produced man, within man. Nature comes to its fulfilment, where, as Kant later formulated it, the unconscious creativity of nature breaks into consciousness. The Renaissance saw the birth of a new western culture, a new consciousness structure. Participation in this progressive productive process inspired the unity of enthusiasm and rationality in men like da Vinci, Goethe and Schelling. Further, it inspired the synthesis of courage to be as oneself and the courage to be as a part. This courage was sorely needed as a new culture with religion and science in conflict came to prepare itself for the heaven-shattering genius of Darwin, and his view of human development as grounded in the laws of natural selection.

The courageous spirit of the Renaissance is still needed today as human beings strive to better understand the implications of human evolution for the psychology of human development. Whether or not we survive, adapt, and flourish may ultimately depend on whether or not our science of human development is correct and beneficial.

Leonardo's mutated memes

The mind in an instant leaps from east to west.

Codex Atlanticus, fol. 204v-a

Unschoolled and unlettered, Leonardo da Vinci was a plucky young apprentice. Although he greatly admired the self-taught artist Giotto the Florentine, in relation to much of 'enlightened' culture, Leonardo was a strict nonconformist. Leonardo abhorred all those who merely imitated the masters. He preferred to work

directly with the mistress, Nature. Being a disciple of experience, a collector of evidence, Leonardo merged his masculine brain with his *maestra* and fashioned for himself clarity: a mind not burdened with the lumber of unnecessary ideas, values and beliefs. For Leonardo recognised that many ideas, values and beliefs - or memes - had acted to shatter the clarity of so many minds around him.

Leonardo's nonconformity meme, counselling us not to imitate, is now a part of culture. Long before Richard Dawkins coined the term 'meme' [1], describing it as 'a unit of cultural transmission, or a unit of imitation' (p.206), many post-Renaissance thinkers had assimilated versions of Leonardo's mutated memes and challenged the leading religious meme systems, or *memeplexes*. Dawkins himself used the 'meme' construct to explain how religions acted as self-perpetuating ideational complexes that have hoodwinked us into spreading their message. The enlightenment meme 'have courage to exercise rational enquiry' competes with the faith meme 'have faith in the absence of evidence'. For those whose 'Faith' meme is not linked with a 'God' meme, the disequilibrium associated with carrying the religion-science memeplex can be resolved [2]. For others, particularly those with some vested interest in creationism, the memeplex battle will rage. Much depends on who you listen to, who you follow, who you imitate.

Importantly, the laws of probability suggest that few of us have gene systems that support Leonardo's nonconformity meme. As living systems we possess a unique form of hard-wired reflexive imitation [3, 4]. Even when intention later enters the mix [5] we continue to imitate [6-9]. And if Richerson and Boyd are correct, culture would not have survived or developed without the fitness benefits accrued via imitation. Without culture as a unique adaptation, humans would not benefit from the valuable skills and information from more knowledgeable others. Without a capacity for imitation, successful child and adult development would be exceedingly slow, difficult, and dangerous [10, 11].

Culture allows us to learn about our world rapidly and efficiently. As Lev Vygotsky describes it, culture provides the 'scaffolding' upon which we construct our world afresh. Cultural systems change, and throughout the dynamic codevelopment of intentionality, bodily, self, and social relations [12], the developing person works with the information available. As such, every generation who hears the call to 'understand thy nature' thinks 'what to select?', 'how to optimize my action based on the selection?', and 'how to best compensate for the loss of information associated with the non-selected paths?' [13]. Although biology is not granted the honor, culture permits the evolution of intelligent selection. Leonardo imitated plenty!

Few disregard the existence of culture. But when someone asks 'how much variation in human behaviour does culture account for?' or 'how is culture transmitted and transformed from generation to generation?' debate is inevitable. Sociobiologists

and evolutionary psychologists take the gene-eye view and tend to think that whatever influence culture has it is so constrained by genes that there is little need to consider its dynamic properties. Human behavioural ecologists view culture as a flexible system that ensures the most adaptive outcome in a given environment. They also assume that culture can be rapidly altered in response to environmental change. Gene-culture co-evolutionists, like Richerson and Boyd, share with memeticists and many social scientists the view that what makes culture different from other aspects of the environment is the information, or knowledge, passed between individuals. Somewhat analogous to the process of genetic transmission of information, they argue that information carried by culture is inherited. As such, cultural traits are a product of cultural history, not a simple product of genes, and not simply evoked by the natural environment [14, 15].

Few scientifically-minded thinkers deny the importance of evolution. Even so, a complete explanation of any human action with quality evolutionary thinking securely bootstrapped involves experiencing a *protracted state of doubt*. Not everyone likes this. We have difficulty thinking about the implications of human evolution for the psychology of human action because it's not easy to do so. Richerson and Boyd liken scientific methods with Zen meditation, "arduous and exacting practices that allow the practitioner to win some lovely, if fragile and fallible, truths, eyeball to eyeball with the great mystery" (p. 255). They also observe that historians and historically-minded social scientists often bemoan the application of *a priori general* models when working to understand concrete events unique to a particular place and time. The question often asked is, can *general* models like those used in biology and psychology really help me to better explain *this* particular episode in history, for example, the conflict in Northern Ireland? Is my strategy of tracing historical contingencies along the concrete path of *action-causing-action* not enough? Does a more abstract, distal (or 'ultimate') path of causality help me to better understand the more concrete, proximal causes that are central to my dissertation?

The war-weary history student may be sceptical. Nonetheless, they may also welcome the knowledge that historical contingency is as important in biology as anywhere else. Further, they may consider the value of exploring how the march of time has shaped the *universal and group-specific* patterns of action that manifest in our economic, political, social and cultural systems. In so doing, the historian may acquire a potentially adaptive *memplex* that provides them with a strategy to develop a *better* theory that supports *better* understanding². This understanding they can then pass on to the next generation.

Genes and cultures

Darwin's key contribution to biology is 'population thinking'. Countering the view that species are essential, unchanging types, and long before the gene was identified as the structural unit marking variation, Darwin saw species as populations that carried a variable pool of inherited information through time. Many 'gene thinking' processes that Darwin never dreamed of are important in moulding populations - including mutation, segregation, recombination, genetic drift, gene conversion, and meiotic drive - but Darwin successfully argued that when individuals carrying some variant were more likely to survive or have more offspring, these would spread through a process of natural selection. Although the information carried by genes is physically separate from the information carried within environments, the process of evolution came to shape the kinds of genetic information that

fostered adjustment to and survival within environmental niches that were being carved. As a consequence of this interdependent dynamic, myriad different species emerged, each adapted with a unique developmental program to specific niches. In structure, process, and function, the collection of organisms on our planet came to look like an expanding series of branches and leaves on a tree [16].

Unique to the evolution of human systems is culture. Richerson and Boyd define Culture as *information capable of affecting individual's behaviour that they acquire from other members of their species through teaching, imitation, and other forms of social transmission* (p.5). Everyday words like *idea, knowledge, belief, value, skill, and attitude* are sometimes used to describe this information.

Culture is essential, a necessary part of the design problem for human psychology. Ideas, values, and beliefs vary from place to place and it is often adaptive to know this. Take your jokes about Catholicism from Galway to Belfast and you might find that nobody's laughing. Move from your villa in the south of France to live in an Arctic Igloo and see how long you survive without consulting with the Eskimos. Edgerton [17] found that if you wanted to predict how an East African responded to questions about childrearing or coping with armed conflict, knowledge of *ecological* differences - whether or not the person was a highlands farmer or a lowlands herder - was less important than was knowledge of which *tribe* the person belonged to. The relationship between tribe and adaptation to change has also been observed. In Nigeria, the Ibo, who emphasise individual achievement, adapted more readily to the new postcolonial market economy than did the Hausa and Yoruba, groups who emphasise hereditary statuses more than individual ambition [18].

Nisbett and Cohen argue that genetic, economic, and climate differences can't fully explain differences in the levels of violence when the Northern and Southern states of America are compared [19]. In the research laboratory, when someone bumped a southerner and muttered "asshole", they tended to stand firm for longer in a subsequent game of chicken, even when the confederate playing chicken with them was a 250-pound football player. Southerners who were insulted stepped aside when they were just 3 feet away. Conversely, Northerners stepped aside when they were 6 feet away, whether or not they had been insulted. Nisbett and Cohen argue that a complex set of attitudes about personal honour make Southerners more polite in general, but also more quick-tempered. (Southerners who had not been insulted stepped aside when 9 feet away.)

People from different cultures entering a common environment carry different behavioural norms. Greely and McCree [20] found that differences in political participation between Irish and Italian Americans was best accounted for by differences in cultural history. Although both groups eventually converged toward Anglo American norms, cultural patterns of voting behaviour persisted for many generations. Importantly, while substantial *individual* variation in core personality traits and intelligence is genetic, little behavioural variation *among groups* is genetic. High heritability within groups says nothing about variation between groups. Korean children adopted by American families adopt the ideas, values, and beliefs of the culture that surrounds them [21].

Population thinking is necessary when considering cultural evolution, much like when considering biological evolution.

However, the population models used to explain persistent variation in language, social customs, moral systems, skills, and artefacts do not imply that cultural information takes the form of *memes* - discrete, faithfully replicating, genelike bits of information [22]. Contrary to a 'simple' meme-eye view, cultural changes cannot be fully explained by reference to the laws of natural selection [23, 24]. Cultures can change more rapidly than the most rapid examples of genetic evolution by natural selection. For example, the complex institutions, artefacts, and behaviours of the Plains Indians arose in less than twelve generations after Spanish frontiersman introduced horses into the area [25, 26]. Individuals also work to modify and improve inherited skills, artefacts, and ideas, and the history of technology illustrates how culture usually evolves by the accumulation of these small variations [27]. Innovations are rarely hopeful monsters created from the mutated memes of a single inventor. Psychological forces act within a population context as a bridge connecting biological and cultural evolution [28].

Culture is a part of biology, and how culture is acquired, used, and transmitted is a function of universal features of human action which, for example, makes some people more likely to be imitated, some moral values more appealing than others, some ideas more difficult to learn, some cultures more readily sustainable [29, 30]. At the same time, existing models of brain structure, process, and function are not inconsistent with the idea that, analogous to the forces of genetic evolution, *selection*, *mutation*, and *drift* act to fashion how some cultural variants spread more readily because, for example, they are easier to learn and remember or more successful in a given niche. Language learners confronted with two slightly different grammatical variants often adopt the simpler variant; this *biased transmission*³ can drive language change [31]. Cultural variants also compete and change in frequency because beliefs can influence fertility. Religious beliefs can affect both the survival and the reproduction of people who practice them [32].

If culture does exhibit key Darwinian evolutionary properties, the methods used to study biological evolution should reveal significant isomorphisms (i.e., parallel dynamics) when human culture is studied. For example, at the level of macroevolution, methods in modern systematics - the study of the diversity of organisms and of the relationships between them - are used to reconstruct the evolutionary history of species based on similarities in their morphological, behavioural or genetic characters. Analogue methods have been used by anthropologists to reconstruct the history of groups of people based on cultural traits. Researchers have found that quality cultural datasets often show just as good fit with a branching phylogenetic model as do biological datasets. Many of these datasets and models have provided new insight into the spread, transformation, and extinction of languages and tool use [33].

Although evolutionary psychologists argue that our psychology is built of complex, information-rich, evolved modules adapted for the hunting and gathering life that we pursued in the past, few of us living in modern societies would survive long in the harsh environments our Pleistocene forbearers lived in. The tribes of the Sahara are information-rich when it comes to finding water, but this information is not stored in their genes; it is stored in their brains, brains that are well-designed to learn in a culturally-varied, information-rich environment. Richerson and Boyd argue that neither a simple gene-eye view nor a simple meme-eye view can explain cumulative cultural adaptation. Culture-making brains developed slowly over more than two million years. Our brain

size increased and our cultural complexity increased; both changes occurred as part of a set of dynamic interdependencies, and these changes must have increased the reproductive success of our ancestors, otherwise the features of our brain that make culture possible would not have evolved. Simplistic models simply tell a simple story.

Although many animals, including our closest relatives, show evidence of social learning [34, 35], only humans show much evidence for the kind of imitation that drives cumulative cultural evolution. While adult chimpanzees tend to *emulate* an observed method of tool use, young children closely *imitate* the model, paying particular attention to the details of how the tool is used [36]. Children sometimes imitate so faithfully that they continue using an inefficient technique long after chimpanzees abandon it in favour of a more efficient strategy [37, 38]

Mathematical models suggest that imitation increases the average fitness of learners by allowing organisms to learn more selectively, learning when learning is cheap and accurate, and imitating when learning is likely to be costly or inaccurate, or when environments are unpredictable. For those who can flexibly shift from the strategy 'imitate' to the strategy 'learn', imitation raises average fitness by allowing learned improvements to accumulate from one generation to the next [39].

These imitation strategies can be thought of as heuristics -- mental shortcuts that help us to make fast and frugal decisions. Heuristics bias and canalize action and have been shaped by natural selection for a reason. Importantly, models that combine the effects of biased social learning, individual learning, and natural selection to estimate the net effects of these processes on the joint distribution of cultural and genetic variants in a population, suggest that adaptation often forces the development of a strong *conformity bias* [40]. Social psychologists and evolutionary psychologists [41] recognize the universal power of the conformity bias, and although individualist cultures sometimes consider conformity to be a negative trait, a conformity bias would not have evolved unless it was beneficial at the population level.

Not only are people biased to imitate the majority, they often imitate successful, prestigious people [42-44]. Mathematical models suggest that this prestige bias can lead to an unstable, runaway process and produce exaggerated characters, analogous to the process that gave rise to peacock tails [24]. Understanding how imitation heuristics are employed (and the conditions that foster various imitation biases) is necessary to understand the rates and direction of cultural evolution. Again, the bridge between understanding our evolved biology and our cultural evolution is assembled via understanding our evolved psychology.

Differences in environment may cause genetically identical individuals to behave differently, but if you want to know why the person develops one way in one environment and a different way in a different environment, you have to find out how natural selection has shaped the *developmental process* of the person so that it responds to the environment as it does. The naïve idea that genes and environment are independent causes shaping phenotypes is now rejected by most developmental geneticists [45-47], but a view still held by some evolutionary scientists is that culture is but one amongst a collection of environmental influences and that there is nothing unique about the psychological mechanisms that govern the acquisition of culture [48]. This view, which ignores the quality of information processing unique to

human systems, leads people to ignore the possibility that novel evolutionary processes are created by culture. Theories that combine phylogenesis and ontogenesis in an integrated frame must explain what causes humans to be *so much more variable* than any other species and why this particular capacity for flexible variation was favoured by natural selection.

Richerson and Boyd argue that humans can live in a wider range of environments than other primates because culture allows rapid accumulation of better strategies for exploiting local environments compared with genetic inheritance. Consistent with mathematical models and a body of empirical evidence, they hypothesise that social learning is an adaptation to increased climate variation during the last half of the Pleistocene [49]. For the last two million years, organisms have had to cope with increasing environmental variability, during which time brain enlargement in mammals increased [50], and during which time brain enlargement in the human lineage began to diverge from the trend of the other apes [51]. Larger brains, although metabolically costly [52], lead to better learning [53], more behavioural flexibility, and a longer life with more intelligence [54].

More generally, the increase in brain size, and the general tendency of brains to minimize their axon lengths, implies that brains have become more modular, both structurally and functionally [55]. Increasing modularity may have enhanced the 'division of labour' and generally improved task performance throughout the course of human evolution. Our neural development is marked by a late-evolving, slow-developing, and slow-degenerating prefrontal cortex and lateral cerebellum, areas of the brain that facilitates a collection of executive control skills such as the ability to sustain attention, switch attention, and inhibit distractions and dominant responses. The lateral cerebellum is massively interconnected with the prefrontal cortex and helps us to learn controlled, specialized actions quickly [56]. These late-evolving neural developments support the skilled action of a culture-bearing organism.

We can construct a sample image: natural selection has made the toxic substances in plants taste bitter to herbivores so that they learn quickly not to consume them. Culture adds something new: information that some bitter tasting plants have medicinal properties. People soon inhibit their natural inclination to reject the bitter and use the plants in spite of their taste. Beneficial information spreads. People learn that painful medical procedures and drugs with nasty side-effects can help them. For those who devote some time and energy to learning the art of medicine, many of the specialized healing sub-skills become automatic, with transmitted knowledge allowing for the development of a culturally-appropriate functional expertise. With the slow refinement of medical technologies over centuries, some people who might never have survived now flourish. And now, as we struggle to master the chronic diseases associated with old age, we can remind ourselves that the trend toward longer life is a function of our cultural evolution. The life period of old age is too recent to have permitted the evolution and refinement of an age-friendly biology and culture [13].

To understand how some actions emerge and persist, you have to think about culture as something unique to environments. Rather than asking how individuals interact with their environments, you have to ask how a population of individuals interact with their environment *and* each other over time. Gene-culture co-evolution provides a reasonable explanation for many developments unique

to the human lineage. For example, paleoanthropologists have argued that culturally evolved projectile hunting technology affected the evolution of morphology, with selection favouring less robust physiques in modern humans as compared with earlier hominid species [57].

Durham [58] noted five ways in which observed variability in human behaviour can result from interactions between genetic and cultural processes: (1) *genetic mediation*, where genetic differences underlie cultural variation, e.g., the way in which features of the vocal tract influence the language used by humans; (2) *cultural mediation*, where culture drives genetic change, e.g., the way in which dairy farming drove the selection of genes that facilitate lactose absorption [59, 60]; (3) *enhancement*, where culture reinforces genetic predispositions, e.g., the reproductive benefits associated with incest taboos; (4) *neutrality*, where cultural variants are adopted independently of an individual's genotype, e.g., when learning different languages; (5) *opposition*, where culture leads to maladaptive traditions, e.g., when cannibalism spread the deadly nerve disease kuru amongst the Fore of New Guinea.

In order for biological and cultural evolution to enter a co-dependent matrix of relations, it has been argued that a critical mass of 'imitators' with a sufficiently developed 'theory of mind' was needed [37, 61, 62], and this critical mass took several million years to develop as the numerous species of early hominids slowly mastered a bipedal stance and the use of their hands, while competing to develop the largest brain, the best set of tools, optimal communication strategies, and the most diverse range of actions [63-67]. Slowly we see evolution and dominance of modern humans who began to spread across the world about 50,000 years ago [68, 69]. Much like the close symbiosis between prokaryote species (which resulted in one of these species evolving to become the nucleus of another, thus producing the eukaryotes about 2 billions years ago), one can think about genes and culture as obligate mutualists that have produced a new level of biological organization. Together they act like two species that synergistically combine their specialized capacities to do things that neither one can do alone. Although there have been costs as well as benefits associated with the unique path of gene-culture co-evolution observed in the human lineage, there is no doubting the path. Understanding the implications of the path for modern humans is another story! The psychologists must grapple with the present action state and work to optimize action in the present context.

Psychological science as imitation?

The complexity of cultural traditions can explode to the limits of our capacity to learn them, far past our ability to make careful, detailed decisions about them. We let the population-level process of cultural evolution do the heavy lifting of our "learning" for us. (ibid, p. 131)

A psychologist would find it difficult to carve useful insights without the *apriori* insights of a 'culture of theory' to bolster their explanations. Observe any human action and consider constructing a system of relations to explain what you observe. A strong power source is needed to enlighten the structure, process, and function of the action in context. Living systems acting with conceptual systems to construct abstracted systems must learn to select. Aesthetics and sentiment permeate the *structural relations* selected. The *action process* described as moving through time is dependent on the structural relations selected for observation.

The purported *function* of the action thus described is a function of the ends toward which the *structured process* is directed.

Pragmatists like William James remind us that formal logic is but a tool. One's philosophy of science is fundamental when the abstracted systems of science are co-opted as the ground from which to investigate the 'how' of concrete systems. But the philosophy of science you assimilate does not provide the answers. As Leonardo da Vinci noted, the answers lie in Nature. Thankfully, Richerson and Boyd's thinking supports quality dialogue between the gene-eye and meme-eye views on human action; they balance their biology and culture well; they balance their sentiment and formal logic well.

Nonetheless, this quality of balance between Nature and Meme is rare in the field of psychology as a whole. Just as organisms compete, the memplexes carried by different scientific sub-cultures compete. The sentiment that we are working to build a general system theory is largely a myth [70]. In-group sub-cultures that practise one form of logical analysis argue with out-group sub-cultures that practise other forms, sometimes accusing one another of carrying memes that lack essential truth [71]. All members of our species have in common an evolved package of sometimes maladaptive action tendencies, particularly when we are faced with modelling the big questions, and most particularly when we are asked to *collaborate* while modelling [72]. A brief survey of evolutionary thinking illustrates the complex combination of competition and cooperation that is driving scientific progress [73]. The battle amongst schools of thought is necessary to drive progress. No school of evolutionary thought is itself complete. Nonetheless, Darwin would be well-pleased with progress to date. The Darwinian theoretical toolbox furnishes the thinker with what Richerson and Boyd describe as *bits of canned logical analysis*, and every student of human action does well to practise using this logic.

Aye, but here's the rub. Thinking with clarity is difficult. The thinker's toolbox evolves so quickly that the craftsman can be left sitting with too many tools and no strategy to focus a functional application. It takes time to observe and imitate the master's use of any given tool. But the desire to create can be strong, even if your tools become outdated the moment you set them to use - even if your application is, in exacting reality, incorrect.

The emergence of wisdom in biology and culture

Pettersson [74] defines nine integrative levels of natural entities; three in the physical range (i.e., fundamental particles, atoms, molecules), three in the biological range (i.e., intermediate entities, ordinary cells, and multicellular organisms), and three in the social range (i.e., one mother families, multifamily society, and society of sovereign states). Tracing the temporal emergence of one integrative level from the level below, and using mass estimations to trace the quantitative doubling time of innovatory entities, he concluded:

- Evolution has been accelerating. Specifically, the period of time before entities of a higher integrative level have emerged from the biological or social level below has, in general, decreased with the advance of time.
- The following functions of culture also show accelerated change: number of different material used by man, number of occupations involving special arts and technologies, the maximum speed of transport by mechanical means, the complexity of man-made objects and the degree of skill and knowledge required to produce them, communication

speed and diversity, killing capabilities, and data processing capabilities.

Also, the doubling times of scientific publication has gone from 15 years in the years between 1750 and 1900 to 9 years from 1900 to 1956. With an increase in the number of 'parts' of reality being described by scientists, there has been a parallel increase in the number of 'schools of thought' designed to map sub-sets of their relations [75]⁴. Much of this activity has been mindless bifurcation that has often failed to consider the quality control necessary for the *application* of models proposed.⁵ The accumulation of more and more discrete abstract relational systems can easily add maladaptive fragmentation to our already limited thinking [76]. The number of relations in a problem set provides a good estimate of its complexity, and we have difficulties managing complexity. If, for example, different schools of thought don't wish to cooperate in working to solve common problems, competing instead for research funding, quality thinkers, etc., then fruitful dialogue is impossible. The evolution of win-win strategies (where the rules of group-dynamic games optimize outcomes for all players) requires successful mergers. Richerson and Boyd note how evolution has enhanced our win-win potential over time, but the conjoint evolution of strong in-group biases continues to limit our ability to expand tribal instincts to a global perspective.

It might be argued that wisdom involves understanding human limitations (at the individual- and population-level) while working to enhance adaptive strengths. For example, thinking and research on wisdom suggests that wise people develop adaptive heuristics that defragment a problem set whilst thinking with greater clarity about its global context. Naturally, if we work to think about optimizing human action, a fragmented mental representation places a greater demand on our limited working memory capacity than does an integrated, coherent mental representation. In other words, without somehow 'chunking' the bits of a problem in working memory, there are more bits of unrelated information being presented as part of any 'solution'. The wise person understands that the more unified our mental models of the world are, the better our ability to work with others and with the artefacts of culture to make efficient and effective our cognitive efforts and consequent actions. The wise person has access to a more unified system of knowledge and the related pragmatics of action that underlie the resolution of problematic situations [77].

Understanding in science is dependent on integrated description. The development of integrated description involves the creation of a schema (or mental representation) that holds all the parts and relations that constitute a problematic situation under investigation. To be functional the schema needs to hold this information together in the same mental space and time. Some theories - for example, the theory of evolution in biology - provide thinkers with both a structural exemplar and core knowledge which can help them to better understand the structure, process, and function of action in the system. In this sense, the schema itself becomes an artefact of culture that can sometimes be used to better optimise action. And, acting as a functional extension of human evolution, science does well to benefit humanity. In order to be beneficial and correct, science needs to evolve a functional design that works to facilitate and not impede action.

"Can we influence the current evolution of human societies in a desirable direction? As humans, we are unusually active agents in our own evolution, because we each choose with cultural variants to adopt and which to neglect. Moreover, we organize institutions ranging from a simple tribal council to highly complex modern ones, such as the research university and the political party, that are designed to direct the course of cultural evolution. Yet, cultural evolution is a very big dog at the end of our leash. Even cultural heroes leading great political movements have modest effects. Gandhi could not prevent the Muslims from leaving India, nor could he persuade Hindus to reform the caste system. Only by attending properly to the population-level processes can we arrive at a proper picture of cultural evolution. With a reasonable picture of cultural evolution in hand, we could begin to understand how we might humanize processes that often exact savage costs in the currency of human misery." (ibid. p. 253)

(Footnotes)

¹ *Not by genes alone: How culture transformed human evolution.* The University of Chicago Press.

² Aside: when evaluating theory we remind ourselves to look for comprehensiveness, parsimony, clarity of constructs, internal consistency, testability, empirical support, and heuristic value.

³ Richerson and Boyd argue that biased transmission occurs when people preferentially adopt some cultural variants rather than others. This includes situations where individuals are more likely to learn or remember some cultural variants based on their content (i.e., a content-based bias, e.g., based on calculation of costs and benefits), use the commonness of a cultural variant as a basis for choice (i.e., a frequency-based bias, e.g., rooted in the assumption that common cultural variants are more successful or more 'appropriate'), or choose based on the observable attributes of individuals who exhibit a cultural variant (i.e., a model-based bias, e.g., imitating a prestigious person). These biases are the result of interacting genetic and cultural evolutionary processes.

⁴ If a school of thought is defined to be an explanation of a problematic situation based on k variables, and suppose that the problematic situation under study actually involves n variables (where n would generally be more than k), then the number $T(n,k)$ of schools of thought that can be formed is given by the formula:

$$T(n,k) = n!/(n-k)!k! \quad (1)$$

which is the same as the number of combinations of n things, taken k at a time. If all values of k from 1 to n are allowed, the sum over k of $T(n,k)$, which is equal to $2^n - 1$, would give all possible schools of thought. For $n = 7$, which is the average number of items a young adult can hold in short-term memory, this number would be 127. Most models in economics, physics, and psychology, model 7 or less variables.

⁵ For example, Ashby's Law of Requisite Variety states that for effective control, the variety available to the controller should be the same as the variety available to the system to be controlled. Ashby's Law implies that if, for example, an economic system to be controlled has n variables, the controller must be able to control all n variables; otherwise they risk the consequences of leaving some subset of those variables uncontrolled. Therefore, if a government wishes to control their economy, a studious way to proceed is to determine how many variables there are to be controlled, and then make available that same number of control levers to the controller. There is no evidence that economists and governments actually do this. Similarly, there is no evidence that models in the field of psychology designed to optimize human action – survival, adaptation, and flourishing – pay any heed to this basic principle, a principle that scholars of cybernetics and systems are generally aware.

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