The Contemporary Global Fertility Decline as a Chapter in Human Evolutionary History

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Abstract

Observed from a biological perspecttive, the fertility decline is puzzling because Darwinian theory predicts that living things will strive to maximize "fitness". But humans are "cooperative breeders". In species that breed cooperatively, reproduction is subject to social influence. The social influence regulating human reproduction comes from direct advice between individuals and the reproductive norms of the community. The "kin influence hypothesis" suggests that by changing the composition of communities and reducing interaction between kin, economic development triggers a process of cultural change. Cultural norms become increasingly inconsistent with the efficient conversion of resources into offspring. To consider the implications of fertility decline and other effects of this cultural change process, we review recent ideas and evidence about how demography influences human behaviour. It appears that the larger the size of a communicating population, the more rapidly it generates useful cultural innovations and the greater the complexity of the culture. Human populations only became large enough to maintain a complex culture during the last ice age. Currently the human population is larger and can communicate more effectively than ever before and, for the first time in human history, interaction between non-kin overwhelmingly dominates social exchange on the part of the majority of the population. We examine the long-term implications of this.

Introduction

Speculation about the longer term implications of the demographic transition is inevitably influenced by ideas about what drives this dramatic change in human reproductive behaviour. We have been attempting to develop an explanation of this change which is based on Darwinian theory. Humans are biological beings. Just like all other living organisms, humans are a product of evolution by natural selection. It does not follow from

this that explanations of human behaviour have to be wholly determined by our biology. But explanations do have to be consistent with the *theoretical underpinnings* of biology.

One stage of the demographic transition, the mortality decline, is not mysterious for biologists. Like all living things, humans strive to avoid death and like many living things, they also strive to maintain the survival of their close relatives. This behaviour is easily explained in Darwinian terms (Darwin, 1859; Hamilton, 1964). Mortality declined because technological and social innovation occurred which increased people's ability to acquire food and other resources necessary for life.

The fertility decline, which typically begins a generation or so after the mortality decline, is much more difficult to reconcile with Darwinian theory. This theory predicts that living things should strive not just to survive but to produce thriving offspring. All living things are descended from individuals who won the competition to produce thriving offspring. The majority of our antecedents are from among the individuals in the past who were better able to acquire resources and convert them into offspring. Contemporary humans, therefore, have inherited the genes of efficient reproducers and so they should possess the abilities and preferences associated with this success. So why are contemporary humans such failures in evolutionary terms? Why is their fertility so low?

Low fertility is expected if resources are scarce. Greater reproductive efficiency is achieved if the rate of offspring production is adjusted to match resource availability. If the declining mortality had increased the size of the population to the extent that resources had become depleted, declining fertility would be expected. But populations undergoing economic development experience dramatic *falls* in fertility which occur even when its members are experiencing dramatic *gains* in prosperity. They can afford to produce many offspring but choose to invest in other things. They do not efficiently convert their resources into offspring, instead choosing to invest unnecessarily large amounts of effort into a few offspring and to invest heavily in their own comfort. Individuals may perceive the amount of effort they invest in themselves and their offspring to be necessary but this belief is imbued by culture. It is not biological necessity.

Numerous studies of pre-demographic transition populations (aka "small scale" or "traditional" cultures) have shown that, even though reproductive behaviour varies widely, individuals living in these cultures make reproductive decisions that are consistent with the predictions of Darwinian theory (Borgerhoff-Mulder, 1988; Chagnon, 1988; Cronk, 1989; and reviews by Cronk, 1991; Hill & Hurtado, 1996; Irons, 1979; Low, 1993, 1999, 2000; Mace, 1998; Wang, Lee, & Campbell, 1995). Their effort is invested in biologically "rational" ways. They make roughly optimal choices about the timing of births, which is essentially the choice between devoting effort to producing a new baby and to maintaining

the welfare of family members already alive. With economic development, people experience rapidly changing values and their choices increasingly diverge from what can be considered optimal.

We have proposed an explanation for the decline in fertility associated with economic development which we have called the "kin influence hypothesis" (Newson, 2009; Newson, Postmes, Lea, & Webley, 2005; Newson et al., 2007; Newson & Richerson, 2009). The hypothesis is consistent with Darwinian theory but, unlike many evolutionary explanations of human behaviour, it does not suggest that the change in reproductive behaviour is the direct result of psychological mechanisms determined by genes that evolved at an earlier stage in human evolutionary history. The kin influence hypothesis suggests that the change is part of a *cultural* evolutionary process that begins with economic development and is triggered by changes in the human social environment.

Evidence and theoretical arguments supporting the kin influence hypothesis have been presented in our previous publications. Our purpose in this paper is to provide further support for the hypothesis by placing recent economic development and the accompanying cultural into an historical context that stretches far back in human pre-history. Then we will speculate about the implications of the current changes. Before proceeding with this, however, we will give a brief description of the mechanism which we believe drives fertility decline.

The cultural evolution of fertility norms

First of all it is necessary to point out that "cultural evolution" as described by current Darwin scholars is very different from the ideas of cultural progress or social Darwinism expounded by some social commentators in the late 19th and early 20th centuries (Boyd & Richerson, 1985; Cavalli-Sforza & Feldman, 1981; Durham, 1991). For example, the suggestion made by Thornton (2005) that the cultural changes of "modernization" might be driven by an idealism that causes people to strive for freedom, consent and equality is not credible to a modern Darwinist. Thornton's suggestion implies that individuals possess an innate preference for freedom, consent and equality. It is certainly plausible that people have a preference for doing what they want to do rather than what they are told to do. But they do not choose these "wants" in isolation. The preferences individuals form are strongly influenced by information they receive from other people (Turner, 1991). Members of Western cultures are socialised to perceive themselves as individual agents (Nisbett, Peng, Choi, & Norenzayan, 2001) and so they may be particularly disinclined to recognize the extent they are influenced by the information they receive from others.

"Evolution", as described by Darwin, does not imply improvement, increasing complexity or progression toward a predetermined outcome (Richerson & Boyd, 2004). It simply states that the characteristics of a population do not change at random. Changes in a population can be explained by events at the level of the individual members of the population. We know that members of each generation have the genes of their parents. It therefore must be the case that the more surviving children that an individual has, the more strongly his or her genetic characteristics are likely to be represented in the population in the future. Cultural characteristics do not change at random either. Changes in the beliefs, rules and values of a population can also be explained by events at the individual level: the conscious or unconscious choices its members make to remember some bits of information and forget others, to espouse some beliefs and reject others, to maintain some values and abandon others. The patterns of cultural variation are the likely to be the result of observable factors. Variation over time and space can be observed, investigated and modelled in order to better understand these factors (Boyd & Richerson, 1985)

As populations begin to develop economically, they begin a process of rapid cultural change which includes dramatic changes reproductive norms *and this change process continues today*. Cultural change does not stop when a population attains some stage of development. This continuing change is a strong and virtually universal pattern. We have suggested that this process is triggered because economic development changes the structure of communities and the pattern of social interaction that individuals experience. Social and technological innovations make it possible for young people to travel far from their natal communities and to make a living independent of their extended families. These innovations also reduce mortality and thus increase population density. This often makes it essential for young people to leave their natal community and seek a living elsewhere.

A number of scholars have observed that economic development changes the social environment and they have also suggested that this may cause or contribute to the accompanying changes in reproductive behaviour (e.g., Bongaarts & Watkins, 1996; Davis, 1937/1997; Kohler, 2001; Popenoe, 1988; Watkins, 1990). Reasons for change have included suggestions that the new social environment facilitates the diffusion of new ideas and that it creates new economic conditions that change the costs and benefits of producing children. But close scrutiny of the course of change in a number of communities has cast doubt on whether either of these mechanisms can entirely account for the link between economic development and continuing cultural change. The pattern of change in some communities may appear to demonstrate that economic change or diffusion is causing the cultural change. But the data do not provide enough consistent support to suggest that either mechanism provides an adequate explanation for the change process

that has now begun in almost all human populations (Cleland & Wilson, 1987; Szoltysek, 2007; Watkins, 1986).

The kin influence hypothesis proposes a different mechanism to explain why the widening of social networks and the change in the composition of communities causes cultural change. The mechanism is based on four assumptions:

1) The cultural norms of a community, including reproductive norms, emerge and are continuously adjusted through the social interaction of its members (Postmes, Spears, & Cihangir, 2001; Postmes, Spears, & Lea, 2000; Turner, 1982; Turner, Hogg, Oakes, Reicher, & Wetherell, 1987). Although information from outside the community undoubtedly influences the information exchanged by group members, beliefs and values are not imposed by outsiders. Members of groups consciously and unconsciously negotiate and agree the norms that coordinate their behaviour and mediate their interactions.
2) Individuals or couples do not decide by themselves whether it is a good time to have a baby. Their decisions are powerfully influenced by the information they receive from the people they interact with and with the reproductive norms of their community (Hammel, 1990; Watkins, 1990). Thus, in humans, reproduction is essentially under social control. We propose that this method of fertility regulation has deep evolutionary roots in our species because humans are "cooperative breeders". We will explain this in a later section of the paper.
3) For almost all of evolutionary history most people spent most of their lives in communities where family members lived near to one another and regularly interacted. Prior to economic development travelling far from one's natal community was difficult. People preferred to move in family groups when migration was necessary. It is impossible to describe a "traditional" community with any precision because the way families and households were organized varied from population to population and from family to family. But in pre-economic development communities, people identify more strongly with their family than they do in economically developed societies where a person often identifies with many different groups throughout his lifetime. The more reproductively successful individuals in pre-economic development societies (i.e. the majority of our ancestors) spent most if not all their lives among their kin.
4) The information communicated among kin reflects an interest in each other's welfare and reproduction. "Inclusive fitness" theory points out that individuals have a genetic interest in the reproductive success of their kin (Hamilton, 1964). It follows from this that interaction between kin will be more likely to include the encouragement of behaviour likely to result in the efficient conversion of resources

into offspring than interaction between non-kin (Newson et al., 2007). Inclusive fitness theory does not predict a perfect identity of interests among family members. To the extent that competition is *within* rather than *between* families, inclusive fitness effects will be reduced (Taylor, 1992) and this may be why family feuds are common but why families often patch up feuds in conflicts with outsiders. But prior to economic development, most people's primary social group is their family. In most cases, their work colleagues and "school mates" are their family members. They work alongside family members and are educated by them. Research in social psychology has shown that humans perceive themselves to be members of groups and this belonging shapes their psychology. When an individual belongs to a group, he internalises the group and acquires a "social identity". Belonging to a group gives him a sense of grounding and imbues his life with meaning (Haslam, Jetten, Postmes, & Haslam, 2009). As a result, people do not just receive economic benefit from family membership; belonging to a family is of great psychological importance to them. In the social environment that exists in traditional communities people's identification with their family is considerably stronger than it is in economically developed societies. People in traditional communities would likely regard promoting the welfare of their family, in the present and in the future, to be one of the main purposes of life.

If these assumptions are correct, the widening of social networks that occurs with economic development will bring about a change in the information being exchanged during social interaction. Because a much smaller proportion of their social interaction is with kin, people will receive less encouragement to further the interests of their family and more encouragement to invest effort in furthering other interests. This will not have an immediate strong effect on behaviour because what people say and do will continue to be influenced by the cultural norms of the population. Over time, however, the change in the content of social information will cause these norms to change to become less family promoting. This cultural change is not a discrete event; it is a cultural evolutionary process that plays out over many generations (Boyd & Richerson, 1985; Cavalli-Sforza & Feldman, 1981; Durham, 1991; Richerson & Boyd, 2005). And it will not only affect fertility norms; it will change beliefs and values that influence every aspect of life.

The evolution of human reproductive behaviour

In biological terms, *Homo sapiens* is a very successful species. In the last two centuries – a mere seven generations – the number of humans on Earth has increased sevenfold. We dominate the planet. Our expansion and the waste products our activities are causing mass extinctions of other species (Wake & Vredenburg, 2008). The huge human brain is usually

given the credit for this success. Our ability to learn, think ahead, communicate through language and maintain a complex culture did undoubtedly play a role.

But as more information has emerged about the pre-history and evolution of our species, it has become increasingly obvious that a big and clever brain does not guarantee biological success. Other factors, including demographic factors, are being identified as playing an important role in the success of *Homo sapiens*. And the insights gained from research into human evolution can inform speculation about why contemporary humans appear to no longer seek biological success and how this might affect future developments.

As we stated above, Darwinists see evolution as driven by the competition to produce offspring and that natural selection favours characteristics associated with more efficient conversion of resources into offspring. It does not follow from this, however, that living things operate with utmost efficiency in the production of offspring. Competition cannot be relied upon to maximize efficiency. This is a true in nature as it is in the economic "marketplace". Natural selection rewards short-term individual reproductive success. To be successful, individuals just have to be more efficient than the competition. "Evolution by natural selection" has no efficiency standards or reproduction targets.

Mammals provide a good illustration of evolved reproductive inefficiency. Only half the individuals in any population of mammals (the females) have the biological equipment necessary to enable a fertilized egg to develop into an organism capable of living independently. The other half of the population (the males) can only reproduce if they can manage to fertilize a female's eggs. Most male mammals contribute absolutely no effort to the care and feeding of their offspring. Typically their reproductive efforts are devoted to attempts to maximize the number of females they mate with.

Humans are one of the few species of mammals that has evolved ways of reducing this source of inefficiency. Human males devote a considerable amount of effort to raising young. Members of societies with monogamy and nuclear family households commonly perceive this in terms of "fathers helping mothers to raise their children". Human reproductive behaviour is therefore often seen to be similar to that of birds like eagles with pair-bonded mates sharing the task of caring for chicks. But human reproductive behaviour is more like that of cooperatively breeding species such as rooks (Hrdy, 1999, 2007, 2009). Men and women do not just care for their own offspring; they help to raise other young relatives too and also non-relatives. Boys and girls help to care for their younger siblings, cousins, nieces and nephews (Hawkes, O'Connell, & Blurton Jones, 1995, 1997; Hawkes, O'Connell, & Jones, 1989; Hill, 1993; Hrdy, 1999, 2007, 2009; Mace, 2000; Mace & Sear, 2005; Sear, 2002; Sear & Mace, 2008; Sear, Mace, & McGregor, 2000; Whiting, Beatrice, & John, 1975). Exactly what kind of care is provided and by whom varies from

culture to culture and from family to family. But in all cultures, members of families and communities cooperate in the care, teaching, provisioning and protection of the young (Brown, 1991).

It may be that changing climate conditions created the conditions that made our ancestors evolve this more efficient method of reproduction. The paleoclimate record shows that about 15 million years ago the Earth was becoming cooler and drier and this was causing the area covered by tropical rainforest to shrink and be replaced by grassland (Zachos, Pagani, Sloan, Thomas, & Billups, 2001). Prior to this climate change, many more species of ape existed and they were much more widespread. Only four species of ape remain today: chimpanzees, bonobos, gorillas and orang-utans. They all live in tropical rainforest habitats and they are all considered in danger of extinction. The genetic similarity between humans, chimps and bonobos suggests that the "hominine" line of descent split from the line which became chimpanzees and bonobos about six million years ago (Barrickman, Bastian, Isler, & Van Schaik, 2008).

Even compared to other large mammals, great apes are extremely slow reproducers (Hrdy, 2009). For example, it is virtually impossible for a chimpanzee female living in the wild to produce more than five offspring during her entire lifetime. Great ape babies are born helpless and are slow to mature. A chimp mother with a new baby must devote the next five years to its care, assuming it survives. Only at the end of this time will she become fertile again and be receptive to males wanting to mate. No other chimp will help provide food for her baby, hold it or even watch it for her. Mother chimps must always be nearby to protect their babies because, if he has the opportunity, a male is likely to kill it. The death of her baby will bring the mother into oestrus sooner and give the infanticidal male an earlier mating opportunity.

Human babies are born even more helpless than chimp babies and they are even slower to mature. But if food is plentiful and plenty of help is available human females can easily produce a baby every two years. The lifetime fecundity of human females can be four times greater than that of chimpanzee females. But the real advantage of cooperative breeding is not so much greater fecundity as greater flexibility. The few cooperatively breeding mammals that exist, such as meerkats and mole rats, tend to live in environments where food is often sparse. When times are hard, cooperatively breeding families avoid extinction by limiting the number of offspring they produce and working together to raise at least a few descendants. Many of the helpers may never themselves get a chance to reproduce but the genes associated with their helping behaviour are passed to future generations via their nieces and nephews.

It is impossible to know when our ancestors began to cooperate in raising young and to cooperate in other ways. Behaviour doesn't fossilize. But, as more fossils of extinct hominins are found, individuals of different ages can be examined. By comparing the size and structure of the teeth, skull and pelvis it has been possible to infer how events in the human life cycle have been rescheduled in the course of evolution (Gibbins, 2008). A number of hominin species emerged after the split with the apes and by about two million years ago, members of the species known as *Homo erectus* had migrated out of Africa and begun to spread across Eurasia.

The implications of being a cooperatively breeding ape

Hrdy (2009) has convincingly argued that adopting cooperative breeding played in role in setting our ancestors on the evolutionary path that led to emotionally modern humans. Cooperative breeding provides a social environment that favours the evolution of such uniquely human capacities as the ability to accurately assess the thoughts and intentions of those around us. Children needed to attract the attention and care of adults and older children. Adults and older children needed to be sensitive to their attraction. They had to empathize. A group of animals that cooperates in the raising of young have to be able to recognize other group members. Strangers have to be treated with caution but those who appear well-intentioned can earn a place in the group. Individuals are more inclined to care for their close relatives but the need to avoid inbreeding makes it essential that groups not be made up entirely of close relatives.

Members of cooperatively breeding groups are subject to reproductive inhibition. When individuals rely on other group members to help raise their young they must be sensitive to cues that will provide information about the availability of help. How likely is it that other group members will be willing and able to find food and help to care for a new baby? If a female produces young at too fast a rate, at inappropriate times or if other group members are simply unwilling to help her, her offspring will have insufficient care and fail to thrive. Natural selection will favour individuals who can accurately judge the amount of care available and take best advantage of it. Humans therefore evolved to be influenced by social information when making decisions about having children.

Different cooperatively breeding species have evolved different mechanisms to control reproduction and to coordinate the parenting efforts of group members (Solomon & French, 1997; Stacey & Koenig, 1990). The mechanisms evolved by ancestral humans reflect the fact that they set out on the path to cooperative breeding with the large brain and reproductive biology of an ape (Burkart, 2009). This means that they learned quickly by trial-and-error but could also learn by watching others. They could understand the aims of those they observed and they could copy them if it seemed reasonable. These early

hominines probably had, like chimpanzees, a simple culture of local traditions (McGrew, 2004; Whiten et al., 1999) and precursors of the human ability to work out consequences of actions and an appreciation of what others are likely to know or be ignorant of (Hare, Call, & Tomasello, 2001). And they had babies that were slow to mature and needed to be fed and protected for many years before they were independent and sexually mature.

Our ancestors eventually evolved the system of controlling reproduction seen in contemporary human societies, a complex and often vague array of rules and customs that change over time and vary from community to community. It is a system that operates through the uniquely human capacity for complex culture. Clearly this cultural system of reproduction regulation could not have evolved before our ancestors acquired our species' unique cognition and behaviours that make complex culture possible. But cooperative breeding is as likely to have been a cause and facilitator of the evolution of these capacities as a result of the evolution culture. Culture and cooperative breeding may have evolved in steps simultaneously ("co-evolved") and it is hard to determine what were the leading and lagging elements of the coevolutionary circuit. Early hominin cooperative breeders may have used non-cultural mechanisms to control fertility.

The behaviours and abilities that make complex culture possible could only have evolved in groups that were cooperative to some extent (Simon, 1990). This is perhaps the most striking with reference to language. Linguists have long noted that people will only listen to language if they can reasonably trust that the speaker will say things that are useful to them. But this suggests another co-evolutionary circuit because, at the same time, language is a powerful tool for *organizing* cooperation (Tomasello, 2008). Culture is information shared by the group and this body of information can only become large if individuals in the group members are willing to share useful information. They must be willing, for example, to share the techniques they use for recognizing and accessing safe nutritious food items. Chimpanzees seldom teach one another or actively help their young to learn foraging techniques (Byrne, 1995). By contrast, humans are constantly scaffold the learning experiences of children even when they aren't "teaching" in a formal sense (Rogoff, Paradise, Arauz, Correa-Chavez, & Angelillo, 2003).

A community of cooperative breeders with simple culture provides a social environment which favours the selection of cognitive traits that allow more complex culture to develop. For such a group to begin to acquire more complex culture, its young and inexperienced members must be motivated and able to learn from and imitate the most knowledgeable and skilled members of the group (Boyd & Richerson, 1996). Then the most knowledge can accumulate and techniques improve with each generation. Comparative studies by primatologists have shown that human children are more motivated to imitate the actions of an adult than young chimps and this suggests a reason why chimps have not been able to

develop beyond simple culture. Chimps will copy the actions of a demonstrator if they can't see a better method of accomplishing a task but children are inclined to copy regardless of whether or not a better method is apparent (Horner & Whiten, 2005). This seems to suggest that chimps are the more intelligent imitators. But despite their inclination to slavishly copy, human children can ultimately select the best technique. This is because they have the ability to reflect on different techniques and chose the best one. Chimps appear to lack this ability (Marshall-Pescini & Whiten, 2008; Whiten, McGuigan, Marshall-Pescini, & Hopper, 2009).

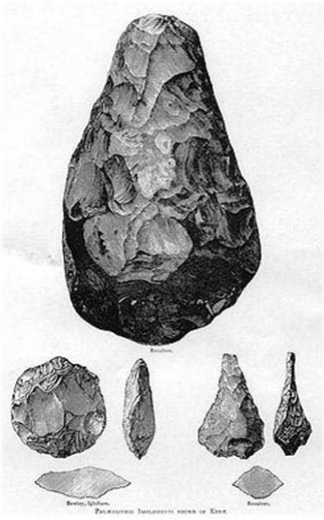
In the chimp social environment it would not be particularly beneficial to be motivated to imitate or to able to reflect on different demonstrated techniques. A young chimp spends almost all its time with its mother and gets little chance to closely observe the foraging techniques of other experienced chimps. A mother is a good model in that she is unlikely to try to deceive or prevent her youngster observing her best foraging techniques. But she is unlikely to be the best model for every aspect of foraging. In this limited learning environment, a young chimp has no chance to compare techniques and will do best if it observes its mother but also relies heavily on independent learning.

In a cooperatively breeding group, youngsters get the opportunity to observe the foraging of many different group members. The individuals capable of choosing the better techniques would be more successful than those who either copied inferior techniques or learned inferior technique for themselves. Thus, over the generations there would be an improvement in cognitive abilities that allowed individuals to rapidly compare techniques and chose the better one.

Another implication of developing cooperative breeding is that with increased effort devoted to provisioning the young, it becomes possible to support larger brains. Nervous tissue contains certain fatty acids which the human body cannot synthesize and so must be consumed as part of their diet (Aiello & Wheeler, 1995). These nutrients are only abundant in foods that are difficult to obtain such as nuts, meat and other animal products. The more brain tissue an animal has relative to its body size, the more effort must be spent to gain sufficient quantities of these fatty acids so that the young are can develop and thrive. The longer it takes a mother to acquire sufficient nutrition to produce a viable offspring capable of living independently, slower her rate of reproduction. The compromise between having more offspring versus have cleverer offspring inevitably places a limit on brain size. The limit is relaxed however if mothers receive help obtaining food during pregnancy and while her children are dependent (Van Schaik, 2009). It is likely therefore that cooperative breeding had been established by the time that larger brained members of the *Homo* genus began to appear about two and a half million years ago (Hrdy, 2009). Evidence of tool use also began to appear at this time.

"Stone Age" climate, demography and technology

In spite of their increasing brain size, the fossil record does not suggest that members of the *Homo* genus were particularly successful, either culturally or biologically. They certainly did not gain technological sophistication rapidly. The signature Stone Age tool, known as the "Acheulean hand axe", first appeared about 1.8 million years ago and continued to be used with only modest improvement until about 100,000 years ago. Clearly being large-brained, flexible fast-learners does not guarantee that a hominin will invent a fancy toolkit but it did enable them to survive changing climates and to live in a wide variety of habitats. Hominine bones and hand axes have been found in many parts of Eurasia and Africa. But these early humans did not seem to be plentiful (Atkinson, Gray, & Drummond, 2008). All contemporary humans are very closely related genetically. Currently, the best explanation for this is that as recently as 80,000 years ago the entire global population of *Homo sapiens* was very small, between one and ten thousand females.

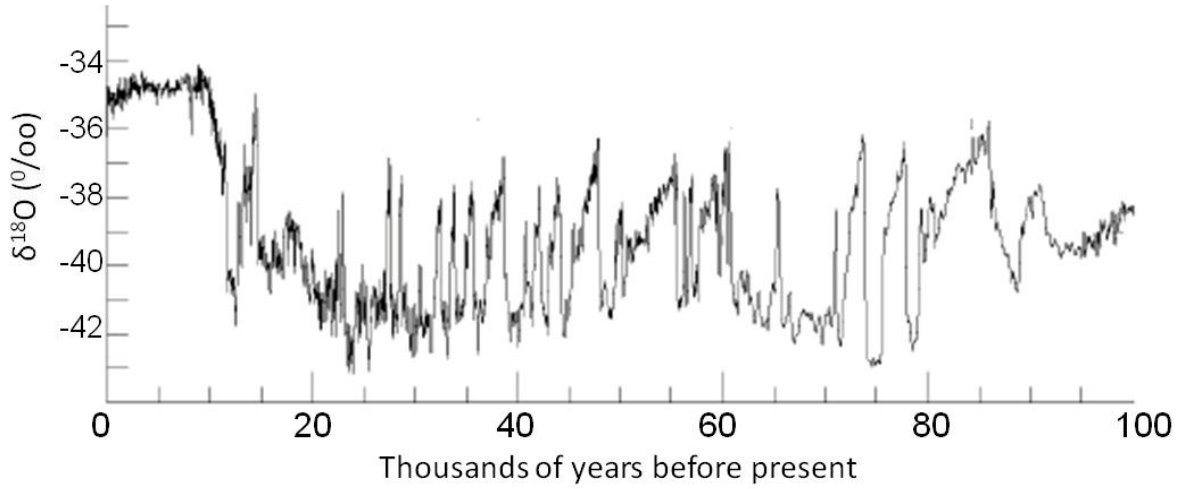


The Acheulean hand axe. used but unimproved by our ancestors for more than 1.5 million years.

Surviving the cycles of glaciation known as "ice ages" which occurred during the last two and a half million years should not have been difficult if the climatic change had been gradual. But recent investigations by paleoclimatologists suggest that, during the periods of glaciation, climate change was very rapid and very frequent, with dramatic changes in temperature sometimes occurring every few thousand years. The frequency of the changes increased with each glaciation so that for a large part of the last glaciation, from about 10,000 to 100,000 years ago, large temperature fluctuations occurred every few hundred years. This variation became especially extreme after about 60,000 years ago. Changes in global temperature can be calculated by measuring changes in an isotope of oxygen at different depths of an ice or mud core.

The figure below summarizes the results from a core taken from a Greenland glacier, showing that changes in global temperature were rapid and frequent for about 70,000 years stabilizing about 10,000 years ago (P.D. Ditlevsen, Ditlevsen, & Andersen, 2002; P. D. Ditlevsen, Svensmark, & Johnsen, 1996). To appreciate how cold and climatically unstable this period was, compare it to the ten thousand most recent years (the furthest left portion of the graph). This period, known as "the Holocene", saw agriculture become established and all of recorded human history. Temperature fluctuation was relatively modest during

this time even though the small fluctuations that did occur, such as "The Little Ice Age" were very disruptive.



The proportion of the 16 and 18 isotopes at different depths of a Greenland glacier provides a measure of the mean global temperature when the ice was laid down. (From P.D. Ditlevson, Ditlevson, & Andersen, 2002)

A number of plants and animal species became extinct during the last ice age, including two of the three species of *Homo* known to exist when the ice age began, *Homo neanderthalensis* in Europe and the tiny *Homo floresiensis* whose fossils were found six years ago on an Indonesian island. By contrast, our own species *Homo sapiens* began to flourish during this period. Skeletons more than 200,000 years old have been found in Africa that are thought to be from members of our own species they are indistinguishable from skeletons of contemporary humans. There is some question about this however because, until about 90,000 years ago, their lifestyle appears indistinguishable from that of hominins that had been living for the past million years. The scarcity of fossils is consistent with the results of the genetic analysis (Atkinson et al., 2008); their population appears to have been very low.

Human artefacts about 75,000 years old found in Blombos Cave, South Africa.

The first signs of change have been found in Africa. Evidence of pockets of denser human population has been found associated with more sophisticated tools and items of personal adornment and artwork. But these glimpses of more complex culture were local and temporary, appearing briefly from about 90,000 years ago. About 50,000 years ago some *Homo sapiens* began to migrate from African and

spread across Eurasia and into Australia.

Then, about 50,000 years ago groups living in western Eurasia, began to develop new tools and a complex culture that endured and became increasingly complex with many intricate tools, body ornaments, cave paintings and sculptures of fat women. Groups associated with these artefacts persisted for thousands of years and their characteristic artefacts, such as the well-known "Venus" figurines, have been found from the Atlantic coast to an area just north of Mongolia. The north eastern part of this range was probably occupied briefly during times of most favourable climate. Archaeological evidence found so far suggests that complex culture began to emerge in other regions quite a bit later, after the last glacial maximum, about 20,000 years ago. By the time the climate began to warm up and become more stable, about 12,000 years ago, the human population had increased considerably and humans were living in all the continents except Antarctica.

The suddenness of the cultural advance in one human sub-population has caused speculation about the possibility that a genetic mutation occurred in this group which restructured the human brain in such a way that more complex behaviour became possible (Klein, 2009). It is suggested that this highly beneficial mutation then spread to human groups in other parts of the world allowing them to acquire complex culture too. The discovery that some human groups made complex cultural artefacts much earlier that this and then apparently abandoned them casts doubt on this idea.

We are more convinced by arguments that it was *demographic* rather than *genetic* change which lead to our ancestors developing more complex culture during the last ice age (Powell, Shennan, & Thomas, 2009; Richerson, Boyd, & Bettinger, 2009). No single brain (however large) is capable of developing complex culture. Culture is the product of a population; it consists of the contributions of many minds working over time, adding new ideas and inventions and refining or abandoning old ones. But useful inventions are rare and so it follows then that the larger the population of people that are interacting and sharing ideas, the more rapidly useful ideas will accumulate and be improved upon. Also, because errors inevitably occur in the recall and communication of information, there is a risk that at some time information, especially more complex information, will not be remembered accurately and be lost to the population. The smaller the population, the greater will be the risk of cultural loss.

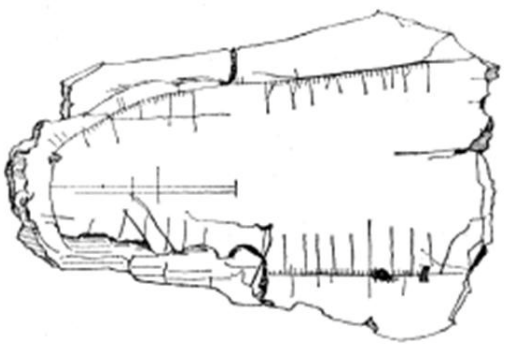
Henrich (2004) showed mathematically that a population below a certain size cannot maintain a culture above a certain complexity and points to the loss of technology by the inhabitants of Tasmania as an illustration. Tasmania was first inhabited about 34,000 years ago during the last ice age when sea levels were lower and Tasmania was connected to Australia. Archaeologists have found that when Tasmania became an island between 10

and 12,000 years ago, people living there had a culture similar to the people living in Australia. They had, for example, boats, fishing equipment and needles to make clothes. But over the intervening years of isolation the small population lost skills and tools. When Europeans landed on Tasmania in the 18th century the naked islanders were found to have the simplest technology of any know contemporary human group with only 24 tools. Diamond (1997)argues that the demographic effect on innovation operates at large scales too.

Rises in the human population may have occurred during the last ice age because the extreme climate chaos expanded the ecological niche of *Homo sapiens.* Our species can couple individual learning and cultural transmission to adapt to rapidly changing environments faster than our competitors and predators. Notice in the climate change graph above (page 13) that temperature fluctuation becomes especially intense about 60,000 years ago. This is roughly the time that humans appeared to grow more abundant and to spread out of Africa. If climatic fluctuations were allowing humans to be more successful, regions rich in resources could have become quite densely inhabited by humans for long enough for cultural adaptations to have accumulated making the population even more successful. Climate change or depletion of resources would have lead to the dispersal of the population and eventually to the loss of cultural complexity.

The populations that settled in western Eurasia may have been able to maintain complex culture may because they were situated on one edge of a huge area known as the "mammoth steppe biome" which during the last ice age stretched from near the Atlantic coast across Siberia to Alaska and Canada. There is no evidence of permanent settlement of the eastern part of this region until nearly the end of the ice age. But the biome could have provided humans living in its western part with a source of game that did not become depleted (Richerson et al., 2009).

There is also intriguing evidence suggesting that some European populations developed institutions and technology that allowed them to maintain a large communicating population even though members spent most of their time living in small nomadic bands. The cultural artefacts of the population that have been found include many pieces of bone and ivory with characteristic scratches. The scratches have been found to match up with phases of the moon and could have allowed bands to keep



Drawing of a piece of Upper Palaeolithic engraved mammoth ivory found in the Ukraine. Scratches on this and similar artefacts match with the phases of the moon. They may have been used as a calendar to allow regular meetings of nomadic small bands.

track of the passage of time so they could meet up at agreed times (Marshack, 1964, 1972). Such meetings would have enabled people to get together to exchange news and ideas and to meet potential mates. It is interesting that the cave paintings produced by this culture have no depictions of warfare, in contrast to the art produced by more recent cultures where the glory and sacrifice of war is a popular theme (Guthrie, 2005). The ability to maintain a peacefully communicating population large enough to maintain a complex culture should perhaps be called "The First Demographic Transition" (Deevey, 1960).

Most people interested in the evolution of human behaviour think about how genes might have evolved that affect behaviour. But if the line of evidence and reasoning presented here is correct, we should also be investigating the role of connections between people and the information that flows along these connections. If the size and connectedness of a population drives cultural evolution, we have a parsimonious explanation for some otherwise enigmatic patterns in human evolution. It explains why large-brained hominins that are indistinguishable from contemporary humans lived for thousands of years using essentially the same tools as the smaller-brained *Homo erectus*. As long as they lived in small unconnected groups, little cultural advancement would have been possible. .

After the end of the ice age, warmer and more stable climates created many habitats that could be more densely populated. People could develop cultural adaptations specific to the environments they inhabited. Culture varied widely between groups and they each evolved independently as innovations and improvements were introduced. It became possible to settle and farm (Richerson, Boyd, & Bettinger, 2001). The domestication of plants and animals made it possible to support a larger population in a given habitat. As farming was invented in different regions and farming practices spread, the human population increased further, triggering was could perhaps be considered "The Second Demographic Transition" (Deevey, 1960). Cultures evolved to be more complex and population grew but human reproduction out-paced the invention of ways to increase food supply so that eventually the size of the population was limited by the "carrying capacity" of the environment.

The history and archaeology of ancient and classical civilizations provides further evidence of the link between the size of a communicating population, the rate of innovation and the complexity of culture. People tended to aggregate in attractive locations creating a communicating population large enough to allow more complex culture to develop including institutions, technology and infrastructure that allowed the population grow further and stay large – for a time at least. Writing was invented several times by a number of ancient cultures. When natural catastrophe, civil unrest or invasion causes damage to the infrastructure and the institutions fail, people disperse and stop communicating. In a remarkably short time much of the information associated with the civilization is forgotten.

The contemporary demographic transition and future implications

Industrialization allowed people to group together in populations larger than our species had experienced before. It began a period of rapid and accelerating cultural innovation. The continuing development of communications technology and the emergence of institutions and infrastructures that facilitate communication have allowed the size of communicating populations to grow and grow. Today's communicating population includes a large portion of the people living on Earth, with additional input from a fair number of people who are dead but whose thoughts and actions are recorded.

In this "global village", technical and social innovation is rapid and accelerating. This has allowed resources to be extracted and processed faster than we can produce children to consume them. As a result, a large portion of the contemporary human population has enjoyed prosperity or the promise of prosperity never before experienced by *Homo sapiens*. There are limits to the rate at which resources can be obtained so, if humans produced children as rapidly as biologically possible, this prosperity could not continue indefinitely. Starvation and warfare would inevitably ensue as people once more had to compete for limited resources. Today's industrialized population would be just another "civilization" that flowered for a time and then declined. The widespread adoption of family limitation gives reason to hope this will not be the case. Note however, that rising per capita income, to the extent that it is used to consume things with negative environmental externalities, will lead to a "carrying capacity" crisis just as effectively as an expanding population with low resource consumption per capita. Our so far feeble attempts to control CO_2 emissions and deal with other environmental problems reduce some of the hope stemming from widespread declines in fertility.

The kin influence proposes that the adoption of family limitation is just one of the many cultural innovations that comprise what has become known as "the modernization process". People began to adopt family limitation because they began to communicate with a far larger group of people and for the first time in human history social exchange between non-kin dominated the social lives of a large proportion of the population.

This does not imply that the fertility decline is merely a minor part of this change. It suggests that during this demographic transition (The Third Demographic Transition?) *Homo sapiens* will experience a transformation as profound as to that experienced during the last ice age when a clever but endangered hominin found the means to maintain a large communicating population and was transformed into a species that would come to dominate the planet. Over the last few centuries humans have developed ways of maintaining a much much larger communicating population. This has turned a highly

competitive species into one whose members continue to compete, but no longer in a biological sense.

When people spend most of the lives isolated in small, family-based groups they tend to see themselves as permanent members of a village or tribe made up of family members and their allies. These groups compete for a limited supply of resources. The ability to produce thriving offspring and ensure the continuation of the group represents success in that competition. The solution to overpopulation is tribal warfare to expand territory and gain resources. It is Darwinian natural selection, but at the level of the group as well as at the level of the individual (Keeley, 1996; Otterbein, 1985; Soltis, Boyd, & Richerson, 1995).

When technology, institutions and infrastructures exist that allow people to make connections and receive information from a larger population, they are no longer so tightly bound to their families or their neighbours. They are inclined to see themselves more individualistically – individuals who are members of several groups simultaneously (Ethier & Deaux, 1994; Tajfel, 1981; Turner et al., 1987). Many of the memberships are temporary. The groupings themselves are often temporary. The result is that throughout their lives people feel bound to many large populations, not just a family, an ethnic group or a nation but many many international communities, communities of demographers, Beatles fans, Real Madrid supporters, online gamers and so on. There may be drawbacks to this new social organization; family and neighbourhood cohesion will be less and perhaps some individuals will be less psychologically healthy (Haslam et al., 2009). But there are advantages at the level of the population.

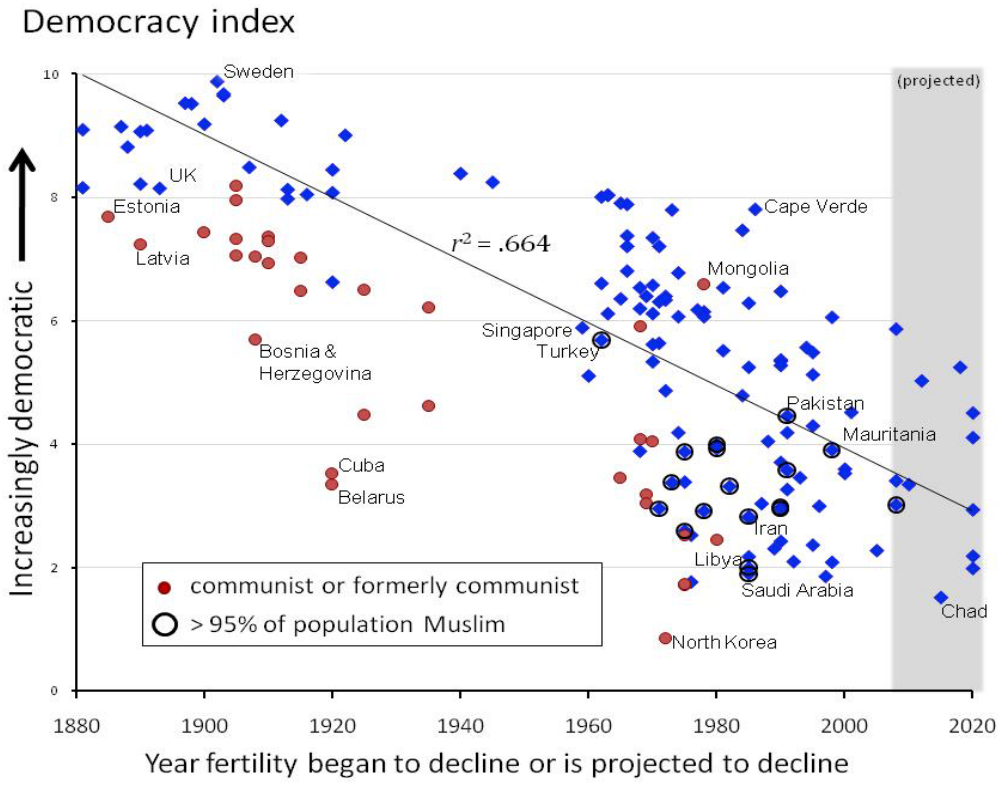
Culture evolves so that competition may be fierce but the goals of competition change. Meeting these new goals becomes irrelevant or even detrimental to the genetic fitness of the individual, his clan or his tribe. Killing and dying for one's tribe cease to be seen as glorious. Producing many descendants and ensuring the continuation of the family line is no longer seen as priority in life for women or men. Instead, the goals of competition are culturally defined and can be hugely diverse. Contemporary humans may feel rewarded if they can buy a new car, win a sports medal, have an academic paper published, any number of bizarre "accomplishments" that have nothing to do with biological fitness. Rules of the competition are established and enforced by cultural institutions. Nepotism and secrecy are seen as signs of corruption, vengeance is meted out by a justice system and not by individuals or families, resources are distributed by a regulated system of trade and people increasingly share a concept of "fairness".

Western countries, which were the first to industrialize, should be furthest along this cultural evolutionary trajectory. Members of these populations should therefore be more individualistic, less inclined to strive for reproductive success and more used to the

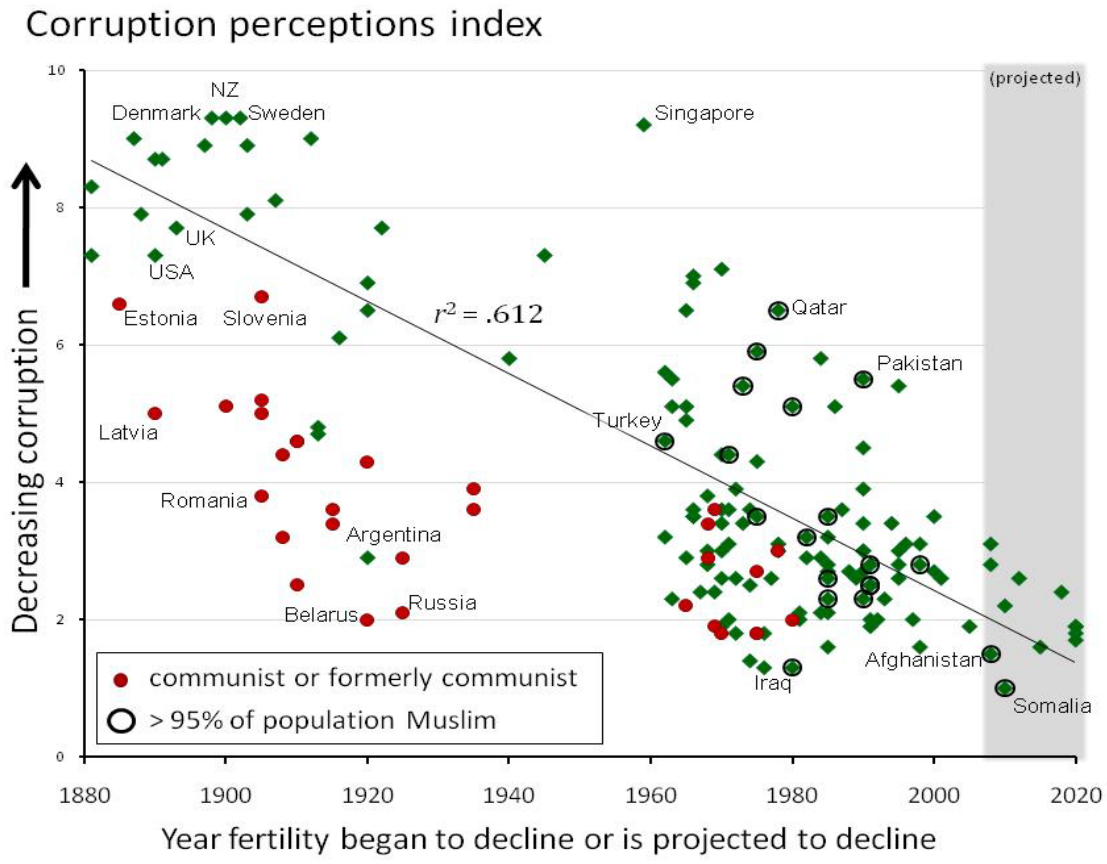
institutions that allow strangers to cooperate and compete in ways compatible with peaceful coexistence between strangers. In these countries, institutions maintaining biologically benign competition have been working longer and are likely to be more effective. Enforcing the rules will be easier in these countries most people have been socialized with the values behind the rules. In countries that are not economically developed or where economic development has just begun people will be less individualistic and more influenced by tribal and dynastic loyalties. These will make it difficult to establish the institutions of business, justice and government that make "modern life" possible.

These predictions are consistent with a superficial view of how countries change after economic development begins and also with a quick comparison of countries today which are considered to be more or less "developed". But we also carried out some more systematic tests of whether cross-national differences suggest that the populations in these countries are in different positions on the cultural evolutionary trajectory we describe (Newson & Richerson, 2009). We suggest that fertility decline occurs in all populations at an early stage in this progression and so the year that fertility began to decline can serve as an objective means of positioning countries on the progression. This is a far from perfect method for testing the predictions because the people living within the borders of a state in 2009 do not represent a single cultural population unconnected from other populations. Nevertheless, the year fertility began to decline in a country predicted a great deal of the between countries in number of dimensions (Newson & Richerson, 2009). We show three examples below.

The "Democracy Index" is an attempt by The Economist Intelligence Unit (http://www.eiu.com) to describe the state of democracy in 167 countries. It is based on the weighted average of answers to questions about electoral process and pluralism in the country, civil liberties, functioning of government, political participation and political culture. Experts who know the country are recruited to supply the answers. A plot of the Democracy Index of a country against year fertility began to decline in the country (above) is consistent with our suggestion that the cultural elements that encourage people to participate in and be subject to democratic government emerge as part of an evolutionary process that includes fertility decline. These elements appear to evolve more rapidly in some social environments than others. Former communist countries and countries whose population is largely Muslim have lower than expected democracy ratings.



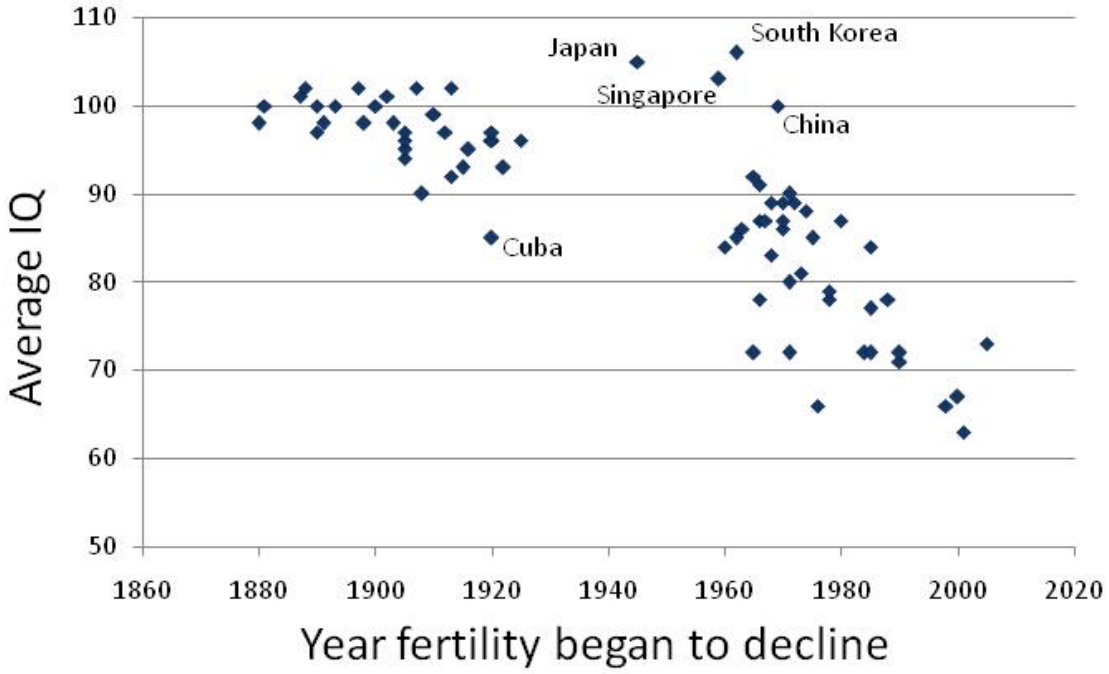
The "Corruption Perceptions Index" is an attempt by Transparency International (http://www.transparency.org) to describe "the degree to which corruption is perceived to exist among public officials and politicians". A plot of the Corruption Perceptions Index of a country against year fertility began to decline in the country (above) is consistent with our suggestion that the cultural elements that encourage people to obey and enforce rules of fairness emerge as part of an evolutionary process that includes fertility decline. Again, these elements appear to evolve more rapidly in some social environments than others. As with the Democracy index, corruption is perceived to be higher in former communist countries but having a largely Muslim population does not have an effect.



The

During the last ice age, humans gained so many new competencies so rapidly that it has looked to some as if the human brain had been somehow transformed by a genetic change (Klein, 2009). But some argue that it is more probable that the transformation was the result of our ancestors finding ways of maintaining larger communicating populations (Powell et al., 2009; Richerson et al., 2009). We may be seeing a similar transformation occurring today as communicating populations increase in size. IQ tests were thought to measure innate mental ability and it has been argued that differences in mental ability are due to differences in genes. However during the 20th century the mean IQ of people in Western countries, where IQ tests have been carried out longest, rose between three and five points per decade (Flynn, 1984, 1987a, 1987b).

Lynn and Vanhanen (2002) estimated what they argued was the mean IQ for the populations of 81 countries based results of "culturally neutral[1]" tests that had been administered in the countries and found considerable variance between wealthy and poorer countries. Plotting the mean national IQ of a country against the year fertility began to decline in a country (below) suggests that the ability perform well on these IQ tests rises steeply at an early stage of this process and then it levels out. The change may be the result of adults investing more in children so they receive better nutrition, health care and mental stimulation.



[1] In fact, it has been shown that so-called culture neutral questions to measure IQ actually show the strongest effect of culture (Nisbett, 2009).

Contemporary humans are enjoying or anticipating lives of greater comfort and with more intellectual stimulation than has ever been possible before. A vast and growing interconnected population is contributing new knowledge and new tools to our global culture at an accelerating rate. The new knowledge includes a growing understanding of the biology and psychology of our species. The new tools include methods of learning even more about ourselves. It is important that we now used this knowledge to try to manage the rapid social and cultural changes that we are all experiencing.

It is often suggested that cultural change in developing countries is due to western values spreading slowly to developing countries as they gain greater wealth and security (e.g., Inglehart & Welzel, 2005; Thornton, 2005). Observations of recent change and contemporary cultural differences are roughly consistent with this explanation. But this interpretation does not take into account the historical and evolutionary context of cultural change we have presented here and it ignores many decades of social psychological research into how social norms form and change (Tajfel, 1981; Turner, 1991; Turner et al., 1987).

An evidence-based understanding of how and why people's attitudes and behaviour become more "modern" will allow development aid to be targeted more effectively. To target aid in ways that encourage good governance, an effective business environment and low fertility, policy-makers need to know what leads people to adopt values and beliefs that support such changes. If adoption is the result of people accepting Western values when they perceive that it will bring them a better life, then aid should be directed in ways that might alter people's perceptions about the West and its values.

But if we are correct, "modern" values do not so much spread from the West as emerge independently in each population as people begin to connect and identify with a wider population. If this is true, then attempting to change perceptions will often be ineffective or counterproductive. Working to increase wealth, health and security will not change the values of a population while members' social networks remain clan-based and tribal. Trying to establish institutions that rely on what many members of the population perceive to be foreign values may even slow down the adoption of these values. A better way to encourage adoption of modern values, in our view, would be to help establish an infrastructure for communication, safe travel and education in order to facilitate wider social networks.

And, if we are correct, "modern values" should not be seen as static or even approaching stasis. Modernization and the demographic transition are still happening in every human population. The widening of social networks does not cause "*a* change" but triggers a change process and on the time scales of archaeology the rate of change is unprecedented.

We can't be sure what the future will look like, but that does not prevent us trying to influence the direction of change. Nor should it. But if the underlying driver of change is a cultural evolutionary process, rather than contemporaneous events, then it is not surprising that attempts to predict, manage and influence social change in developed countries have not been very successful.

It isn't surprising that individuals or groups of people in developed countries often believe things that aren't true and make decisions that are not in their best interests. A lot of the social information they receive is of poor quality (Glover, 2009). Advertisements, for example, are produced with the express purpose of trying to persuade people do make decisions that are in the best interest of the advertiser. The human brain did not evolve in an environment where there was so much information and so much choice so there is no reason to think that *Homo sapiens* would have evolved the cognitive skills to make effective decisions in such an environment. It may therefore be reasonable for governments to think of ways of developing institutions that will increase the quality of information that is presented for public consumption. We need to be guided by something more sophisticated than a simple distaste for censorship or a belief in "free speech". A "happiness warning," like tobacco health warnings, might do: "the following is a self-serving message designed to increase Acme Inc's profits, not necessarily your well-being."

The one thing that we, as evolutionists can predict with certainty is that there will always be natural selection. If trends continue, family limitation will be adopted in virtually every human population in the next few decades. But there will continue to be individual-level and probably population-level variation in the number of children produced. Inevitably then, cultural and genetic traits associated with higher fertility will become more prevalent while those associate with lower fertility will become less prevalent. For example, unless they can keep attracting new members, groups with lower fertility such as female academics will be less represented in future population, Meanwhile, groups which encourage isolation in family-based communities, such as Old Order Anabaptists, some Roma and Ultra-Conservative Jews will become more common if they can continue to persuade their children to follow their parents' ways. In the same way, genes associated with a disinclination to mate, such as those which make people more likely to prefer same-sex relationships (Mustanski, Chivers, & Bailey, 2002) will become less common. And meanwhile, genes associated with higher fertility such as a love of babies or a disinclination to obey reproductive norms will become more common (Kohler, Rodgers, & Christensen, 1999). Of course, the effects of global environmental change are quite unpredictable, as are many other things relevant to forecasting the future evolution of humans. But we can be pretty sure that present demographic behaviours are unsustainable.

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