1 Introduction: The Evolution of Culture in a Microcosm

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Evolutionary speculation constitutes a kind of metascience, which has the same intellectual fascination for some biologists that metaphysical speculation possessed for some medieval scholastics. It can be considered a relatively harmless habit, like eating peanuts, unless it assumes the form of an obsession; then it becomes a vice.

—R. V. Stanier, Some aspects of the biology of cells in H. Charles and B. Knight (eds.), *Organization and Control in Prokaryotic Cells*

As the quotation here suggests, this volume is full of the vice of speculation. Yet any student of the human condition can hardly avoid it. Somehow culture—or at least the culture-bearing ape—evolved. An evolutionary perspective on human culture, which is much less fashionable now than it was 70 or more years ago, seems inevitable, yet the social sciences actively resist it, allowing ill-informed conjectures from other sciences (which does little to increase the interest from the social sciences of course).

In this introductory chapter, I try to do two things: The first is to deal frontally, and speculatively, with what I take to be the "big questions" about the evolution of human culture. This may serve as a partial introduction to the more detailed explorations in other chapters in this volume. The second is to give the reader some grist for these speculative mills. I will argue that if we look at the details of any culture, it is quite clear that we need an evolutionary perspective to understand how such features could have arisen (note that such a perspective is quite consistent with other kinds of social science explanations). I will take as an example an island culture, which because of its relative isolation can serve as a microcosm in which to explore these issues.

The Big Questions

I take the following questions to express the fundamental issues that must be addressed in trying to develop a framework in which to think about the evolution of culture:

How Do We Embed the Phenomena of Culture within Evolutionary Theory?

We need of course to avoid the dichotomy the natives advance, with "culture" opposed to "nature," and find a way to see culture as just a part of nature, as evolutionary business as usual. The problem then is to determine what is the right framework in which to do this in order to situate culture within the scope of evolutionary mechanisms. What exactly are the properties of culture that make it special and out of the ordinary, and how are we to account for the fact that humans are obviously adapted to and for culture?

Why Did Culture Happen (more or less) Only Once? What Exactly Is the "X-Factor" in Our Lineage?

Exactly how often culture has evolved in the development of life on earth will depend of course on how it is defined. Finding culture among the apes is merely to find pale shadows of our kind of culture in our very own lineage, and thus to reassure us that there is indeed some evolutionary account for culture (rather than its being, for example, some accidental freak of nature). Even if we concede even paler shadows to some birds or cetaceans, there is no doubt that there is only one beast that has what Tomasello (1999 and chapter 10 in this volume) calls "ratchet culture"—the ability to build up ever more complex cultural and technological skills over generations. The question then is, what exactly lies behind this human ability, and what selected for it; that is, what is the X-factor and what kind of origin story can we concoct for it?

Let us take the questions in turn. There is a growing consensus, despite inbuilt resistance in the humanities and social sciences, that culture must be seen as part and parcel of the biosphere, and thus that there has to be some evolutionary story about humankind, not just as an ugly ape, but as a culture-bearing species with the ability and inclination to develop apparently limitless social and ideational complexity. However, there is absolutely no consensus about how to construct an explanatory framework for the origin of culture, and there are plenty of divergent strands of opinion. We need some framework that—without any magic "skyhooks" as Dennett (1995 and chapter 6 in this volume) has it—can provide the mechanisms by which the biological preconditions for culture could have evolved in the normal way that organisms evolve, and culture could have progressively raised the stakes, so that the biological preconditions were ratcheted ever upward. As Theodore Dobzhanzy (1962: 18) put it 40 years ago: "Human evolution cannot be understood as a purely biological process, nor can it be adequately described as a history of culture. There exists a feedback between biological and cultural processes."

The idea of a feedback relation between culture and genome is at the heart of what we can identify as the new synthesis, namely, "twin-track" theories of gene–culture evolution. There are various brands on the market (see e.g., Cavalli-Sforza and Feldman

1981; Lumsden and Wilson 1981; Boyd and Richerson 1985; Durham 1991), but they share the idea of a universal Darwinism, in which evolutionary theory embraces the study of all kinds of "replicators," where a replicator is any entity (such as a computer virus) that can copy itself by preserving information. Cultural entities, from items of technology to words, tunes, or fashions, can copy themselves through the actions of their hosts or "vehicles," suggesting a parallel between genes and "memes" or cultural replicators (Dawkins 1976, 1983: 109–112). Or, to look at it in a more conventional way, cultural entities can be transmitted by teaching and learning across generations, allowing "descent with modification" in Darwin's (1872: 3–10) succinct definition of evolution. The useful synthesis by Durham (1991) emphasizes the ideational nature of this cultural track, or line of descent, a point to which we will return. In these theories, both genetic and cultural tracks are seen as self-replicating strands, which share the fact that they are (1) informational, (2) partially independent, yet (3) potentially mutually influencing.

Both tracks are subject by hypothesis to universal Darwinian processes of selection. The interactions between the tracks produce a great upward spiral in "design space" (as Dennett has it), crucially with culture as part of the selecting environment, putting a premium on the underlying cognitive capacities that make the learning and production of cultural information possible. Figure 1.1 tries to represent this graphically, showing culture and genome spiralling up in design space over evolutionary time,

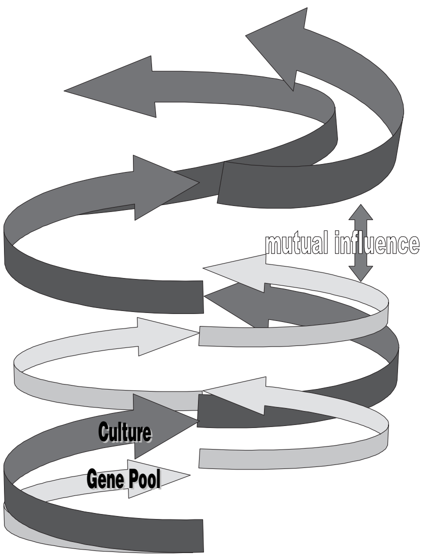

Figure 1.1
Twin-track evolution with feedback.

with an increasing independence as culture comes to have a life of its own, even being able to cushion the effects of natural selection on the genome.

There are a number of immediate challenges to this picture, which we should deal with right away. How can this close interaction work, the sceptic may ask, when the speed of adaptation in the biological track is severely restricted by the glacial pace of biological innovation (through mutation and reproduction over generations), while cultural evolution relies simply on ideational innovations that can jump the barriers of vertical (generational) transmission, and seems to be ever accelerating? However, there is an important existence proof that two separate strands of replicators that reproduce and adapt at quite different rates can nevertheless be deeply interlocked by mutual adaptation. I am referring of course to interspecific symbiosis. Take the classic case of the sycamore fig and the gall wasp (but see Combes in chapter 2 for an overview of different kinds of symbiotic relationships). The female wasp enters the fig inflorescence to deposit her eggs, and in doing so fertilizes the fig. She lays her eggs in the internal flowers; the males hatch first, fertilizing the infant female wasps while they are still embedded in the flowers, which have become galls. The males die and the females leave to repeat the cycle (Paracer 1986: 169–170). The fig relies absolutely on the wasp for fertilization, and the wasp only reproduces inside the fig flower; the two species are locked in an evolutionary embrace that neither can escape. Fig and wasp are constituted of separate tracks of DNA that can never intermingle; the fig provides the nuptial bed, the cradle, and the tomb for the wasps. They are obligatory symbionts, yet the male wasps live only days, whereas the fig tree can live for hundreds of years. In the same way, human biology and culture, though information channels with quite distinct pathways, different time trajectories, different vehicles, and different selection pressures, have become indissolubly linked. The human body is unlikely to survive without clothing, cooked food, tools, and other fundamental cultural replacements for teeth and claws. The parallels are spelled out in table 1.1.

The parallel takes us further. We know that some of the great leaps in evolution, "punctuations" if you will, have taken place in the special circumstances of twin-track

Table 1.1
Twin-track evolution: The parallel between symbiosis and gene: culture evolution

	Fig and wasp	Culture and human genome
Separate symbiotic tracks	Of DNA	Of ideas and practices and DNA
Context of life-span	(Male) wasp within fig	Individual within culture
Obligate symbionts	Fig depends on wasp, wasp depends on fig	Individuals depend on culture, culture depends on individuals
Differential speed of change	Many wasp generations to each fig generation	Culture changes faster than human genome

evolution, which allows a spiral of mutual adaptation in which the two strands can ultimately fuse into a single system. This is the story of the evolution of the eukaryotic cell. [The mitochondria and chloroplasts that occur in eukaryotic cells seem to have originated as separate organisms that took up residence inside other cells; see Margulis (1981) and Combes in chapter 2]. In a somewhat similar way, the interaction between culture and genome in humans has produced an extraordinary symbiotic hybrid, yielding a quantum leap in adaptational flexibility, which allows humans to exist in every niche on the planet and beyond. The process appears to have been initially gradual, but then to have accelerated (see Foley in chapter 3 in this volume).

A second immediate challenge to theories of twin-track evolution is the uncertain nature of the feedback mechanisms between the two tracks. Even in biological mutualism, such feedback systems are still somewhat unclear, but those involved in gene–culture evolution seem entirely obscure. There have to be potential feedback mechanisms in both directions: from genome to culture, and culture to genome. The genome to culture route is easier; it is clear that biological capacities can facilitate or make possible cultural adaptations. Thus the anatomy of the hand and its motor control were the prerequisite to tool making, or the human vocal apparatus and its neural underpinnings were the foundation for producing language. Culturally variant technologies and distinct languages rest upon a shared biological foundation. Thus during the course of human evolution, neurophysiological adaptations (e.g., in cognitive capacities and motor skills) would have afforded new cultural forms. However, the feedback loop from culture to genome is altogether harder. How could the growing use of tools, for example, have possibly influenced the underlying neurophysiology and anatomy that supported it? How, in short, can one explain Lamarckian effects while avoiding the Lamarckian fallacy?

There are in fact a number of perfectly plausible mechanisms by which culture can have feedback effects on the genome. Here, for example, are half a dozen candidates:

1. Natural selection in a cultural environment Selection operates on the phenotype through the environment. That environment can be partly constructed by the organism itself, which is involved in a process of niche construction (Laland et al. 2000). Thus the selecting environment can be cultural. Take fire. The use of fire softens food and increases its recoverable nutritive value, while rendering plant toxins and bacteria in flesh relatively harmless. It probably lies behind the progressive reduction of dentition that we associate with the development of *Homo sapiens* from *Homo erectus*, and perhaps also changes in the gut that are not visible in the fossil record.

2. The Baldwin effect Behavioral changes can feed back into the genome by exposing the organism to new environmental pressures, e.g., through the colonization of new ecological niches, where natural selection can eventually "fix" a surrogate of the behavioral adaptation in the genome (Baldwin 1896; Deacon 1997: 322–323). Take

clothing. With it, early humans could move into much colder environments, where natural selection would gradually favor a less gracile, less African body shape, one better adapted to the same circumstances that the clothing was adapted to. Thus the Inuit (Eskimo) peoples have evolved special physiological adaptations to extreme cold (such as vasodilation in the limbs, the ability to produce glucose from meat instead of from carbohydrates), but it was only the technology of creating clothing from skins that made inhabiting the arctic possible in the first place.

3. Group selection In the normal case, natural selection operates on individuals. Among humans, however, where culture-bearing units compete for resources, if a group can act as a single whole (e.g., in conflict), it may survive or perish as a whole (Wilson and Sober 1994). Cultural or technological superiority can then force a less well-equipped group into extinction (see Boehm 1996 and chapter 4 in this volume, and Boyd and Richerson in chapter 5, for limitations on the mechanisms). This is a likely scenario for the Neanderthals of northern Europe, and recent research (Krings et al. 1997) suggests that our genes have triumphed without sharing theirs.

4. Kin selection in culture-bearing kindreds Group selection can be related to the better-understood mechanisms of kin selection, in which altruistic behavior by one individual on another's behalf can benefit the donor if there is sufficient biological relatedness between them. Small groups, such as hunter-gatherer bands, are kindreds; they are typically both culture-bearing units and descendants of a common ancestor. The mechanisms of kin selection will thus tend to keep the minimal culture-bearing unit afloat (see Boyd and Richerson, chapter 5).

5. Sexual selection Darwin (1871: ch. 8) considered that many aspects of human morphology could be attributed to sexual selection, that is, the choice by females of their mates. If a culture sets up boundary conditions for reproduction (e.g., the payment of a bride price or success in economic or political arenas), it translates the biological foundations for those social skills into reproductive success, thus ultimately fixing those skills in the genome. Humphrey (1976) introduced the idea that the most demanding aspects of the environment for primates are their own typically complex social systems, and thus that primate intelligence can be ascribed to the mental gymnastics required to survive and reproduce in there systems. A quite plausible story for the evolution of the biological foundations for language can be told in terms of sexual selection (Deacon 1997).

6. "Auto-domestication" Every dog reminds us of the power of selective artificial breeding, even over a relatively few generations. In this case, humans are the breeders, the dogs our slaves. Of course we do selective breeding in our own species, as in strategic infanticide and infant neglect, in planned marriages and the harems of despots. We also selectively invest in our young, differentially affecting the reproductive success of our offspring. Darwin (1871: ch. 2) speculated about these effects in the planned marriages of Prussian soldiers and in Spartan infanticide, but noted that

there were distinct limits to the extent to which humans have applied breeding techniques to their own kind, even in slavery. Still, unpalatable though it may be, some degree of auto-domestication is probably observable in every society, and may have been rife in human history (see e.g., Voland 1998; Beise and Voland 2002).

Such a list of mechanisms is bound to be controversial, on account of the wars between the ultra Darwinists (such as Williams 1966; Dawkins 1976; and Dennett 1995) and the soft Darwinists (such as Gould and Lewontin 1979 and Rose 1997), who don't like Darwin's dangerous idea neat, without a dash of seltzer (see Sterelny 2001 for a dispassionate assessment). The difference is that the ultra Darwinists emphasize one level of replicator, the selfish gene, and strict adaptationism, while the soft Darwinists emphasize the whole hierarchy from gene to organism to supraorganism (e.g., distinct species in symbiotic association), and embrace the idea of other mechanisms, such as symbiosis, group selection, niche selection, "spandrels" and exaptation, and even wild chance. When considering the evolution of culture, we are dealing with a rare (even unique) event, closest in kind to symbiosis or mutualism, and it perhaps makes sense to entertain the broadest array of possible mechanisms. In any case, it will suffice for the current argument that at least some such feedback processes—by which cultural attributes might have effects on the genome—can be presumed to exist. Certainly it is hard to envisage how our species could possibly have evolved the way it has without adaptation both to and for culture—naked and defenseless, slow yet terrestrial, with a gut and dentition requiring prepared food, with nearly a third of the natural life-span spent in dependent childhood.[1]

Perhaps the most powerful argument is, again, an existence proof. Durham (1991: 226–285) develops a careful argument from earlier work that distinct food-preparation techniques have resulted in microevolutionary adaptations in human groups. Thus human groups differ in their ability to digest milk in adulthood. In most humans, the production of the lactose-digesting enzyme, lactase, shuts down after weaning, and many individuals then exhibit severe side effects from drinking milk. However, in northern European dairying populations, and equally among milk-drinking African pastoralists, most individuals can absorb lactose throughout adulthood. There is an interesting intermediate group that contains both lactose absorbers and nonlactose absorbers, such as peoples on the Mediterranean fringe. Here dairying takes a different cultural form; fresh milk is first soured and turned into yoghurt or cheese, where bacteria digest the lactose. The fit between cultural practice and the distribution of relevant genes in the populations is precise enough to strongly support the causal relation, and alternative hypotheses either fail detailed analysis or are compatible with the role of agricultural practice as the dominant casual factor. In addition, the kind of time scale involved, in thousands of years, is sufficient for this kind of feedback to have taken place.[2] If we can demonstrate this kind of microevolution under cultural feedback in perhaps as little as forty generations, there is no reason to doubt that similar processes have taken place in many other cases.

Other examples of the effects of cultural adaptation on the genotype can be seen in the differential prevalence of type II diabetes and hypertension across cultures. These have sources in metabolic thriftiness and salt conservation, respectively—adaptations to insecure, difficult, preagricultural conditions. Indigenous populations that converted to agriculture and trade suffer a much higher incidence of these diseases than Europeans, who have adapted to "the unconscious domestication of humans by agriculture" (Diamond 2002: 707). Durham (1991: 103–153) also documents a similar interaction between agricultural practice, malaria, and sickle-cell anemia in West Africa.

A third challenge to theories of twin-track coevolution is a rejection of the parallel between information in the genome and information in the cultural track. Cultures, the challenge goes (see e.g., Midgely 2001), are not built out of replicators or "memes" to be likened to genes, as Dawkins (1976) suggested. Indeed, the idea of memes—without clear ideas about the larger structures built out of them—has incurred the ire of social theorists, who do not like to see the highly integrated institutions of social life treated as unstructured masses of memes.[3] Sociocultural systems are systems, not heaps of transmissible traits. The parts of systems cannot be replaced by random objects unless the objects happen to fulfill the same function as the parts (think of a spare part in a car engine). So how seriously should we take the theory of memes? Leaving aside its sufficiency for a theory of culture, there are fundamental internal unclarities about memetics, and serious deviations from the genetic model, as the following list suggests (see Dennett 1995:352–360 and chapter 6; Midgley 2001):

- DNA has only syntax, while memes have semantics; copying of genes is mechanical, copying of memes is intentional and pays attention to the semantics. Dennett and Sperber (chapters 6 and 7 in this volume) explore the implications of the fact that people reproduce what they take to be the intentions behind actions (hence the importance of a theory of mind, which is extensively discussed in this volume). While Dennett suggests that this can be thought of as just a higher-level editing procedure, Sperber holds that this dooms memetics.
- Genes do not cross lineages, memes routinely do; there is horizontal as well as vertical transmission. It is notoriously difficult to tell diffused traits from lineally inherited ones in culture. In anthropology in the 1920s, this was a major contention, and even today there are neighboring languages where the experts can't agree whether the languages are related by descent or by convergence through borrowing.
- Memes by descent versus convergent memes: How can one distinguish inherited memes from parallel invention, especially since part of an idea might be inherited and the rest developed independently? Consider also that evolutionary psychologists like to think that many alleged memes are just phenotypic expressions of genes.

- Memes blend in the very process of replication, genes do not.
- The fidelity of reproduction: DNA replication is nearly perfect but memetic reproduction is mutuation-prone. Indeed the transformation of memes in reproduction might be one of the most important properties of cultural facts, suggesting an alternative model (see Sperber in chapter 7).
- Memes have to be isolates, and thus independent units. However, cultures (as mentioned) are structured assemblages of ideas, and there is no obvious basic unit. Take a kinship system. Is the meme the notion of "mother's brother," "uncle," "collateral kin," or indeed the whole structured system of kin terms, or is it the associated behaviors or the inheritance customs built on that system, or what exactly?

In short, memes do not really look like genes. They lack Mendelian principles of segregation and assortment, veridical copying, and vertical descent, and they pass through the active filters and recombinations of the mind, not automatic splicing and editing procedures. There are many further basic issues; for example, if genes are selected via their phenotypic effects on their vehicle (the organism), what exactly are memes, meme vehicles, meme phenotypes, etc? Much more work would be needed before we could be said to have a serious theory of memetics (see Aunger 2000; Laland and Brown 2002). Sperber (chapter 7) suggests that a proper analysis of cultural reproduction is going to involve recognition of mental representations that play causal roles in action sequences. The whole reconstruction of social science along naturalistic lines is required, in a direction more like medical epidemiology than the operation of natural selection on DNA.

It is therefore important to see that the theory of twin-track coevolution doesn't depend on the meme. The units of transmission and the modes of cultural reproduction may be quite varied, yet the reproduction of culture across time and space is indisputable. We can note that cultural phenomena are both vertically inherited and horizontally borrowed, and that the units transmitted (or, rather, actively learned and used) can be individual traits or whole systems (I will give the example of number systems later, but there are also cases of whole languages being borrowed to replace an inherited one). We can also note that what can be passed on can be a situated practice (such as how to make a canoe), residing as much in honed motor skills as in mental templates. Consider piano playing. The piano itself is the product of a long cultural heritage of making stringed instruments, but the object does not by itself convey Beethoven concertos or even the art of the pianist. There is a whole cultural complex surrounding the piano, combining craftsmanship in wood, motor skills, long musical training, notions of musical intervals, the conventions of musical notation, the practice of musical performance, and so forth. As this makes clear, treating culture as a set of purely mental abstractions in order to set up the gene–meme analogy is to artificially divorce the concepts from the behavioral practices that support them and through which they are learned.[4] In the second part of this chapter, I will return to a consideration of the essential properties of culture that need to be taken into account by any theory of cultural reproduction.

Let us now turn to the second fundamental question raised earlier, namely, if culture is such a good thing, why did it happen (more or less) only once in the history of life on earth? And why did it happen in our lineage, and not in lineage after lineage? First, a few caveats are in order. As mentioned earlier, the rarity of the phenomenon depends somewhat on what you mean by "culture" (a subject fraught with disagreement; see e.g., Fox and King 2002). Even if we take it to include any kind of behavior transmitted by learning across generations, which thus marks off one group of the same species from another, culture is still going to be strikingly rare, with some few examples from, e.g., the oscine birds (Hauser 1997: 273–300), whales (Rendell and Whitehead 2001), and chimpanzees (Whiten et al. 1999; McGrew 1992). These exceptions hardly alter the picture, given the limited and specific domains involved, because they do not exhibit the property of indefinite accumulation of innovations that is the signal mark of human culture (what Tomasello calls "ratchet culture"). Nevertheless, they may be crucial for understanding the full-blown primate version. Every trace of a parallel to human culture is to be welcomed, since the discontinuity of human culture from everything else to be found in nature is an essential problem for evolutionary theory. A second major caveat is that we, of course, are not the only species to have had highly developed cultures. However frugal you are with the appellation of "culture," there will be at least a dozen hominids (many of whom are not our ancestors) that had it! Thus the Neanderthals, who now seem clearly to have belonged to a distinct lineage (Krings et al. 1997), had all the trappings of hafted tools, clothing, control of fire, funerary rites, and so on. We share with all these rival hominids a relatively recent ancestor (within the last six million years or so).

So what was the X-factor, the magic ingredient for culture? Of course we are not interested in all the preconditions of culture—that would take us all the way back through the great chain of being. What we are interested in is the added something that takes us out of the general run of mammals, or indeed of other highly social organisms like the ants. A good way to get a grip on the X-factor is to look at our nearest relatives and ask, do they have it, and if not, why not? A good case can be made for chimpanzee culture (Whiten et al. 1999), although the differences among groups may have an as-yet unascertained ecological basis. In this volume, though, the predominant view is that chimpanzees do not make the grade. Premack, Hauser, and Tomasello all concur in that opinion, although Hauser and Tomasello offer different reasons why they do not.

There are a great many behavioral and functional candidates for the X-factor in the human lineage, and these preoccupy other authors in this volume. For example, Dunbar argues for a special role for advanced communication systems in holding large groups together. Tomasello emphasizes the special role of social and cultural learning and the theory of mind (or "mind reading") that underlies it. Boehm and Hauser identify the nature of morality and inhibition, while Foley ridicules the idea of any single X-factor, emphasizing instead multiple dissociated factors such as planning, technology, learning, and language. One thing all these functional candidates have in common is that they would have driven the evolution of higher mental capacities, and thus the development of a larger brain.

Cognitive Candidates for the X-Factor

The brain seems to have been, along with the hand,[5] the central locus of gene–culture coevolution—the main organ on which selection pressures favoring culture must have worked. The human brain is about three times larger than might be expected for a primate of our size, and the development of this greater capacity is roughly correlated over a period of two million years with increasing cultural complexity, as measured by tool use (see Foley in chapter 3). What is so great about a large brain? Ants can calculate complex navigational paths without one, busily checking solar ephemerides and doing trigonometry (Gallistel 1990), and Gallistel, Gelman, and Cordes in chapter 12 try to persuade us that when it comes to math, the main human advantage is being able to talk about concepts that exist antecedently in primate cognition. In general, there is no consensus across the cognitive sciences about what makes our large brain such a special computing device. One assumption (lying behind the careful comparative study of brain size in, e.g., the chapters by Foley and Dunbar) seems to have been that what is crucial is largely a matter of the sheer quantity of RAM as it were; that is, a relatively undifferentiated neocortex. The specifics then depend on learning. Universal Darwinism can be applied to the developmental trajectory of the neocortex, and one can look at the whole gigantic wiring of synaptic connections as a selective process (Changeaux 1985; Edelman 1987; Singer in chapter 9), with distinct kinds of selection—natural selection over deep time, developmental selection during early ontogeny and brain maturation, and selection over the life-span in response to environmental and cultural pressures. This approach suggests that the magic ingredient is not so much a specific genetically determined brain component (running a single "native" machine code as it were) giving us Culture (with a capital C) in the singular, but rather a highly adaptable computing device that can run any number of high-level programs, giving us cultures in the plural. In chapter 9 Singer introduces an interesting twist to this argument. The evolutionarily new areas of the brain, although composed of much the same tissue, are secondary association areas, which take their input from older primary sensory areas. The new areas seem to be especially dedicated to multimodal metarepresentations, realized as massive assemblies of cells that bind lower-level representations through synchronicity of firing. It is these metarepresentations, indefinitely stacked, that make possible a theory of mind. Thus more of the same brain tissue can have emergent properties, in this case the particular properties (as Tomasello and Dunbar argue) essential to culture.

Instead of fixating on encephalization (or sheer brain size relative to body weight), there is another way of looking at the brain, namely, as a ramshackle collection of ancient modules, or specialized processing units, for some of which we may be able to tell good adaptationist stories. The rival assumption, then, is that the phylogenetic additions to the human brain are qualitative, giving us highly specialized brain tissue, as most clearly exemplified by the language areas of the brain. These additions may have provided us with a range of functionally specific "modules," adaptations targeted by natural selection, perhaps for many areas of activity, including technology and Culture (with a capital C, i.e., the underlying learning capacities and motivational structure). In general, most students of comparative neuroscience agree that it's not the sheer size of the human brain that should be the focus of evolutionary speculation, but rather those areas that show the greatest relative growth (see Dunbar and Singer in chapters 8 and 9).

Deacon (1997) argues that language is the key functional adaptation, and there is much in this volume to support that idea. Hauser (chapter 11), however, emphasizes the frontal lobes, which are strongly associated with inhibition. Without the inhibition of immediate reflexes, physical or mental, there is little possibility of maintaining a single train of thought, let alone the extensive planning of future action, or any kind of morality. In fact, Hauser shows that lack of inhibition, like alcohol, masks the considerable reasoning powers of many primates. Other candidates for uniquely human cognitive skills include mathematics. However, in chapter 12, Gallistel, Gelman, and Cordes take a close look at numerosity skills across species and come to the conclusion that human mathematical skills are based on a phylogenetically ancient system of estimating quantity that is transformed only through language.

This modular perspective, at least as defining human cognitive skills, can thus be taken much too far. The doctrine that human cognitive abilities are all innately coded in the brain dominates the cognitive sciences, and this has been extended to what are taken to be the major cognitive features of culture (see e.g., Barkow et al. 1992; Jackendoff 1992; Talmy 2000, vol. II: ch. 5, Plotkin 1997; and responses in Rose and Rose 2001; Brown 2002). The reasoning is that the mind is the fundamental filter for possible cultures. Every meme that cannot be learned or processed by the mind dies an instant death (a point that is true as far as it goes).

The next (and completely unwarranted) assumption is that there is not much else to culture; to understand the mental filter is to understand the biology/culture interface, or as Plotkin (1997: 253) puts it, "a theory of culture is first and foremost a psychological theory." Cultural variants are just meaningless variation—noise in the system. Such a stance fits with a number of strands of ultrareductionist thinking in current thought, in evolutionary psychology, and in sociobiology, and with the extreme forms of nativism in the cognitive sciences. However, it mistakes a precondition for culture for the phenomenon itself, which is not a psychological phenomenon but a historical one in an ecological context, and not a property of an individual, but a property of a population with elaborate divisions of labor and knowledge.

The problem with this kind of nativist reductionism, in which there is nothing in culture that is not essentially in the organism, is that it has lost sight of the central phenomenon. It is the variability of culture that is responsible for its adaptive value, by extending the phenotypic range of the genotype. The quite extraordinary thing is that in prehistoric times we already inhabited lands with permafrost and scarcely any vegetation on the one hand, and lands with unremitting heat and scarcely any water on the other, and about 30,000 years ago we had crossed hundreds of miles of open water by boat (see later discussion). The cultural basis for this radiation is advanced technology—of clothing, boats, food processing, desert navigation, and so forth. If there was only one form of culture, for example, only one form of kinship, only one kind of political system, only one set of tools, only one type of religion, we would all happily be ultrareductionists talking of instinct instead of culture (and we would all still be in Africa). That is not the phenomenon we are trying to explain.

Take language. The most astounding fact about language is that it is variable in both form and content. We are the only species in nature's vast spectrum of organisms with a communication system that varies in both form and meaning.[6] We can even change its modality from the vocal-auditory channel to the manual-visual one, as in the natural sign languages of the deaf (a point I will return to), or in the written modality for that matter. No other animal can do that. Theoretical linguistics has, under Chomsky's guidance, been preoccupied with discovering the underlying architectural commonalities in language, dubbed universal grammar. The term has suggested to many nonlinguists that there is really only one language, with superficial clothing of different kinds (different sounds, for example). Nothing could be further from the truth. Languages vary in fundamental ways; for example, they may have as few as a dozen distinctive sounds or as many as a dozen dozen (141 is the record); they may or may not have morphology (affixes on words, such as the plural on "pen-s"), they may not make familiar word-class distinctions (as in English nouns versus verbs), they may or may not have a fixed word order, and so forth.[7] Languages are so diverse that establishing even a short list of universals (in the sense that all languages have them) has proven frustrating; they tend to be trivial predictions of the sort that all languages have at least one vowel (otherwise you could hardly hear them!). Most empirical universals are conditional predictions of the sort "If a language has property X then it probably has property Y," nearly always with attested exceptions. And we still have more than 90 percent of languages to look at!

Ultrareductionists have tried to treat language, just like the communicative systems of other species, as an instinct (see e.g., Pinker 1994). They have claimed that language is an essentially universal medium for broadcasting universal thoughts. This is absurd; a particular language reconfigures our thoughts. So much of our cultural heritage is encapsulated in cultural concepts packaged into words. I don't expect the Rossel islanders of Papua New Guinea (see the next section) to comprehend the notion of a sonata or calculus, anymore than I find it easy to understand their concept of *ngm:aa* ("shell coin one denomination lower given as security for the loan of a shell coin one denomination higher, in the series of shell-coins called *ndapî*") or *chimi* ("two persons A and B such that A stands to B in the kinship relation *kênê* and B stands to A in the kinship relation *chênê*"). Elsewhere I have called the doctrine that holds that not only formal operations, but also the very content of our thoughts are determined by our genes, simple nativism (see Levinson 2000). What is right about simple nativism is that it insists on the prestructuring of our mental abilities. What is wrong about it is that it minimizes or ignores the role of ontogeny and learning, and minimizes the very stuff of our evolutionary success, namely, the cultural variation that is our special system for rapid adaptation to differing environments. Culture is a way of generating phenotypic variants far broader than a strongly canalized expression of the genotype alone can manage.

If the mental X-factor is not a set of prefabricated systems with standardized output, what is it exactly? Quite clearly it is a set of learning mechanisms that can accept a broad spectrum of input, but can output a narrow band of acceptable behavior that is in line with the very specific local input. Language again reminds us of the fundamentals. The sound systems of languages vary enormously. Rotokas has just eleven distinctive sounds (and five vowels), while Rossel Island language (Yélî Dnye) in the same Island Melanesia geographic region has ninety (and thirty-three vowels), some of them unique to just that language. This is a huge difference in auditory discrimination, so the learning mechanism must tolerate that broad spectrum of possibilities.

Human infants have special cognitive abilities that are built for exactly this cultural variation. For example, in the realm of vowel sounds, infants of just 6 months have been shown to restructure their auditory space according to the local language; the space becomes systematically and irreversibly distorted, so that sounds that are acoustically equidistant will now become assigned to the same or different categories along language-specific lines (Kuhl and Meltzoff 1997). The end result is a range of spectacular biases in our auditory perception, which make adults unable to even hear the difference between sounds that are fundamentally distinct in some other language. Thus the initial perception system ends up systematically skewed. Exposure to a specific language rebuilds our perceptual acuities, and it does so at such an early age that it seems inescapable that the system is built for handling diversity. [We know that other primates exhibit a similar tendency to hear sounds as belonging to categories, but not this ability to distort the acoustic space through learning; see Kuhl (1991), Hauser (1997: 324)].

This example may serve as a token of the special kind of cognitive ability that is required for a culture-bearing species. In this case the infant needs to know in advance that speech sounds are important. It needs to presume that there are significant local categories to be discerned using complex statistical pattern matching, and then it needs to learn to ignore some sound distinctions while acquiring heightened perception of others, thus distorting acoustic space in line with the input. We may expect that some of these cognitive underpinnings for learning cultural variants are highly modality-specific, like our vowel example, while others may be general learning capacities. Culture-acquiring children cannot be preprogrammed to shoot accurately with a bow anymore than to play the piano (both are local cultural objects), but they can be built to expect highly precise motor routines in hierarchically organized schema for specific cultural purposes. Obviously there are many other preconditions for culture, including the motivational structure, metarepresentational abilities (chapter 9), special memory abilities, and the ability to inhibit antisocial urges (chapter 11). However, these alone will not give you culture; for that, you need the special ability to know what kind of pattern to look for and to identify the local variant in a broad spectrum of possibilities. It is for this reason that "mind-reading" abilities are correctly emphasized by Tomasello, Singer, Dunbar, and other authors in this volume.

If simple nativism (reductionist evolutionary psychology) is an explanatory dead end, the reason is that it has lost sight of the explicandum, the variable end product that is the whole advantage of the human mode of adaptation. We can grant that human cognition is highly structured, but culture is not the projection of that structure alone. The theory of coevolution offers us a much better way to think about human cognitive abilities—as developing in a space with distinct attractors, both cognitive and cultural. Take the words for colors in different languages. Some languages have only two basic color words, some have eleven or more (not counting specialist terms or kinds of basic colors; see Berlin and Kay 1969; Hardin and Maffi 1997). There is a correlation with culture; cultures with dyes and weaving, paints and painted decoration have more developed color terminologies than those that do not. The limiting case is a language like that spoken on Rossel Island (see later discussion) where there is no technology of color and only the rudiments of a system of color terms (Levinson 2000). However, as a culture acquires interest in color words, there is a distinct order in which color words are "fractionated" out of more global cover terms, so that soon simple white, red and yellow, and green or an amalgam of green and blue are labeled. The order seems to reflect perceptual salience, influenced by cultural preoccupations (e.g., Mesoamerican obsessions with turquoise and jade may have attracted solutions in the direction of a green and blue amalgam). The outcome is a balance between perceptual salience and cultural interest.

Generalizing the model, the idea is that the architectural complexity of any human cognitive ability can be apportioned between two sources: innate predisposition on the one hand and cultural and experiential input on the other. Native predisposition may be less in the way of innate ideas (representational nativism) and more in the way of constraints on information processing, owing to the structure of the brain and perceptual organs (architectural nativism; see Elman et al. 1996). These cognitive constraints have evolved hand-in-hand with culture, and they bias cultural transmission. By bias I mean they weight the probability of exact replication, or, if one prefers (see chapter 7), affect the chances of transformation.

The advantages of the coevolutionary account of human abilities is that for most absolute universals it is possible to come up with cultural counterexamples; for example, a culture in which brothers marry sisters (Ptolemaic Egypt), or languages that do not have well-established color terms or have unique sounds that are not made in any other language (Rossel Island), or cultures in which different spatial coordinate systems are used in everyday cognition (as in Guugu Yimithirr; see Levinson 2003), and so on. However, universals of a statistical kind are much easier to find, implying systematic biases; there are historical, social, and ecological conditions that set functional constraints, and there are cognitive limits on reproducible ideas and practices.

So where are we? The X-factor is a set of cognitive adaptations for culture. They include necessary preconditions, such as the mind-reading abilities emphasized by Singer and Tomasello and the inhibition emphasized by Hauser. However, they cannot include precise instructions for the contents of a culture in the way that the evolutionary psychologists propose; cultures are just too variable for that. Rather, they must include specializations for tuning in to local cultural patterns, as illustrated by the case of language where long before they understand a word, infants are already shaping a soundscape for the language they will learn. This allows rich local adaptations to be preserved in the cultural environment in which the child grows up.

Why do no other species use the same trick of displacing highly detailed adaptation into a cultural mode? If culture is that good a trick, why did we have to wait three billion years for our species to come along and exploit it? Here we have to admit that current explanations are rather feeble. Biological anthropologists stress that in metabolic terms the brain is ultraexpensive tissue to maintain (Aiello and Wheeler 1995), and large crania make for dangerous births. But this only suggests that a monkey or dolphin with a bit more gustatory effort might have developed cultures, which they haven't. Perhaps no explanation is necessary. Is culture simply in such a distant nook in Dennett's (1995) design space of possible adaptations that the chance of any other species traveling there is infinitesimally small? Or perhaps there is more transmission of learned information going on in other social species than we can currently discern. None of this is satisfying, but the answers must wait on the comparative biologists.

Some Crucial Properties of Culture—Reminders from an Island Culture

For most chapters in this volume, culture is the explicandum. What exactly do we need to account for? Here, as reminders, are some crucial properties of culture, which any theory of cultural origins must take into account:

System complexity without a single designer Just like organisms, social and cultural systems display intricate designs beyond a level that could be achieved by any individual designer, even if there was one. Consider, for example, languages, kin classification systems, rituals, large-scale irrigation systems, or building methods. It is systems rather than traits like memes that need an evolutionary account.

Multiplicity and variation There are thousands of distinctive cultures (taking languages as a gross indicator, there are on the order of 6000 to 8000 today). The variation across cultures consists both in distinctive elements and in distinctive arrangements of elements (consider, illustrating again with language, distinctive phonemes and distinctive arrangements of phonemes into possible word forms). Until recently at least, geographic and social separation correlated with cultural difference; cultures left to their own devices diverge. There is also variation within cultures, which often provides the source of innovation and change.

Vertical transmission and cladistic character Cultures derive partially by "descent with modification" (in Darwin's one-liner defining evolution). Thus the cultures of far Oceania are all derived from the Lapita culture of the first Austronesians, the first human colonists of the area. Many of the basic adaptations, such as crops, outrigger canoes, and stilt houses are still shared from this ancestral culture of c. 5000 years ago. Through vertical transmission, cultural phenomena can become extraordinarily stable. The bifacial hand axe holds the record as a cultural object that remained essentially unchanged for a million years, but there are many cultural ideas and objects of more modest antiquity, for example, languages with 3000 years of continuous written history (Chinese, Tamil), Egyptian statuary conventions with 3000 years of continuity, elements of architectural style like the Corinthian column with 2000 years of nearly continuous use, the spoked wheel with an ancestry of at least 4000 years, the mason's round mallet with 5000 attested years of use, the alphabet with nearly 3000 years of antiquity, and so forth.

Horizontal transmission and cultural diffusion In addition to vertical transmission, cultural ideas and techniques are borrowed. Consider the technology of warfare, Creole languages, or song styles. However, there are also striking examples of parallel invention, similar to parallel evolution in biology (as in the placental versus marsupial analogues of moles, wolves, mice, etc.). These suggest that the design space has some tight intrinsic limitations.

Cultural phenomena are cumulative They can embody the wisdom of generations of experience, e.g., how to process poisonous plants, which fish to avoid, what to do in the case of rare environmental catastrophes. This is one of the crucial adaptive advantages that humans have over other creatures. We inherit the results of millennia of experimentation without any of the costs or dangers.

Cultural phenomena are not always adaptive Cultures include large proportions of elements that appear functionless, sometimes even deleterious, to both cultural preservation and biological success. An evolutionary approach can help us to understand how such features are nevertheless propagated.

Culture, group selection, and the feedback to biology Cultural groups can act as wholes, taking collective decisions upon which the biological survival of the whole group depends, as in war or response to environmental catastrophe. They can also be extinguished by ethnocide and by enculturation into larger groups. Such processes can be observed in real time. Even processes of microadaptation or coevolution between a culture and the gene pool can be directly observed.

Such a list immediately suggests the necessity of a Darwinian account. Cultures have design without a designer, evolving by the selection of existing elements of variation in accord with functional requirements, speciating in new ecological niches, with elements transmitted over scores of generations. On the other hand, some elements of culture are more like parasites, jumping hosts horizontally and then melding with the vertically transmitted information (a pattern that only rarely occurs in biological mutualism). In the shrunken world created by Western exploration, exploitation, and communication, the latter epidemiological pattern of course has come to the fore, but it is the former cladistic pattern that was perhaps dominant before the age of the empires.

In the rest of this chapter, I want to illustrate some of these essential properties of culture by drawing on just one culture that better illustrates the nature of cultural entities in human prehistory than our own gigantic, rambling, fast-changing conglomerate. Although none of the following observations are startingly original, I hope they will serve as vivid reminders of points that we often forget. Our explanatory models for coevolution can improve only if we have the explicandum, the nature of traditional cultures, constantly in mind.

An Example: The Culture of Rossel Island, Papua New Guinea

Rossel Island lies about 500 km off the coast of New Guinea, the easternmost island in the Louiseade Archipelago. It is a small volcanic or "high" island, 34 km long by 14 km wide, with a central mountain range 850 m high that is clad in rain forest. Despite fluctuations in sea level, it was not connected to other islands during the Pleistocene, and consequently has a relatively limited fauna and flora compared with the mainland (see Mayr and Diamond 2001 on the Melanesian island world). It is separated from the nearest other islands by difficult waters full of reefs, for which reason there was little contact with Western shipping until the early 1900s, with a resident Catholic mission only set up in 1953. It has a small human population; in 1920 there were 1450 Rossel islanders, while the current population stands at 3884. Such a small population, relatively cut off from migration, is likely to exhibit both founder effects and genetic drift in its population biology.[8] Small, isolated populations of this sort are vulnerable to natural disasters of various kinds, including diseases, cyclones, and drought—not to mention potential conquest from more numerous neighbors. Physical anthropologists have shown that the inhabitants of Rossel Island are shorter (at c. 155 cm for males) and darker and less brachycephalic than neighboring populations (Armstrong 1928). A recent study of genetic markers shows that they are not close kin to most of their neighbors, but rather to highland mainland New Guinea populations (M. Kayser, personal communication). Biologically then, the Rossel Island population is distinct from the populations of most Oceanic islands, which derive more directly from an Asian stock associated with the spread of Austronesian languages throughout the Pacific from about 4000 BP.

Culturally, too, Rossel is distinct. The inhabitants (who I will sometimes refer to as Rossels) speak a language they call Yélî Dnye, which is not clearly related to any other existing language, and certainly not to the surrounding Austronesian languages. It has many unusual complex properties to which I will return later. The islanders are culturally distinctive in many other respects too. Compared with their Austronesian neighbors, they have a quite different musical system, distinctive canoes and houses, their own indigenous shell money system, and a dual-descent kinship system that contrasts with the matrilineal descent systems on neighboring islands. Neighboring peoples point to the absence of traditional pottery, drums, carving, tattoos or other forms of visual art, and to the peculiar and apparently unlearnable language, and they regard Rossel culture as a thing apart. The presumption must be that Rossel Island culture is an ancient cultural continuity, a remnant of the pre-Austronesian offshore cultures that we know from radiocarbon dates to have inhabited the islands of near Oceania more than 30,000 years ago (Kirch 1997; Spriggs 1997). It is not of course a frozen cultural relic. Closer examination shows many borrowed cultural traits, and the culture has no doubt developed in its own distinctive way over the intervening millennia (and most recently under colonial impact), but it seems indubitable that it descends from cultures that were in the area before the Lapita peoples speaking Austronesian languages passed through 4000 years ago. From that pre-Austronesian time the culture almost certainly inherits taro and sago cultivation, nut-processing technologies (see later discussion), patrilineal inheritance of land, many properties of the language, and quite plausibly, cultural patterns of house construction, a musical system, and so forth.

With that preamble, I would now like to exemplify some of the key properties of culture listed earlier, in order to put some flesh on those bare bones. We will take the features in turn.

System Complexity Without Any Single Designer

I propose the following hypothesis: Cultures will tend to become more complex over time, up to the limits of the transmission process (where transmission is constrained by what is individually learnable on the one hand, and by social and cultural constraints, such as the degree of division of labor, or whether the society is literate, on the other). A fundamental reason for this is that in a culture, the lack of fidelity in reproducing ideas and practices is much less likely to be "fatal" to the continuation of the practice than the high probability that a mutation will be fatal to an organism. Consequently, nondeleterious innovations and variations can accumulate, even though they may require constant adjustments of the system in which they occur (cf. how sound changes in language can require distinctions being lost in one place to be remade in another, as in the English great vowel shift). Between innovations themselves and the adjustments of the system that are then required, complexity can accumulate. Such complexity will be eroded, not just by transmission error (for example, by children's simplifications while learning), but also more systematically by contact with other cultures and creolization. Contact, trade, and cross-cultural communication are levelers of cultural distinctiveness, as exemplified by the current spread of Western practices across the world.

Given the inaccessibility of Rossel Island, its cultural complexity has extended to somewhere near the limit for a society without literacy or a significant division of labor. As a start, take the language. It has the largest phoneme inventory (ninety distinct segments) in the Pacific, and many sounds (such as doubly articulated labial coronal stops) that are either unique or rare in the languages of the world. Among the fifty-six consonants are many multiply articulated segments; e.g., /ṭpṇm/ is a single segment made by simultaneously putting the tongue behind the alveolar ridge, trilling the lips, and snorting air through the nose. Such multiple articulations are a formidable barrier to the learner since different emphasis on one or the other articulation can give a quite different auditory flavor, sounding more like a /t/ or a /p/ or an /n/. Once the learner is past the sound hurdle, he or she faces another formidable obstacle. The language has an extremely complex system of verb inflection (with thousands of distinct inflectional forms). For example, the properties of the subject (singular, dual, plural, first, second, or third person) of the verb is marked before it, but with a single syllable that also encodes tense, aspect, and mood; altogether there are 144 combinations of these. In addition, substitute forms are used where the subject has been mentioned before, is close or visible, is in motion, or where the sentence is counterfactual or negative, thus providing well over a thousand possibilities. Meanwhile, after the verb, another particle marks a lot of the same information, together with the person and number of the object. To reduce the combinatorial explosion of distinctions, all nine possible subject combinations (e.g., second person dual) are grouped into two categories, "first person or singular" versus. "second or third person dual or plural," called monofocal and polyfocal, respectively, in the Papuan linguistics literature).

This particular and unusual kind of grouping happens to be found also in the Gorokan languages on the mainland, indicating a possible distant relationship to peoples more than 1300 km away. The point is that here is a complex but logical and consistent way of cross-referencing subject and object (together with tense, aspect, and so forth) on the verb; the subject is categorized twice using different categories, once in front and once behind the verb. It is an intricate piece of clockwork designed by "the blind watchmaker"; that is, by eons of use by generations of individuals whose tiny unseen slips and innovations have been sculpted into a functional system by the selective forces of learners and users of the language.

Yet another barrier to the learner is that most verbs supplete (varying in root like English *go* versus *went*) in many grammatical contexts. The overall result is that the language is at the boundaries of learnability. Hardly any mature individuals (such as non-native spouses) who have immigrated into the island community ever learn to speak the language, and children of expatriate Rossels do not fully acquire it from their parents alone.

This kind of intricate complexity is familiar to scholars who work on the languages of small, relatively isolated indigenous communities, whether in the Americas, Australia, or New Guinea. In the case of Rossel language, we know it has been cut off in a sea of Austronesian languages for more than 4000 years, and has been left as it were to develop on its own, in the inevitable direction (I am suggesting) of complexity. In contrast, languages that function as a lingua franca across borders and boundaries, such as English, Indonesian, or Spanish, cannot sustain such complexities (at least in their interethnic uses), tending toward the simplification found in creoles. They are leveled by the need for commonality, and in many cases by the fact that they are learned as second languages for limited functions.[9]

Cultural complexity on Rossel can be found in many other practices. The kinship system is effectively a dual-descent system in which individuals trace their membership in both matrilineages and land-bearing patrilines. The kin terminology, with more than forty terms, is classificatory; that is, all terms apply, not just to a single individual (such as English "mother"), but to a large class of individuals (such as English "cousin"). There are three distinct ways to decide who falls into a class. You can reason genealogically; e.g., my mother's mother's brother is a *mbwó*, just like my brother. You can reason by clan membership; any male of my matriclan of my generation or an even generation counting from mine (e.g., two generations up or two down) is a *mbwó*. Or you can reason relationally; if my *pye* (someone in the class of my mother) calls someone *kênê* ("mother's brother"), then I can call him *mbwó*. Now here is an interesting case of design without a designer. Here is a calculus of relationships that will unerringly assign individuals to the same class by different rules, while keeping the whole system objectively coherent, so that if you call someone *kênê*, then that is consistent with my calling him *mbwó*, given that you are my *pye*. Incidentally, all these rules change if you are a female calculating the system from your point of view, but the end product is consistent with the system used by your brother.

Working the system requires incredible genealogical knowledge. Mature Rossels know their own descent lines up to ten generations deep, and in many cases more or less have a command of the entire genealogical relations between any two individuals on the island. Knowing these relationships is essential to the proper use of kin terms, the assertion of rights, plans for alliance and marriage, and correct deportment and the appropriate use of taboo language (alternative words for items such as clothes and body parts, which are used in the presence of in-laws).

Another cultural institution is an indigenous shell money system, famous in anthropology as the most complex indigenous system recorded (Armstrong 1928; Liep 1983a), with about twenty named denominations of shell coins in two parallel series. The purchase of a pig may involve up to 1500 coins of one series and 800 of the other, a quantity that no man has in his pocket (or rather basket, as appropriate on Rossel Island), and which must be assembled by an elaborate system of loans and securities requiring hundreds of transactions following specific cultural rules. High-value coins can be borrowed only by presenting the next lower denomination as security, the loan of which in turn will require its own security and so on down the line. Purchases thus mobilize extensive networks of kin and business associates, in a manner reminiscent of the joint funding of some enormous engineering project like the Channel Tunnel. Again, we have a system of great intricacy that has no doubt evolved culturally over thousands of years—a system whose design the Rossels attribute to the gods.

It seems that many Rossel cultural institutions have developed a complexity that approaches the limit for cultural transmission across generations in a society without literacy or even any significant division of labor. Every adult knows the same essentials, with expertise confined to those of relatively advanced age (in a society with an average life expectancy of about 45 years). What is complex is not of course merely the constituent ideas (the memes if one will), but their articulation into a functional whole.

Multiplicity and Variation

It is a commonplace that cultures vary. Yet anthropology textbooks are replete with generalizations about institutions across unrelated cultures, be it kinship, witchcraft, or warfare. Although few anthropologists agree about the details of such generalizations, the overall picture is nevertheless clearly one of variation within constraints. Let us concentrate first on the variation, the uniqueness of particular cultural institutions; however, it is important to not lose sight of some of the remarkable similarities.

So far, we have seen intricate cultural systems on Rossel Island, which have evolved to fulfill precise design requirements without any mastermind behind it all. How have they arisen? By cultural evolution of course; that is, by selection of variants over generations until the systems have come to fulfill ever more complex functions. That presupposes variation. Can significant cultural variation exist in a population of only 4000? Yes it can. Take the language. There are two main dialects, an eastern and a western, differing in syntax, morphology, and lexicon. Now take the eastern dialect. It is separated into a northern and a southern variety, divided by a mountain range. Now take the southern variety. It has an eastern and a western subvariety. Now take the western subvariety. Small differences can be found among most villages. There is variation all the way down. Similar variation can be found in most other cultural practices. A Rossel islander looking at a sago-processing device (a chute with a funnel and a strainer, all made from local bush materials) can tell where the maker came from, for there are "dialects" of sago-processing devices. The same is true for a host of other cultural features, from baskets to song styles.

There are of course exogenous sources of variation also. After a storm, a canoe from another island sometimes washes up on the beach, spurring experimentation with canoe design. Visiting traders come seeking exotic marine produce for sale as aphrodisiacs in Asia, supplying diving goggles which spur new fishing practices. Young men return from the mainland with messianic religious ideas or the concept of home brew. A woman from another island who has married in introduces a new kind of basket. And so on (see Liep 1983b for the history of colonial influences).

Small indigenous communities, despite the "traditional" epithet, in some ways exhibit a wider range of variation in cultural practice than that allowed by the solutions to practical problems found in industrialized societies, where language is standardized, clothes come off the rack, bread comes from a large-scale bakery, or entertainment arrives via an electronic tube. Since the existing strands of variation are the stuff on which cultural selection works, traditional societies contain the resources for rapid change if it is required.

Given cultural evolution, why can we discern clear commonalities and resemblances across cultures, as in kinship, religion, and political systems (admitting of course that there are many distinct types)? One source of convergence is what we might call the cognitive bottleneck. Cultural elements have to be learnable, memorizable, and computable on a reasonable time scale. They also have to conform to our motivational propensities.[10] There are also sociological, economic, and ecological constraints. Many conceivable cultural systems (pure communism, for example) just wouldn't work.

Another source is cultural borrowing (see the section on horizontal transmission). And there is always the possibility of inheritance from a common ancestor, as discussed next.

Vertical Transmission and Cladistic Character

I have already outlined the way in which the culture and language of Rossel Island is distinct from the Austronesian languages and cultures on the nearest islands. The relationship between those Austronesian languages is now well understood (Lynch et al., 2002), and a family tree can be reconstructed from the papuan tip cluster (the languages surrounding Rossel Island) up to the higher western Oceanic grouping, then up to proto-Oceanic and all the way back to an Asian proto-Austronesian. In some cases one cannot be sure whether one is dealing with sister languages or languages that have converged by borrowing at a later date, but generally the cladistic pattern is quite clear. In contrast, in the offshore islands to the east of Papua New Guinea, including the Bismarks, Bougainville, and the Solomons, there are about thirty non-Austronesian languages, including Rossel's Yélî Dnye, whose relationships to one another, if any, are much less clear (these are so-called Papuan languages, a term hat might misleadingly suggest a language family, but in fact only means they are non-Austronesian). The very fact that we cannot reconstruct any certain relationships between them suggests a much greater time depth for this wave of human settlement than the Austronesian spread of c.3000–4000 years ago. As mentioned, we have radiocarbon dates from the Bismarks that go back to 35,000 BP, and from Buka (then part of a Greater Solomons landmass) that go back nearly to 30,000 (Kirch 1997; Spriggs 1997), so we must assume that most of the islands of near Oceania were settled in the Pleistocene. Recent evidence suggests that by 20,000 BP these peoples were cultivating taro and various nut species (Spriggs 1997: 38), exploiting an introduced or semidomesticated arboreal marsupial (the gray cuscus, *Phalanger orientalis*), and trading obsidian for edged tools (Kirch 1997:35). Current speakers of offshore Papuan languages may be descended from these early colonists, or from later waves of immigration in the early Holocene. But the high estimation of taro, nut, and cuscus as foods survives in the modern Rossel value system, suggesting some ancient cultural continuities.

I have mentioned that recent genetics ties Rossel islanders to the eastern highland populations of New Guinea over a thousand kilometers away, rather than to the neighboring islanders who speak Austronesian languages.[11] I have also mentioned that there is the occasional linguistic feature (e.g., the classification of first and singular persons in monofocal verbal inflections) that suggests just such a tie, in this case to the Gorokan languages. Perhaps in the long run we will be able to establish connections both to the main island and to other offshore Papuan languages (see Terrill et al. 2002). In the meantime what is clear is that this small population has retained many cultural features over deep time, developing them to an extreme of complexity, through vertical transmission over the generations via implicit learning and explicit instruction. Children accompany adults on almost every kind of venture or expedition, and they thus have an extensive understanding of most aspects of the cultural system before they reach puberty.

Horizontal Transmission and Cultural Diffusion

Isolated though it is, over millennia Rossel Island has no doubt had plenty of visitors, not always intentional, because the reefs have sunk many a ship. Even without visitors, wandering Rossels have returned with alien ideas, or ideas embodied in cultural objects have washed up on the beaches. The cultural repertoire includes many features similar or identical to those on neighboring islands. Much of the agricultural system, some of the house and canoe styles, even the matrilineal clan system with bird totems is shared throughout the Massim area. Today the inhabitants have been missionized for half a century, sing English hymns in church, wear Western clothes (secondhand from Australia), and use metal tools and nylon fishing lines.

To some limited extent we can reconstruct the contacts with the outside world before Western ships first showed on the horizon in the eighteenth century. In precolonial days, legends recount trade with the neighboring Sudest Island, controlled by a few a "big" men or political leaders. From Sudest came clay pots, stone ceremonial axes, and the plumes of birds of paradise; in return Rossel sent precious shell necklaces for use in the Kula trade (Liep 1983b). Further back in mythical time, Sudest is held to be the source of various important cultural items, including the dog, the yam, and the sailing canoe. Although such myths cannot be taken as history, they do consistently paint a picture of Sudest as the source of many cultivars and elements of technology. Since there has been no archaeological investigation on Rossel, we cannot date these imports directly.

However, the language gives us important clues. Although the lexicon shows very few loans from Austronesian languages, those words that have been borrowed tell a fascinating story. Take the words for numbers. The language of Rossal Island has a full-scale decimal system that is entirely regular in construction (100 is denoted by "the tenth ten," 1000 by "the tenth, tenth ten," and so forth). The words clearly show their Austronesian origin. For example, Rossel *peeti* or *paati* ("four") is clearly derived from proto-Oceanic **pati*, Rossel *limi* ("five") from proto-Oceanic **limá*, and so forth. Because the language of Rossel Island has a huge phoneme inventory, loans are apparently not corrupted but are represented faithfully. Note that we also have Rossel *waali* ("eight") for proto-Oceanic **walu*. The interest of this is that in most of the surrounding Austronesian languages, "eight" is represented in a different way—as "five plus three"—because the Papuan tip cluster subbranch of Oceanic to which these languages belong innovated such a "five plus" system about 3000 years ago (Lynch et al. 2002). Thus Rossel language borrowed the number "eight" before that subbranch spread. There must have been earlier Oceanic peoples who were in contact with the Rossel people. A few aspects of proto-Oceanic are better represented in Rossel language than in the local Oceanic languages that are now neighbors today!

If we look at the other Oceanic loans in Rossel language, we find words for aspects of material culture, such as "pot," "bottle," "lid," "clay pot," "woven coconut mat," "grass skirt," "armband," "shell necklace," and so forth—items that we may assume were borrowed with their names.[12] The lime used to get the maximal "kick" out of chewing betel nuts was also clearly a cultural borrowing; the words for the white branching coral from which it is made and the lime pot it is kept in are loans. Other loans reveal the borrowing of seafaring knowledge and equipment; the words for "sail," "wind," "westerly wind," "fish poison," etc. are also Oceanic loans. If we believe this evidence, Rossel islanders before, say, 3000 years ago lacked cooking and storage vessels, woven mats, and various kinds of clothing and adornment. They may also have lacked the main stimulant of today, the betel nut,[13] and they seem not to have had sailing canoes, and perhaps had very modest maritime technology.

What use did the inhabitants of Rossel Island have for a counting system that runs smoothly into the thousands (mainland Papuan languages often have a body-based counting system that terminates at, say, 31, on the navel)? To this day it only has one predominant use: counting the shell money mentioned earlier. Was this money system also a cultural borrowing? Shell beads that date back to 8000 BP have been found in archaeological sites in the Bismarks (Spriggs 1997: 59), and shell armbands occur in pre-Austronesian sites in the Solomons (Kirch 1997: 41), but a preoccupation with shell valuables is a distinctive feature of the Lapita culture (starting c. 4000 BP), which is presumed to belong to the first Austronesian-speaking peoples of Oceania (Kirch 1997: 236–238). It seems likely then that the shell-money system, now a distinctively Rossel cultural trait, was at least elaborated through contact with Oceanic peoples.

In trying to trace the diffusion of cultural traits, one has to take into account the possibility of independent invention. Take the polished stone axe, not chipped but ground down in the "neolithic" manner. Cultures all over the world, from South America to Australia, seem to have developed the polished axe, long after the dispersal of humans, and when they had long been out of contact with one another. [In fact, the earliest known examples probably come from Pleistocene New Guinea (Spriggs 1997: 59), and the same design was in use on Rossel Island until about 1900.] Yet the axes look almost identical, whether they are made in Mexico or Queensland. Somehow the functional requirements, given human cognitive and anatomical skills, converge on a single optimal design in Dennett's (1995) design space. Such examples of convergent solutions are numerous: the ladder, the basket, rectangular houses with pent roofs, even the idea of domestication of local plants. In language, for example, there are restricted types of design in many parameters. For example, case systems are either nominative-accusative (where subjects share one case and objects another, such as *he* versus *him*) or ergative-absolutive (where the object of a transitive verb is the same case as the subject of an intransitive verb). Cultural convergence is just like parallel evolution in biology, where striking parallels in design arise independently. In the case of culture, these tell us something important both about constraints on cultural design, which is perhaps quite largely cognitive in nature, and the tendency toward optimal design, and thus about the ceaseless selective pressures in the evolution of culture.

Distinguishing diffusion from parallel invention can be difficult. Perhaps given time, Rossel islanders would have invented the ladder themselves, but it is just as likely that they saw a specimen before they got around to inventing one independently. Take Rossel language. It has an ergative case system, but so do perhaps a quarter of the world's languages, scattered from the Caucasus to Middle America. However, this case system in Rossel language also makes a difference to the syntax, so the language can be said to have an ergative syntax. That is much rarer; perhaps less than 2 percent of languages with an ergative case have an ergative syntax, and there are only a few known pockets around the world—one in Mesoamerica and one in Queensland, just 500 miles away across the ocean from Rossel Island. Is this a trace of ancient diffusion, or even ancient inheritance from a Sahul ancestor (Sahul is the name of the archaic continent that included New Guinea and Australia until 9000 years ago)? Who knows?

The general point here is that even the most traditional of cultures are porous to new ideas, especially, as we have seen in the Rossel Island case, ideas that are in a broad sense technological, including what Goody (1977) has called "the technology of the mind" (exemplified here by the decimal system). It is this that gives cultures the ability to change rapidly and to adapt to the greatest danger that faces any human group, namely, other human groups.

The Cumulative Nature of Cultural Transmission

Nothing perhaps tells us more about the virtues of Lamarckian inheritance than the procedures cultures employ for exploiting the environment. Consider the wild nuts collected and eaten on Rossel Island. Some of these show up in archaeological deposits on the mainland well before the Austronesians arrived (Kirch 1997: 39–40), so the practice of exploitation is ancient. Now consider that many of these are deadly poisonous if they are eaten before processing. On Rossel Island, the *kwee* nut, for example, is the fruit of a large vine, yielding large 5-cm nuts in giant pods. However, if it is eaten raw, the *kwee* nut is fatal. It has to be deshelled, the kernels roasted until they are soft, then pounded and placed in an open-weave basket in a fast-flowing river for 5 days. Two boys who in 1997 stole some nuts from the river after only 3 days of leaching almost died, frothing at the mouth; they were saved by the administration of the seeds of another plant (the antidote *polo*), which made them vomit. Rossel islanders exploit half a dozen species of forest nut that need processing in a similar manner, but some need longer roasting or leaching for only 2 days, and so forth.

Experimentation with foodstuffs in the tropics is a hazardous enterprise. Tropical plants have evolved all sorts of chemical defenses against the huge and bountiful insects that would otherwise chew them up. Even walking through the bush requires care because the leaves and sap of many trees are caustic. Some of these poisons also have their cultural uses. For example, three plants are used to poison fish—the roots of one, the leaves of another, and the fruits of a third. These three plants are carefully planted in the bush and nurtured, ready for use. They are crushed and are sufficiently powerful that a basketful will poison an entire river, sending its fish gasping to the surface, so that a whole village can collect the bonanza. In addition, many such plants have medicinal properties if they are used in carefully controlled proportions known to specialist medicine men.

Rossel Island is surrounded by magnificent reefs inhabited by more than 1000 species of fish—the richest marine life in the world. Indigenous knowledge about fish is highly developed. There are hundreds of single-word names for species and genera of fish, with recognition that juveniles of the same species can look very different from adults. Some fish are known to be poisonous. A species of pufferfish (*mt:enge*, an Arothron species) is carefully avoided as deadly poisonous at one end of the island, but at the other end is eaten after the poison sac is extracted. More intriguing perhaps is the treatment of big game fish like barracuda, which can accumulate ciguatera poisoning (by ingesting reef fish that have themselves ingested poisonous *Gambierdiscus* or *Ostreopsis* algae). The symptoms include nausea, loss of sensation, and occasionally death. The islanders treat such fish with caution. Large specimens are rejected; smaller ones are carefully gutted, skinned, and boned and then tested. If the flesh is very firm, they are rejected; if not, the raw flesh is put on the lips and if any tingling or pain is felt, the fish is rejected. Only fish processed and tested in this way are eaten, and cases of poisoning are then rare.

These examples make obvious the enormous and crucial value of accumulated, traditional knowledge. No individual could hope to test all these essential sources of nutrition and survive. Although bush foods are not crucial if root crops are available, they are essential in times of drought or between harvests. Arriving on such an island, Robinson Crusoe would either starve or rapidly poison himself. Of course such accumulated knowledge is vital in many other cases as well: being able to "read" the weather, the tides, and the winds is essential to safe canoeing or fishing. Discerning the best soils is essential before starting the labor-intensive task of felling the rain forest if next year's crops are to be successful. More than 200 kinds of bush plants and trees are exploited for building houses, making ropes, constructing canoes, making glues, or weaving baskets. Every individual may experiment a little bit, but it is done within the guidelines and with the safety net of millennia of accumulated wisdom about the local environment. We tend to forget that many domesticated species, such as almonds, lima beans, cabbage, potatoes, tomatoes, rhubarb, watermelons, and eggplants derive from poisonous or intensely bitter wild ancestors (Diamond 1998: 118). Some major domesticates remain poisonous until they are cooked (potatoes if at all green or sprouted) or specially treated (manioc). Others require major processing to extract the nutritive content, such as sago, where the starch is leached out of pulverized palm trunk. Such cultural knowledge obviously unlocks natural resources and enhances biological fitness, building a much larger, healthier population than would otherwise be possible in an environment like Rossel Island.

Cultures Include Functionless or even Deleterious Elements

The annals of anthropology are full of records of apparently irrational behavior, magic rites, rituals, unnecessary violence and warfare (and plenty of attempts to show that, given the native views, such madness maybe makes sense after all). It would be fairer to focus on some of our own idiocies, but I will stick to plan and give one example from Rossel Island. The islanders were cannibals up until the 1920s at least. To this day, they believe that no one dies naturally, but is the victim of sorcery. If an important man or chief died in the past, the sorcerer was identified by divination, and made to produce a victim to be eaten at the mortuary feast for the chief, the relatives receiving high-value shell money in compensation (Armstrong 1928: 103–114). There were also other occasions for cannibalism, including the consumption of shipwrecked aliens and the eating of persons who had defiled sacred places or otherwise caused trouble. The practice of cannibalism is now dead (in fact it seems to have been gladly dropped in response to colonial pressure), but the underlying ideas about sorcery remain.

I have yet to find a Rossel islander who does not believe in sorcery. It is a universal belief, and every death proves the point. Even murders are attributed to sorcery; the murderers were either themselves sorcerers who incapacitated the defenses of their victims, or coerced others to do the deed by threatening sorcery. There is a shrine to a spirit who inflicts countersorcery. The bereaved may go there and purchase revenge from the keeper of the shrine; the spirit then inflicts the sorcerer with cancer or another wasting disease like tuberculosis. Anyone dying of a wasting disease in a village where there has been an earlier death can be assumed to be the sorcerer who caused the earlier death; again, the one death proves the truth about the other. Specialist diviners and orators skilled in veiled accusations make a career out of the system.

This self-justifying system of beliefs casts a pall over every otherwise happy circumstance on the island. People go to intracommunal feasts and dances with both happy anticipation and watchful anxiety, for communion with strangers gives a sorcerer opportunities. In the same way, venturing into the hinterland alone or at dusk is full of dangers. Pregnancy, birth, and childhood are also times of joy and special danger. Visitors to other villages hasten to the relative safety of their kin or clansmen, taking special care with food. Suitors and those on "banking" expeditions for shell money travel full of trepidation and precautions. In short, social intercourse on the entire island is constrained and limited by fear of sorcery. No wonder dialect differences can flourish despite geographic proximity.

I take this as just one example of a deleterious cultural practice that may in the past have had biological consequences, since eating human flesh can pass on fatal diseases (see Durham 1991: 393–414 for an overview of the effects among the Fore of highland New Guinea). Existing beliefs about sorcery are also deleterious, since they restrict the circle of marriage, lessen trade and economic exchange in times of dearth, and undermine joint ventures and political alliances. Since a cultural system is a web of beliefs, some of which (like the poisonous nature of certain foodstuffs) are better not directly tested, once a deleterious practice becomes embedded in tradition, it is hard to eradicate. In traditional societies, the very mechanisms that guarantee a probability of vertical transmission will protect useless or even harmful beliefs from rapid elimination.

Culture, Group Selection, and the Feedback to Biology

As discussed earlier, group selection is a controversial mechanism in evolutionary theory. However, it seems odd to doubt the efficacy of culture in political decisions that affect the life chances of entire groups. In March 1997, cyclone Justin hit Rossel Island and circled over the island for 4 days, dumping more than 3 m of rain and whipping the island from every side with winds of up to 250 km an hour. At the time, I was on a neighboring island on my way to Rossel, and I was thus able to observe the immediate aftermath at first hand. Sailing toward the island a few days later, the sea was glassy smooth but full of logs, dead fish and crocodiles, and other debris. When the island came into sight, the tropical forest, normally intensely green, was entirely brown, denuded of leaves and burnt by salt spray right up to the central mountain peaks. Landslides triggered by the colossal rainfall left huge gashes on the mountainsides. The lagoon was brown with sediment and the reefs were covered in sand. Indeed, the whole local topography had changed, with new islands on the reef, rivers having changed their courses; the rain forest was flattened, and stretches of mangrove forest were washed away. Remarkably, there had been little direct loss of human life, despite the fall of many large trees, landslides, and the collapse of most of the houses, with even parts of coastal villages swept out to sea by huge waves that came over the barrier reef.

In fact it turns out that Rossel Island culture is adapted to cyclones, which are experienced as direct hits once or twice in a decade. Every village has a cyclone house, a barrel-shaped long-house of sturdy construction built directly on the ground, unlike everyday houses, which are raised on stilts. These are not a recent innovation—they are mentioned in 1849 as an unusual feature observed from offshore by Thomas Huxley and crew, who were unable to land on the island (see Armstrong 1928: 14–15); indeed Rossel islanders hold that the cyclone shelters were designed by their principal deity, N*gwonoch:a*. They are only 2 m high, anchored to the ground by sturdy piles, roofed with thick sago leaf, and equipped with benches raised off the floor in case of flooding. They are jointly maintained as a community resource.

There was an immediate and decisive community response to the disaster of cyclone Justin. Virtually all the normal food crops had disappeared in floods and landslides, leaving scarcely any seed tubers. The islanders know well that in such circumstances they rely crucially on sago. Sago is the starch leached out of the pith of *Metroxylon* palms. It is processed by pouring water against the pith held in a sieve or net; the starchy water is evaporated to yield a flour, all utilizing another elaborate indigenous technology. The cyclone knocked down all the mature sago trees, which are privately owned. Such felled logs must be processed in a few weeks before they mildew and become infested by pests. The community response was immediate; private ownership was waived and communal teams were set to extracting the sago starch, which when dry can be kept for about 4 months. This was to be the main means for survival.

There were other essential community responses. Drinking-water sources were fouled by salt spray, dead animals, and fish; the best sources were selected and communally cleared of debris and cleaned out. Community labor was used to clear villages and repair houses where possible. Thatch was in short supply, and communal labor was used to retrieve the sago leaves that lay on the ground and to collect a wild substitute from a short palm in the bush, although individuals thatched their own houses. Those whose houses were unrepairable lodged with their neighbors.

The extent of the disaster now became clear. Covered in sand, the reefs no longer sustained a rich marine life, and offshore fish and shellfish had effectively disappeared; indeed marine life only slowly recovered over the following year. Some fish, shellfish, and crabs could be found in the mangroves, but protein was now scarce because most of the pigs had perished in the storm or gone wild. Coconuts, an important source of fat, would not be available for a full year either. Sago palms with their essential thatch and useful starch, would not be available for 3 years. What about bush foods? The rivers had changed their courses, and the usual supply of prawns, eels, and fish was gone. The dense rain forest, as mentioned, was stripped of leaves by the wind; those surviving turned brown and dropped from salt burn coursed by windblown spray. Without the leaves, the forest floor dried up and the fallen leaves rotted like a giant compost heap. No rain fell for weeks. Those few seed tubers that had survived were treated as communally owned and carefully planted in the soil. Unfortunately there was none of the usual nurturing shade and moisture, and the soil was poisoned by salt. Then just as the rains returned, there was a plague of caterpillars that ate every shoot that sprouted. The caterpillars would normally have been happily occupied eating the leaves of the forest, but now the entire insect population of the island had only the seed tubers to feast on! (Many of the insect species that now became apparent seemed entirely new to the islanders, who imagined they had been transported to the island by the cyclone.) Community teams daily set out to crush the insects underfoot. The caterpillar plague peaked about 3 months after the cyclone, by which time the forest trees were tentatively putting forth leaves again, but it would be a year before bush nuts were available. Then the surviving wild pigs descended on the gardens in search of the precious tubers, making only the gardens closest to villages defensible. Community hunts with packs of wild dogs strove to hold the pigs back in the mountains.

It is in this context that the wisdom of the intense communal response immediately after the cyclone becomes clear. Without the requisitioning of the sago, there would have been large-scale famine, and without communal efforts to save the seed tubers, there would have been no following generation of garden produce. The cleaning of the water holes prevented disease, which might easily have swept through the communities. In the event, the population was malnourished for 6 months, but by November it was on the road to slow recovery. In the interim, a second calamity—drought, insect plagues, or an epidemic—could have had disastrous effects. Captain Cook recorded that the 1775 cyclone that hit Pingelap in Micronesia reduced the population from 1600 persons to a mere 30 by 1777 (cited in Cavalli-Sforza et al. 1994: 352). The fate of the Rossel island population at this critical time hung on a thread. What saved it was coordinated communal effort, which was made possible by an effective political system built on a local variant of the "big man" system (persons who acquire authority through effective use of exchange and the distribution of resources). Here the indirect benefits of the shell-money system can be seen; " big men" acquire their authority especially through control of shell money, which is required for marriage, death, and major traditional undertakings. Young men in search of wives thus affiliate with these elders, who can direct their activities and so wield real power.

I have recounted this episode in detail because I think it makes a clear case for the role of the group, as an effective joint "superorganism," in the biological survival of the population. The effectiveness of the group depends on its role as a culture-bearing entity with transmitted traditions about how to prepare for cyclones with cyclone houses, how to deal with the challenge of storing enough food (requisitioned sago) to stave off starvation during the immediate period of shortage, and how to overcome private interests (in sago trees or seed tubers) through the exercise of political power in the interest of group survival. A group without these mechanisms is not likely to muddle through such a disaster. However, these mechanisms also depend on biological underpinnings: the ability to inhibit private interest, to pull together in times of stress, and also more generally the cognitive abilities that make long-term communal planning possible.

Still, many will feel that the feedback from culture to biology is a thing that happened in deep prehistory (hence the popularity of the evolutionary psychology manifesto of “space age man with a stone age mind”). Nevertheless, microevolution, with feedback loops, is discernible in the course of just a handful of generations. Take the case of deaf communities, which usually support a manual sign language. Recent research has established that sign languages of this kind are full-fledged languages, with all the expressive power, syntactic flexibility, and lexical richness of any natural language. In Europe and America these languages have become relatively standardized in institutions for the deaf, but in other lands they have evolved more haphazardly wherever a critical mass of deaf people have come together. A number of village sign languages have been reported where a persistent strand of hereditary deafness has consistently generated a number of generations of deaf individuals. On Rossel Island there is such a strand of hereditary deafness, where a number of families have three generations or more of deaf individuals. Not only these individuals, but also the hearing members of the family and indeed all members of the villages where they live have developed a sign language for effective communication. This system, like most of the other reported village sign systems, remains to be scientifically researched. My initial investigations of one such family with three deaf adult children show that the sign system is capable of conveying quite abstract messages; for example, about events in the future, things witnessed in the past, or hopes and desires in the present. By virtue of the developed sign system, the deaf members of this family are fully integrated members of the village community. Two of them have married in the traditional way, involving complex exchanges of shell money between kin, and have children, some of whom are deaf, so the sign system will have a future utility, and is in effect a strand of cultural tradition in the making.

Now consider for a moment the interaction between the biological and cultural elements here. A strand of hereditary deafness prompts a cultural development, a systematic system of manual signs. In turn that systematic sign language renders the deaf individuals fully functional members of society. Their extended kin therefore invest them in the normal way, providing the shell money necessary for marriage. This legitimates biological reproduction, which in turn gives continuity to the genes that generate the strand of deafness. This is a microsystem of gene–culture coevolution over a handful of generations whose properties can be directly studied (see Aoki and Feldman 1991).

Conclusion

In the first part of this chapter, I outlined the kind of general considerations involved in trying to understand the evolutionary background of culture. There I hope to have established that twin-track theories of gene–culture coevolution are perfectly plausible, and moreover do not depend on the meme, that is, on a culture particle, as it were, mimicking the gene. Just as the soft Darwinists imagine natural selection operating on many levels, selection of cultural forms can apply at any level, from a minor design feature (such as the curve of a canoe prow) to a whole system of interrelated parts (such as a kinship system or a language). In a phylogenetic perspective, the crucial locus of gene–culture coevolution is cognition, because without the cognitive foundations for culture (abilities to "read" other minds, to inhibit actions, to learn any number of cultural variants in some domain), the accumulative character of human culture could not have gotten off the ground. In an intraspecific perspective, cultural variety allows geographic radiation into specialized niches, where microevolution in response to particular conditions (extreme cold, malaria, lack of salt) can arise. In a comparative cultural perspective, once cumulative aspects of culture start to pervade the environment, they in turn act as a selecting environment acting directly on the genotype (as illustrated by, e.g., the systematic association of dairying cultures and the genes for lactose absorption). In an intracultural perspective, genetic diversity within a cultural group can lead to microevolution of culture, as illustrated by sign languages of the deaf.

In the second half of the chapter, I have given a set of reminders about some of the crucial properties of culture that need to be modeled by any encompassing theory of cultural evolution. The target for explanation, a particular culture, has particular properties. It is not a heap of traits, but a system of systems of amazing complexity; there is variation all the way down to the individual. Some properties of individual cultures have extraordinary robustness to change; others are subject to rapid change, borrowing, and cultural exchange. Cultures accumulate successful trials of myriads of adaptive experiments (as in the example of processing of poisonous foods), but they also accumulate nonadaptive or even deleterious features. Aspects of culture can confer adaptive advantage on entire groups, and special microadaptations of culture to genetic impairments can evolve rapidly. I illustrated all this with examples from a relatively isolated society of simple technology, the kind of society that predominated through human prehistory.

I would like now to try and draw these two strands closer together. The parallel between genetic and cultural evolution sometimes seems forced. Gould (1991: 63) went so far as to say that "I am convinced that comparisons between biological evolution and human cultural or technological change have done vastly more harm than good." However, there are lessons to be learned from the exercise. One is that conservatism, i.e., resistance to change, is essential to the growth of complexity. In genetic evolution, conservatism is built in through the fidelity of reproduction; mutations are the exception, and most of them are extinguished. If the meme was the full story for culture, cultural change as a whole would be as rapid as fashions in clothes or pop songs, and in that case "ratchet culture" could not exist. For cultural accumulation, there has to be a reservoir of continuity. One brake on rapid change may be the process of cultural learning in the household, where initially the new generation learns from the parental one, so that by the time offspring are peer oriented perhaps the cultural core is already established. But this is hardly sufficient.

A second much more powerful force for conservatism is the power of systems. A single individual can change a word or two, but can hardly make much impact on a language. Even the greatest jurists have a barely discernable impact on a legal system, and the English kinship system has scarcely changed in half a millennium or more. Like machines, sociocultural systems resist random ad hoc changes because they have to function. Furthermore, unlike machines, sociocultural systems are the outcome of thousands of individuals each doing their part; my changing the script isn't going to stop the rest of you from carrying on. Given that sociocultural systems are, as it were, simply a web of concepts, intentions, and actions, their stubborn resistance to change is remarkable. Even when change appears on the surface, the system may remain stable. Changing hemlines, the pronunciations of words, or the style of pop songs (the kinds of examples that memetics focuses on) does not change the underlying system of clothing, language, or musical intervals. To borrow de Saussure's analogy for language, you can play chess with any arbitrary collection of shells or stones, providing the values of each piece are preserved. Systems are articulated sets of values and are not to be identified with the substances that temporarily substantiate them.

Cultures are systems larger than the individual. No one individual controls all the knowledge and practices, which are distributed throughout a population in a complex division of labor and cognition. Consider again something like a kinship system; the male and female perspectives on such a system differ in many essentials. There are interesting studies of distributed cognition (see Hutchins 1995) where a team (such as navigation team on a vessel) serves as a computing device to yield practical solutions (e.g., the course to navigate). If one asks what are the background conditions that make such a procedure possible, they include, first, the assumption of the fidelity of transmission of the procedure (we must think the others know what they are doing), second and crucially, the presumption of cooperation and trust—we must trust that we are each doing our bit as well as we can.

The general presumption of truth telling is essential to learning a language (how could you learn what "rabbit" means if the probability is that "That is a rabbit!" is false?). Cooperation and trust of this order are rare or non-existant in nonhuman animal behavior, and the evolutionary explanation of how it could arise runs straight into the conundrum of altruism: In an altruistic society the cheater always does best, so there are only limited, special circumstances in which altruism can be a stable evolutionary strategy (see Boehm, chapter 4 and Boyd and Richerson, chapter 5 this volume). One possibility is that it is this cooperation that has in evolution driven the mind reading that Tomasello (1999 and chapter 10) judges to be the crucial ingredient for culture. Being able to "read" others' intentions to a considerable depth is essential to cooperation, but it is also essential to detecting cheaters. A person might have all the right cooperative intentions up to some point, and then develop an additional intention to mislead. Consider. This example: When you and I cooperate to move a log, I have to see that you are intending to pick up your end if I pick up my end, but I also want to be assured that you don't later intend to make me drop it on my toe. Overall, the cognition of cooperation is much more demanding than the cognition of competition because competitive goals are preset but cooperative ones have to be communicated and established (see Levinson 1995 for the formal argument). The ability to mind read will act as some guarantee against cheating, or maximizing at the expense of one's fellows. Thus general considerations suggest that cognitive complexity may have been driven both by the cooperation that underlies culture and the need to protect it.

Notes

1. This assumes a life expectancy of 45 years for our prehistoric ancestors, with puberty at, say, 15 (as in current traditional societies, such as that is Rossel Island, discussed later).

2. Computer simulations show that a few hundred generations are easily sufficient to bring a rare mutant allele to dominance in a population, even with a low selection coefficient (see Durham 1991: 242–243 for references). In general, Lumsden and Wilson (1981) suggest a "thousand-year rule," under which 1000 years can be sufficient time for feedback from cultural to biological evolution. Dairying in the Near East certainly goes back 6000 years.

3. For some pithy remarks on Lumsden and Wilson's (1981) "culturgen" unit, see Hallpike (1982:13): "The definition is so vague . . . that a culturgen could be any discriminable aspect of human thought or behavior whatsoever: It is as though the "thing" were to be proposed as the basic unit of physics."

4. The ideational view of culture has a relatively short history and remains dominant only in American anthropology, being first articulated clearly by Goodenough (1957).

5. The modern human hand displays a range of grips that are quite impossible for an ape. *Homo habilis*'s more humanlike hands emerged with the first Oldowan tools more than two million years ago, but the size of the spinal chord remained limited right through into *Homo erectus*, implying relatively crude motor control. Even Neanderthals had hands that were distinctly different from those if modern humans (see Trinkaus 1992).

6. Oscine birds have song dialects, but only the form, not the function, is variable across dialects (see Hauser 1997: 273–300).

7. For the range of sound systems, see Maddieson (1984); for word order see Austin and Bresnan (1996); for noun versus verb, see Mithun (1999: 60–67).

8. Genetic drift increases over time at a rate that is inversely proportional to the size of the population; genetic distance d over time t in a population of size N increases according to the formula $d = t/2N$.

9. The measure of relative complexity in languages is nontrivial and has been much discussed, especially in the context of Creole languages. See the special issue of *Linguistic Typology* (2001, vol. 5 no. 2/3) for discussion and references.

10. As discussed in the first section, it is not necessary to assume that, say, witchcraft is an innate idea (then we all ought to subscribe to the identical doctrine) in order to account for its widespread belief. Human malevolence is empirically exemplified; it is the belief in a special kind of (supra-)natural force that has to be explained. And that might indeed be explained by our in-built social cognition, giving us a propensity to read the world as driven by intentions (see Levinson 1995).

11. Rossel islanders do, however, show significant proportions of markers on the Y-chromosome that are associated with Oceanic peoples (Manfred Keyser, personal communication).

12. In principle of course Rossel islanders could have borrowed fancy new names for good old, familiar objects, but it is unlikely. There are many different kinds of lexical borrowing, but in contexts of nonintense cultural contact (presumed relevant here) a major tendency is for lexical borrowings to be associated with new objects, practices, and concepts. In cases of intense contact, however, the bets are off; almost any aspect of language can be borrowed for a wide range of motives (see e.g., Thomason and Kaufman 1988).

13. The earliest (pre-Austronesian) archaeological evidence for the use of the betel nut goes back nearly 6000 years on the New Guinea mainland, but it does not appear in island deposits until perhaps 2000 years ago (see Kirch 1997: 40, 217).

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