Prof. Rex Li's Writings

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Title:	Co-evolution of Genes and Culture: A Mathematical Proof
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Summary/ Abstract:	Herbert Gentis, an economist-turned-social theorist, tried to offer a mathematical proof of co-evolution of genes and culture.

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Co-evolution of Genes and Culture: A Mathematical Proof

(A) Background

Many scholars support the idea of gene-culture coevolution, i.e there is interaction of genes and culture in human evolution, where human genomes affect culture and vice-versa. One scholar, Herbert Gintis, argued that "Gene-culture coevolution is responsible for …cooperation, fairness and retribution, the capacity to empathise, …virtues as honesty, hard work, piety and loyalty." (Gintis, 2011)

(B) Problem

Genetic transmission through generation is slow. Our genetic endowment changes little over thousands of years, thus the idea of constant human nature of greed, lust, aggression, etc. Also genetic study is hard science while culture is soft and elusive. How can gene coevolve with culture to create fairness and honesty? What mechanisms and evidence? Gintis argued that the process is complex and the concept of gene must be expanded: "the standard view of the insular gene producing a single protein" is outdated.

(C) Mathematical Proof

Gintis offers a mathematical proof to support gene-culture coevolution. He tried to defeat the argument that culture " is an effect of genes that can be factored out in the long run". He tries to show that:

The denial of gene-culture coevolution is prima facie untenable

He did so by creating three vectors:
g = genetic variables
c = cultural variables
e = environmental variables

See his mathematical proof and argument in half a page.

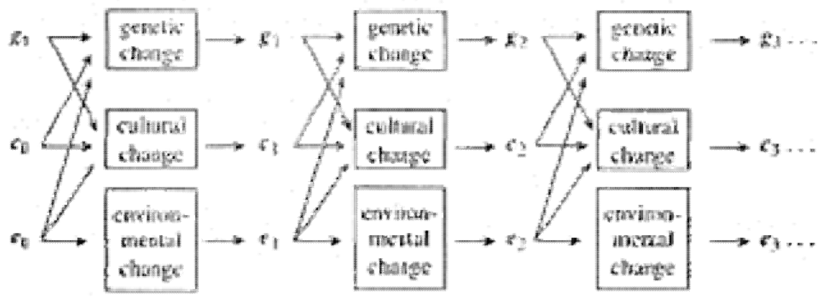

Figure 1. The dynamics of gene–culture coevolution.

It is clear from this body of empirical information that culture is directly encoded into the human brain with symbolic representations in the form of cultural artifacts. This, of course, is the central claim of gene–culture coevolutionary theory.

2. CULTURE IS NOT A BY-PRODUCT OF GENETIC EVOLUTION

It might be thought that the complex and intimate interaction of genes and culture outlined above is overdrawn, and that human genetic evolution is the effect of genetic inclusive fitness maximization, culture being an effect of genes that can be factored out in the long run. For instance, the eminent evolutionary psychologist David Buss holds that 'Culture is not an autonomous casual process in competition with biology for explanatory power' [51, p. 407]. This denial of gene–culture coevolution can be shown to be *prima facie* untenable. To see this, suppose we have a vector $\boldsymbol{g}$ of genetic variables, a vector $\boldsymbol{c}$ of cultural variables, and a vector $\boldsymbol{e}$ of environmental variables, including the prevalence of predators and prey, weather and the like. In an evolutionary model, the rate of change of variables is a function of the variables, so we have

$$\dot{\boldsymbol{g}} = F(\boldsymbol{g}, \boldsymbol{c}, \boldsymbol{e}), \tag{2.1}$$

$$\dot{\boldsymbol{c}} = G(\boldsymbol{g}, \boldsymbol{c}, \boldsymbol{e}) \tag{2.2}$$

$$\dot{\boldsymbol{e}} = H(\boldsymbol{e}). \tag{2.3}$$

Note that it is plausible for $\boldsymbol{c}$ to affect the nature and pace of environmental change, in which case it should be included in equation (2.3). We abstract from this causal path in order to strengthen the case for Buss' argument. The contention that culture is an effect of genetic fitness maximization in this framework is the assertion that $\boldsymbol{c}$ can be eliminated from these equations. Under what conditions can this occur? Taking the derivative of equation (2.1), and substituting equations (2.2) and (2.3) into equation (2.1), we get

$$\ddot{\boldsymbol{g}} = F_g(\boldsymbol{g}, \boldsymbol{c}, \boldsymbol{e})F(\boldsymbol{g}, \boldsymbol{c}, \boldsymbol{e}) + F_c(\boldsymbol{g}, \boldsymbol{c}, \boldsymbol{e})G(\boldsymbol{g}, \boldsymbol{c}, \boldsymbol{e}) + F_e(\boldsymbol{g}, \boldsymbol{c}, \boldsymbol{e})H(\boldsymbol{e}). \tag{2.4}$$

If $\boldsymbol{c}$ is to be absent from this second order differential equation, the derivative of the right-hand side of equation (2.4) with respect to $\boldsymbol{c}$ must be identically zero. Thus, we have

$$0 = F_{gc}F + F_gF_c + F_{cc}G + F_cG_c + F_{ec}H. \tag{2.5}$$

All five of the above terms must then be identically zero, so $F_c = 0$, implying that $\boldsymbol{c}$ does not enter on the right-hand side of the defining equations (2.1)–(2.3); i.e. genes are not a function of culture. This is obviously not appropriate for humans, since both genes and culture are functions of culture.

Figure 1 illustrates this dynamical process. Note that as long as there is high fidelity cultural transmission over multiple generations (signified by the middle row of horizontal arrows), genetic and cultural evolution are inextricably intertwined. By contrast, for species that do not have cumulative learning, these arrows are absent, and despite the fact that genes affect culture in every period, there is no cumulative interrelatedness of genes and culture.

We will give two examples of understanding human evolution using gene–culture evolution, the repositioning of the larynx and other physiological changes facilitating linguistic communication [52], and the role of culture in creating a genetic predisposition for cooperative activity in humans [53].

3. GENE–CULTURE COEVOLUTION AND THE PHYSIOLOGY OF COMMUNICATION

The evolution of the physiology of speech and facial communication is a dramatic example of gene–culture coevolution. The increased social importance of communication in human society rewarded genetic changes that facilitate speech. Regions in the motor cortex expanded in early humans to facilitate speech production. Concurrently, nerves and muscles to the mouth, larynx and tongue became more numerous to handle the complexities of speech [54]. Parts of the cerebral cortex, Broca's and Wernicke's areas, which do not exist or are relatively small in other primates, are large in humans and permit grammatical speech and comprehension [55,56].

Adult modern humans have a larynx low in the throat, a position that allows the throat to serve as a resonating chamber capable of a great number of sounds [57]. The first hominids that have skeletal structures supporting this laryngeal placement are the *Homo heidelbergensis*, who lived from 800 000 to 100 000 years ago. In addition, the production of consonants requires a short oral cavity, whereas our nearest primate relatives have much too long an oral