Degenerative Phonology

Daniel Silverman

Part 1

Theory

Chapter Two

Background

Let's consider the intellectual history of degeneracy—its origins, its debasemant, and its rehabilitation—by summarizing four papers on the subject: Mason 2010, Whitacre 2010, Edelman and Gally 2001, and Deacon 2010. It will emerge that the proposed pressures and principles affecting the structure and evolution of the morpho-phonological system are qualitatively non-distinct from any and all other complex adaptive—that is, degenerate—systems.

1. Mason 2010

Mason succinctly characterizes a degenerate system as one in which "heteromorphic variants [...] are isofunctional"; "degeneracy exists in a population of variants where structurally different components perform a similar, but not necessarily identical, function with respect to context." Deriving from the Latin *degeneratus*, "something is said to degenerate when it 'moves away from its genus or type, so that it is no longer general or typical' (Schwartzman 1994:68)" (quoted by Mason p.277).

But despite such value-free origins, degeneracy as a characterization of systems and their components has endured long stretches of unsavory application. The concept was employed by Christian ideologues in their characterizations of apostates, heterodoxists, Jews, and anyone else who deviated from Church doctrine. Its cultural and religious application was thus readily wieldable by those who would impose conformity on (or call for the elimination of) "degenerate" individuals or groups: the generational transmission of religious and cultural practice should not be subject to variation and selection, but instead should never stray from the straight and narrow, that is, from that which came before. Spanish cosmographer Juan López de Velasco (c.1530-1598), for example, cautioned that even travel to distant lands be curtailed, as adaptation to different climatic conditions might induce both biological and cultural changes to the Christian European ideal.

As applied by naturalists, degeneracy was found to be a useful way to characterize growth and development, while still adhering the to tenets of Creationism. Variation may thus be the result of degeneration from divinely ordained prototypes. French naturalist Georges-Louis Leclerc, Comte de Buffon (1707-1788), for example, considered both New World domesticated animals and Native Americans themselves to be degenerate in character. German naturalist Anton Dohrn (1840-1909) regarded all lower animal life as descended from humanity by means of natural selection: initial perfection of divine origin devolves into degenerated life forms.

With respect to matters of emotional and mental health, received wisdom about degeneracy seemed ready-made to characterize deviant thought and behavior. French psychiatrist Bénédic Morel (1809-1873), for example, appealed to the heritability of degenerated traits in his proposed etiology of mental illness. Hungarian-born Jewish political philosopher Max Nordau (1849-1923) asserted that degeneracy manifests itself in an individual "incapable of adapting himself to existing circumstances" (quoted in Mason, p.280). American dental surgeon Eugene S. Talbot (1847-1924), associated degeneracy with a “what-ails-ya” list of perceived maladies and their triggers, including “contagious and infectious diseases, destructive behavior, toxic agents, unfavorable climate, mental decline, consanguineous and neurotic intermarriages, juvenile obesity, impure food, arrested development, skeletal anomalies, sensory deterioration, paranoia, hysteria, idiocy, and one-sided genius [presumably, savantism – D.S.], as well as social parasitism, moral degradation, and cultural demise” (Mason p.280).

Ideologically-infused applications of degeneracy achieved their verdant fruition in the mid-Twentieth Century when the German government, in cooperation with its many sympathizers in Europe and beyond, implemented its policy of murdering all Jews, a minority ethno-religious group characterized as a degenerate race possessed of a degenerate culture. But with the advent of modern biological investigation, degeneracy's rehabilitation as a value-free term slowly began.

In early 1955, British biologist Francis Crick (1916-2004) sent a personal note to the “RNA Tie Club”, an informal organization dedicated to the study of RNA. Therein, Crick discusses a proposal of the club's co-founder, the Russian-Ukrainian physicist George Gamow (1904-1968) concerning the relationship between nucleotide combinations and their coding for amino acids: four nucleotides, in more than one triplicate combination, may code for the same amino acid. Crick brands this many-to-one correspondence as “degenerate” in character:

> (1) In Gamow's scheme several different base sequences can code for one amino acid […] This “degeneracy” seems to be a new idea [...]
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> (2) Gamow boldly assumed that code would be of the overlapping type. That is, if we denote the sequence of base pairs by 1 2 3 4 5 6 ...., he assumed that the first amino acid was coded by 1 2 3, and the next by 2 3 4, not by 4 5 6. Watson and I, thinking mainly about coding by hypothetical RNA structures rather than by DNA, did not seriously consider this type of coding,
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> (3) Gamow's scheme is essentially abstract. It originally paid lip-service to structural considerations, but the position was soon reached when “coding” was looked upon as a problem in itself, independent as far as possible of how things might fit together. As I shall explain later, such an approach, though at first sight unnecessarily abstract, is important. (Crick 1955:5f.)
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> ...
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> Although...there maybe no simple relationship between the different triplets of base-pairs representing one amino acid, it is obviously sensible to investigate forms of degeneracy which derive from simple structural ideas, as Gamow's did [sic]. (Crick 1955:13)

Increasingly freed from the burdens of its etymology, degeneracy could now be deployed at liberty as a property of biological and evolutionary (and, as will be seen, of many other, or even *all*) complex adaptive systems. A degenerate system's characteristic traits of *robustness*, *evolvability*, and *complexity* (Whitacre 2010) are succinctly conveyed in the italicized portion of the following quote from Mason, pertaining to evolutionary theory:

> Trait selection requires more than one structure from which to select. The presence of two or more different ways of doing the same thing or encoding the same information is crucial for an evolutionary system. This degeneracy means that an organism can vary

> without compromising function. It creates the potential for variation and ensures the organism against perturbations. In addition, it installs greater pluripotentiality underlying functional continuity for future deployment. *As the system evolves, it can become less fragile in the face of its own variation. Degeneracy creates a surplus of structure for later exaptation*. (p.281; italics added)

Moreover, the absence of any pre-ordained design components in a system that has evolved to degenerate status obviates the need for positing any draconian “top-down” and/or “bottom-up” motivations for such systems' structural interdependencies, and further allows for these systems' ever-contingent modifications to their overall structure. As cleverly remarked by Mason (p.283), “instead of stating, 'the cellular machinery that evolved before the Cambrian was highly *generative*, (Hauser 2009:190), we are probably better off enquiring how the cellular machinery during this period was highly *de*generative” (italics added), the point in part being that the many-to-many character underlying a system's form-function structural integrity is not inherent, but is, rather, emergent, even if inevitable.

2. Whitacre 2010

Whitacre observes that the superficial conflict between genotypic evolvability and phenotypic stability—that is, that mutable genetic traits might culminate in the entrenchment of robust phenotypic ones—is readily reconcilable when acknowledging the degenerate nature of the system as a whole: as single phenotypic traits may be underlain by distributed genetic ones, then genetic variation may persist while maintaining and enhancing phenotypic fitness. Such a system is degenerate in much the same way as Gamow proposed that a single amino acid may be built from distinct nucleotide triplet combinations, and (for present purposes) the way phonetically distinct morphs may encode identical semantic content. As Whitacre writes, “On the one hand, robustness is achieved through a connected network of equivalent (or nearly equivalent) phenotypes. Because of this connectivity, some mutations or perturbations will leave the phenotype unchanged […] On the other hand, evolvability is achieved over the long-term by movement across a...network that reaches over truly unique regions of the fitness landscape” (p.5). That is, the very stability that many-to-one form-function relationships confer upon a system also allows for new variants that might improve overall functionality. In contradistinction to the actual state of evolutionary-biological affairs, an entrenched one-to-one (*non*-degenerate) form-function relationship—even when there is a multiplicity of such relationships such that redundancy is present—would indeed confer robustness on those traits already in place, but in the absence of degeneracy, such traits would be far less likely to passively reap the specifically *evolutionary* benefits that degeneracy confers.

Whitacre further emphasizes the limited value of *local* analyses in our attempts to understand any given element's functionality. We have already referenced this important point in Chapter One. Recall that considering allomorphs in the absence of the conditions that induce their differences fails to reveal the degenerate nature—and the degenerative capacity—of the system (as in Figure 1.2). Rather, reference to *context*—and to *bonding* in particular—is absolutely necessary to our understanding of the linguistic systems' degenerate nature and capacity (as in Figure 1.3). The full functional role of a particular component can only be determined by investigating the various contexts in which its forms are present, and thus how they are distributed throughout the system as a whole: “different components can contribute to the same function and [one] component can contribute to several different functions through its exposure to different contexts” (p.6).

An example from biological systems: glucose metabolism may proceed both through the glycolysis pathway, and through the pentose phosphate pathway. Under varying conditions, one pathway may substitute for the other with no diminution of function (Saur, Heri, Perrenaud, and Fischer 2004). Much as we will explore in the context of phonological patterning, the two pathways may be characterized as engaging in a compensatory or "trading" relationship of sorts: distinct sub-systems underlie a single function such that a conditional under-performance by one component may be offset by the activity of another, one whose function is undiminished by the local conditions affecting the first. As Whitacre writes, "localized stresses can invoke a distributed response" (p.8).

This sort of distributed functionality of a system's components yields to their genuine structural complexity as embodied in their *hierarchical organization*, such that the system's elements are at once functionally segregated *and* functionally integrated. Indeed, the greater the functional integration of a system's independent components, the more robust and evolvable the system becomes. Robustness and evolvability thus go hand: a trait may remain stable in the face of environmental variability ("canalization") or a trait may adapt in the face of environmental variability ("adaptive phenotypic plasticity").

Discussing the degenerate nature of evolution by means of natural selection in particular, the following quote from Whitacre nicely captures the qualitative non-distinctness of the various underlying pressures and principles acting on *any* complex adaptive system, evolutionary-biological, morpho-phonological, or otherwise:

> It is well-accepted that the exceptional properties of [complex adaptive systems] are not a consequence of exceptional properties of their components. Instead, it is how components interact and inter-relate that determines (1) the ability to confer stability within the broader system (robustness), (2) the ability to create systems that are both functionally integrated and functionally segregated (complex[ity]), and (3) the ability to acquire new traits and take on more complex forms (evolv[ability]). It would seem that any mechanism that directly contributes to all of these organizational properties is a promising candidate design principle of evolution. (p.12)

3. Edelman and Gally 2001

Edelman and Gally open their paper on degeneracy by remarking that evolution by means of natural selection does not entail *progress*, but nonetheless does bestow a greater degree of *complexity* on that which evolves, and moreover, that biological evolution takes place not only due to *external* (environmental) pressures, but also due to the degenerate nature of any system's *internal* components: "[degeneracy] is a prominent property of gene networks, neural networks, and evolution itself" (p.13763).

Technological innovation now permits laboratory demonstrations of degeneracy in action, even at the genetic level. "Knocking out" one gene *may* result in trait modification or loss, but also, may *not*. For example, the induced loss of specific protein synthesis in mice *may* confer this loss to progeny, but also, may *not*. While bestowing "junk" status to such components—those whose elimination results in no loss of function—may be tempting, a more compelling explanation for phenotypic robustness in the face of genotypic modification or elimination resides in degeneracy: "the gene networks of the affected animals are degenerate, allowing widespread, compensatory adjustments" (p.13763). Importantly, such compensatory measures are not assumed to be genetically pre-programmed themselves, such that functional re-dispensations are directly genetically encoded: “degeneracy is not a property selected by evolution, but rather is a prerequisite for and an indispensable property of the process of natural selection itself” (p.13763). This assertion is based in part on the observation that compensatory measures are context-conditioned: “if the affected animals were placed in different environments, definite phenotypic effects could emerge, some of which might even be lethal” (p.13763).

As Whitacre does, Edelman and Gally are quick to establish the relevant distinction between functional redundancy and degeneracy, referring to Gamow's analysis of polypeptide chains as case a par excellence: recall that there are many more nucleotide triplets than there are amino acids for which these sequences code. The authors offer a long list exemplifying degeneracy at many different levels of biological organization, including the genetic, the metabolic, the nutritional, the inter- and intra-cellular, the immunological, the neuro-anatomical, the sensory, the musculo-skeletal, the behavioral, the inter-species, among others.

Any individual component thus *may* be necessary, but insufficient, to the survival of any given organism or species; necessary because its deployment is required across a number of critical functions such that its deactivation *may* induce systemic failure, but insufficient because it requires interaction with other components to serve a function. Thus, for example, “even proteins having no apparent structural, physiologic, or evolutionary relationship can together perform degenerate roles” (p.13764f.)

As noted, degeneracy is observed at multiple levels within the biological hierarchy. The immune and olfactory systems of vertebrates are illustrative cases. In both systems, recognition of a huge array external agents is made possible by a finite system of receptors organized in a degenerate arrangement. At the musculo-skeletal level, within a highly circumscribed overall body plan consisting of a small inventory of jointed connections, there is a multitude of ways to achieve any particular outcome; the authors ponder the number of ways a monkey might swat a fly on its nose. In perhaps the limiting case—that of vertebrates' systems of neural connectivity—many trillions of connections ultimately subserve a far smaller inventory of functions. With respect to brain morphology in toto, “although, in the past, variations in the gross shape of the brain were studied carefully in efforts to find correlations between anatomical features and mental abilities or propensities, it is now accepted that these efforts are largely fruitless. Instead, it is [now] recognized that many different patterns of neural architecture are functionally equivalent, i.e., functional neuro-anatomy is highly degenerate” (p.13765). Such a characterization is most pertinent for present purposes with respect to the antiquated notion of a brain-based “language center” that is still in vogue within certain realms of linguistic pontification.

With respect to sexual reproduction, it is not solely the exuberant levels of gamete production that ensures a species's reproductive success. After all, if all gametes were genetically identical, redundancy would be in place, but the system itself would be guaranteed to fail through its inability to adapt to changing environmental conditions. Rather, gamete over-production is necessarily linked with gamete variation—a now-familiar degenerate state of affairs in which structurally distinct elements subserve a single function—thus culminating in reproductive success, ensuring both end-product stability (organismic reproduction) and end-product change (organismic adaptability):

> Each genetic variant has a unique potential for good or ill, and each combination of variants contributes to a novel phenotype to be subjected over time to evolutionary winnowing […] When considered in this light, one appreciates more clearly the fallacy

> of speaking of a gene or genes for size, shape, intelligence, etc. All observable properties of an organism are determined by the working of a degenerate network of many genes […] [I]n the absence of degeneracy, it is likely that most mutations eventually would result in lethality, for then there would be no trade-off between individual gene action and gene network interaction […] Any "compensation" that occurs is a statistical result of the tradeoff between specificity and range that follows in complex systems having degeneracy. (p. 13766)

4. Deacon 2010

According to Deacon, the pressures affecting the organization of complex adaptive systems—language among them—"bear a resemblance to Darwin's mechanism of natural selection, often differing in only one respect (e.g. form of duplication, kind of variation, competition/cooperation). A common feature is an interplay between processes of stabilizing selection and processes of relaxed selection at different levels of organism function […] [*I*]*rrespective of the mechanisms involved*, if these conditions are present, a lineage will tend to become adapted to local conditions if given sufficient time and generations" (p.9000; italics in original). We have already preliminarily considered how such pressures play themselves out: variation and stability are inherently intertwined, in the sense that it is the very variation present at one level of structure (say, the genetic, or the phonetic), that is subject to selection (say, organismic or allomorphic reproductive success) such that functionality remains robust even across varied contexts, contexts that are subject to varied conditions and pressures (say, physical-environmental or morpho-syntactic placement).

Deacon considers not only the evolution-like pressures at work on language *structure*, but also, the evolution-like pressures that may be responsible for the language capacity itself: "By paying attention to the way Darwin's concept can be generalized to other systems, and how variants on this process operate at different interdependent levels of organism function, explaining the complexity of language and the language adaptation can be made more tractable" (p.9000).

From Charles Lyell (1863) and Alfred Russell Wallace (1869) in the immediate post-*Origin* era, to more recent scholars like Charles Thaxton (1984) and Noam Chomsky (1986), it has been asserted that Darwin's idea is incapable of accounting for the complexities of certain organic traits. For example, Thaxton (with co-authors Walter L. Bradley Roger L. Orsen) rejects the idea that chemical compounding is responsible for organic life, in much the same way that Chomsky rejects the idea that language evolved in service to conspecific sound communication, but instead, is "special". And while Deacon indeed acknowledges that not all evolutionary developments are adaptive, still, he notes that one would be hard-pressed to characterize language as a *mal*adaptation. Moreover, "The appeal to pure accident. e.g., a 'hopeful monster' mutation, to explain the evolution of such a highly complex and distinctive trait [as language] is the biological equivalent of invoking a miracle" (p.9001), and thus both its functional utility and its structural complexity position language to withstand the mere assertion that it has not been subject to the evolutionary pressures common to other complex adaptive biologically-based systems. Indeed, Deacon points out that almost all modern scholars properly ignore such rejections of the explanatory power of Darwinism.

Rather, Deacon proposes the following:

> [A] constellation of learning biases and changes of vocal control evolved in response to the atypical demands of this distinctive mode of communication. To the extent that this

> mode of communication became important for successful integration into human social groups and a critical prerequisite for successful reproduction, it would bring about selection favoring any traits that favored better acquisition and social transmission of this form of communication. (p.9002)

Like Edelman and Gally before him, Deacon also considers how other biological systems, too, are subject to generalized Darwin-like pressures and principles that may be characterized as degenerate in character, among them, the neural system that ultimately undergirds cognitive complexity. He points out that the mammalian brain takes its shape as a consequence of predetermined genetic instructions (resulting in an over-abundance of connectivity early in the lifespan), in necessary combination with the plasticity that manifests itself under the inevitably varying environmental conditions common to each individual organism (resulting in the winnowing and the potential reorganization of connectivity at later stages). The mole rat, for example, a blind species that nonetheless has vestigial eyes, is born with a thalamic visual nucleus, but this area is quickly innervated with auditory nerve fibers. Again then, we see how an over-abundance of form ensures robustness of ultimate function: "the species-general global pattern of connectivity that is under strong but low-resolution guidance becomes the scaffolding for subsequent selectional differentiation in response to signal-mediated activity-dependent competition for synaptic ability […] 'neurons that fire together wire together'" (p.9002).

The parallels between this system of "overproduce-then-cull" and that of morph selection in language evolution should now be crystal clear. While form and function vary among systems, the overall pressures on their general architecture may be seen as having a common source: complex adaptive systems have naturally and passively attained degenerate status, such that any individual function may maintain both its robustness and its evolvability as a consequence of its being underlain by multiple forms. "The replication, variation, and differential preservation that together characterize natural selection have their counterparts in the redundancy, degeneracy, and functional interdependence that characterize intraorganismic processes" (p.9003).

As Deacon shows, systemic redundancy may be present at both the system-internal and system-external levels. The now-familiar case of gene duplication exemplifies system-internal degeneracy, in which replication is necessarily subject to mutation, and mutation is necessarily subject to selection. Adaptive modification may thus concomitantly entrench functionality and enhance adaptability to new contexts and new conditions, thus entering into new or pre-existing sub-systems that are also subject to formal and functional modification:

> The relaxation of selection that is created by the functional redundancy consequent to gene duplication enables what amounts to a random walk away from the gene's antecedent function. But because a random walk produces incremental deviation, there is a significant nonzero probability that one or more of the increasingly variant forms within a population of organisms will 'wander' into a related interaction relationship with some duplicate counterpart, and again become subject to selection for any interactive deleterious or synergistic effects. It is no surprise, then, that gene families descended from a common ancestral gene often form synergistic functional complexes. (p.9003f.)

As an example of system-external degeneracy, certain fruit-eating vertebrates are no longer capable of synthesizing ascorbic acid, which serves an important antioxident function. This loss of function was likely due to external circumstances: environmental conditions—the availability of edible Vitamin C-rich fruit—served to "free up" dedicated *internal* systems, and so the process has been off-loaded to *external* ones. Selection shifted from the purely physiological (ascorbic acid synthesis) to the largely sensory and behavioral (searching for and eating ascorbic acid-rich foods).

Turning to language in particular, Deacon points out a number of ways in which its structure and its neuro-biological underpinnings are qualitatively and quantitatively distinct from the sound communication systems of other species in ways that strongly suggest its degenerate origins and maintenance: (1) Language is massively multi-functional whereas lower animal sound communication is functionally highly circumscribed, typically employed for sexual advertising and alarm signaling, (2) language evinces “duality of patterning” (Hockett 1960), whereas it far from clear that any animal sound communication is even remotely as complexly structured, (3) language has off-loaded instinctual vocalizations to other systems, whereas instinct is likely responsible for *all* non-human sound communication, (4) language learning is heavily reliant on an extended period of socialization, whereas other sound communication systems are not, (5) language triggers activation throughout the brain's neural substrate (especially the forebrain), whereas animal sound communication is highly localized to subcortical regions, and (6) language complexity is inextricably bound to and intertwined with both social and cognitive complexity, whereas such binding and intertwining is far more tenuous as we descend the tree of animal life. Most relevant to issues of present concern, (7) “[l]anguage itself exhibits an evolutionary dynamic that proceeds irrespective of human biological evolution. Moreover, it occurs at a rate that is probably many orders of magnitude faster than biological evolution, and is subject to selective influences that are probably quite alien from any that affect human brains or bodies […] Indeed, just as evolution is aided by evolution-like processes involved in ontogenesis, we should expect that the social evolution of language should itself exhibit analogous processes due to redundancy, degeneracy, and functional interdependency” (p.9005).

Deacon concludes by emphasizing that the complexity of language structure and the simplicity of its acquisition are consequences of its passive evolution, and little more. Still it must be pointed out that the unique status of language precludes our placing it at some notch on any given scale of complexity or learnability. Language structure is “complex” in comparison to what? Language acquisition is “simple” in comparison to what? Given its unique status there is simply no context in which language might be placed such that comparison with other systems might be illuminating, or even possible. Still, although *language is what it is,* Deacon effectively conveys what language is *not*: neither the capacity *for* language nor the structural particulars *of* language is an immediate product of genetic instruction, nor does language have its origins in an isolable genetic mutation, nor do linguistic features lend themselves to purely evolutionary biological explanation. But just as importantly, language is not a purely cultural construct that lends itself to the sorts of learning by which many other complex knowledge systems may be mastered.

5. Summary

Deacon's evocative characterization of the particular selective influences on language structure as “alien” highlights the remarkable uniqueness of our species' vocal communication system. Still, however many unique aspects there are to this system, its systems-within-systems, and its functional components, the main point of this chapter has been to demonstrate how *un*remarkable linguistic degeneracy is. All of Mason, Whitacre, Edelman and Gally, and Deacon point to the pervasive generalizability of the the pressures and principles that account for the form and function of any and all complex adaptive systems. In the case of language, the system's robustness, evolvability, and complexity derive from pressures that are straightforwardly—and emphatically—qualitatively non-distinct from those underlying the patterning and behavior of other degenerate systems. In short, language is unique, but language is not “special”.