

Book Review

A major feat of intelligent synthesis

A review of *The Birth of the Mind: How a tiny number of genes creates the complexities of human thought* by Gary Marcus. New York: Basic Books, 2004.

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The title and subtitle of this book raise the expectation that we will find out something about the relation between genes and the mind, suggesting that it provides a new perspective on the mind/body problem. I have to confess that when I first read through Marcus's volume I had the same experience I had when reading Popper and Eccles' "The Self and its Brain" some years ago. After patiently following Eccles' careful description of this and that neurophysiological mechanism, I felt I had somehow missed the connection when all of a sudden he switched into talking about the mind as if he had built a satisfactory and convincing bridge from the neurophysiology of the brain to the "mind". In the case of Marcus' book I initially had the same difficulty, in this case going from "gene" to "mind". However, things became clearer when pausing to reflect on how Marcus uses the term "mind". He avoids all manner of metaphysical complications by restricting himself to the use of "mind" as short-hand for the sorts of things that take place in Popper's world 2, the "world of mental processes", such as thinking, perceiving and remembering. Marcus follows the sage maxim that if you cannot define what a thing is, try at least to describe what you think it does. So, be warned: his book does not claim to illuminate the reader on the mind/body issue, in spite of the title (indeed, at one point, Marcus confesses "I use the term "mental gene" as a bit of a joke" p. 80). What Marcus sets out to do, and he does so very successfully, is to describe how a deceptively small number of genes can create the conditions conducive to the development of the mind in the sense in which most of us, by common understanding, use the term.

This is an important book for evolutionary psychologists, and especially for born-again evolutionary psychologists. By "born-again" I mean individuals who have come to evolutionary thinking somewhat late in their academic life, with a background in social psychology or in Skinnerian behaviorism. Having been raised in a setting where sole emphasis was on the organizing and instructive effects of the environment on the organism, this group, after floundering about for decades without notable progress, literally had an epiphany when encountering evolutionary

psychology. They were bowled over by the apparent simplicity and power of this (to them) new approach. However, they came to this new way of looking at things without a solid foundation in either evolutionary thinking or understanding of the genetics and functional aspects of the biological substrate thought to underlie behavior. This created a situation in which a near-fundamentalist fervor was paired with large gaps in the knowledge that is necessary to fully appreciate “how things might work”. Marcus’ book helps link gene action to behavior, and may be considered a *sine qua non* for serious evolutionary psychology.

One of the reasons why Marcus’ book is so valuable, not only for the layperson but also someone immersed in the field, lies in its unusual amount of reference documentation. Fully 1/3 of the book is taken up by references, glossaries and an appendix, all of which deepen the reader’s involvement and understanding. Although many of the references are familiar to me (such as my favorite didactic vehicle for explaining gene/behavior relations to students, the *Aplysia* egg-laying hormone story), many others were not, and I owe much to Marcus’ breadth of reading, which has enriched my understanding of gene action.

This review will not cover the book chapter and verse, but will focus on its most salient aspects. This, I hope, will give the reader a sufficient impression of those delights that the book holds for the evolutionary psychologist. Marcus begins his exploration, appropriately, with the nature/nurture question, and by posing his two paradoxes: 1) how can a small number of genes guide the development of brains that contain tens of billions of neurons and which are characterized by a rather invariant general architecture across our species and 2) how can the brain be as flexible as it is, given this invariant architecture?

In addressing these paradoxes, Marcus places great emphasis on the interaction between nature (genes) and nurture (environment), because he is convinced that the interaction holds the key to the reconciliation between the two paradoxes. Indeed, the interaction between processes guided by genetic instructions and their modification via feedback from the environment can be considered the dominant theme of the book. Throughout, Marcus describes interactions at all levels and in different contexts. For instance, when the mRNA leaves the nucleus, its effects are for naught if the proper mix of amino acids - among other things - is not available in the soma of the cell. Marcus points out, more topically, that the dream of reconstructing dinosaurs from dinosaur DNA, *à la* Jurassic Park, is likely to remain a dream because the DNA will not find in its immediate environment (that is, the “modern” cell into which it is implanted) the appropriate biochemical substrate that can interact with the signals generated by the dinosaur DNA. In the chapter “wiring the mind”, the developmental aspects of interaction between neurons of the unfolding brain and their immediate environment are described, with many current and beautiful examples. Here, the interaction takes the form of, if-then prepositions, e.g., “if this protein or factor is encountered, the growing cell will differentiate in that direction, or move its processes in that direction, or come to rest in this layer”. Of course, interactions extend beyond that level. Throughout, Marcus stresses that the

brain and the genome that underlies brain function is responsive to the external environment. In the earlier chapters, in which differentiation of the unfolding nervous system is discussed, there are examples of how in the development of the sensory machinery of brain, external influences interact with the unfolding neural substrate. That substrate unfolds on its own, to a point, but in order to end up with a useful working brain, it is informed and modified by external inputs.

Ultimately, even the social environment has a direct impact, not only in the development of the brain but in the continued life span functioning of the brain. As Marcus puts it “genes aren’t just for kids, they are for life” (p. 169). By this, he means that environmental inputs feed back signals to the DNA which, in turn, produces proteins that modify the response to the environmental inputs; this happens throughout the life span, as distinct from the earlier DNA/surround interactions that take place in shaping the brain. A specific example is learning at the cellular level, in which environmental input activates stretches of neuronal DNA which in turn produce changes, via structural proteins, in the receptor membrane that modify the neuron’s responsivity to further input. Another example concerns changes in daylight duration that gain access to DNA which responds by sending out proteins or polypeptides that initiate, in many species, a cascade of changes that affect hormone levels and reproductive behaviors.

To return to the first paradox - how a small number of genes can direct the development of an entire large brain - Marcus provides an extensive answer in “Paradox resolved”. Illustrating these elements with numerous examples, Marcus summarizes several points that capture the way in which small numbers of genes can give rise to complexity:

- Genes do not provide blueprints of structure but, rather, a guide to process.
- Genes work in combination. In the conventional view, 100 genes code for 100 proteins, but if one considers that each gene codes for two sets of 50 proteins, their effects may lead to 50 x 50 combinations of proteins. Clearly, the possible number of permutations is gigantic.
- The same set of instructions can be used everywhere in the body; Marcus uses the analogy of compression schemes in computer languages that specify simple procedures. The analogy suggests that genetic instructions for certain recurrent schemes do not have to be reinvented, depending on where in the body they occur, but can be expressed flexibly anywhere where they are needed.
- The same genetic instruction can be used recurrently so that, for example, each of the legs of a centipede does not have to be constructed with different DNA specifications, but shares common code with the other legs. (p. 157).

In the context of the “Evolution of mental genes”, Marcus addresses many important evolutionary aspects of gene action. Just a couple are mentioned here. For

instance, he provides a number of suggestions of how new gene functions arise through simple mechanisms such as gene duplication. Thus, different mutations in the gene that duplicates the code for photoreceptors could lead to specialization for different wavelengths. In the context of evolution, Marcus also addresses the issue of matching genes between species and the somewhat surprising realization that so much of, let us say, chimpanzee DNA lines up with human DNA. Here, the huge percentage of matching DNA code is deceptive because the difference most likely lies in regulatory genes that can bring about very large differences in spite of constituting a small amount of DNA.

Are there any quibbles? Only minor ones, concerning differences in emphasis rather than fact. Marcus tends to focus on proteins coded by DNA stretches and allows for more than one protein per gene. But it is also useful to emphasize that precursors for particular proteins can be chopped into numerous polypeptides, many of them very small, just a few amino acids long. As a common example, the pro-opio-melano-cortin stretch coded by DNA serves as a precursor that contains the instructions for the production of longer and even very short polypeptides (such as enkephalins) that can have physiological effects by themselves or as part of larger functional portions of the code. These polypeptides can be separated out by restriction enzymes. Minor changes in nucleotide base sequences in the code for the formation of the polypeptides can produce polymorphisms (RFLPs = Restriction Fragment Length Polymorphisms) that are themselves subject to selective pressures. It seems to me that Marcus, although making brief mention of the general principle (p. 81), does not sufficiently exploit this important contribution to the plethora of ways in which a gene can contribute to great complexity.

While reading the book it occurred to me that a group of individuals who might benefit from reading Marcus' book are the proponents of Intelligent Design. Their creationist credo holds that complex forms must have been created *de novo* because they could not have arisen by chance. Such an argument could perhaps have been more easily maintained with the "one gene/one enzyme" scenario. However, any objective reading of the material provided by Marcus makes it very difficult, and perhaps intellectually dishonest, to persist in the suggestion that chance and selection cannot produce immense complexity in biological systems.

In summary, a most satisfying book. Marcus represents important ideas in a fluid and entertaining style, without compromising scientific content. There is an impressive breadth in his synthesis, as noted also by other reviewers, and he meets the ultimate goal of writers of books that span the bridge from the popular to the specific: that the book can be read at different levels by readers with different levels of background information. Although evolutionary psychologists can get the bits and pieces of what Marcus offers spread across texts and journal articles, I am not aware of any other work that informs so elegantly, comprehensively and clearly about current work in the basics of gene/behavior interactions. A major feat of intelligent synthesis!