PHILOSOPHY OF MIND

Who Watches the Watcher?

Christoph C. Adami

Douglas Hofstadter has made a career of thinking about thinking, and he is rightfully famous for writing the Pulitzer-winning *Gödel, Escher, Bach: An Eternal Golden Braid* (*1*) at the tender age of 27. That book was a roller-coaster ride that defied classification then as today, but much to the author's chagrin the central message that he tried to convey, concerning the nature of human consciousness, seemed to have been lost among the fireworks. It is this shortcoming that Hofstadter (a professor of cognitive science at Indiana University) seeks to correct in the playful and intensely personal *I Am a Strange Loop*, in which he explains human consciousness while exploring (and coming to grips with) his own.

I Am a Strange Loop
by Douglas Hofstadter
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The nature of human consciousness has been debated through the centuries, at least since Descartes posited that a special substance, the *res cogitans*, conferred upon humans (and only humans) the ability to think and feel; have ideas, wishes, and concerns; display empathy, dislikes, or wonder. This dualist view of the world—dual because it presupposes the existence of two radically different substances, one to make the mind, and another to make everything else in the world—still, in one form or another, informs the thinking of a surprising (to me) number of philosophers of the mind. Hofstadter is not one of those. His approach is decidedly materialistic, that is, he seeks an explanation of the phenomenon of consciousness using physical law only. However, he is not interested in a neurobiological explanation (even though he is fully convinced that consciousness must be explainable within neurobiology) because he believes that as our consciousness is perceived at the level of symbols and thoughts, our explanation of it should occur at this level of description also.

Hofstadter's explanation of human consciousness is disarmingly simple. Even though he spends most of the book giving examples and analogies from realms as disparate as particle physics and boxes of envelopes, the main idea is simply that our feeling of a conscious "I" is but an illusion created by our neuronal circuitry: an illusion that is only apparent at the level of symbols and thoughts, in much the same way as the concepts of pressure and temperature are only apparent at the level of 10^{23} molecules but not the level of single molecules. In other words, Hofstadter denies consciousness an element of ontological reality, without denying that our thoughts and feelings, pains and longings have an "inner reality" when we have them. But to show that consciousness is a collective phenomenon of sorts, he needs to delve deep into the theory of computation and, in particular, Austrian mathematician Kurt Gödel's proof of his incompleteness theorem, as these concepts are key to the idea the author wants to convey. And he does this admirably in a mostly playful manner, choosing carefully constructed analogies more often than mathematical descriptions.

Gödel showed in 1931 that any formal system that is complicated enough must contain statements that are patently true but remain unprovable within that formal system. The important point here is that the true statements Gödel explicitly constructed play a dual role: they can be understood at a higher—that is, symbolic—level, while representing purely number-theoretic assertions at the same time. To achieve this, Gödel constructed a mapping between conceptual statements (such as "This statement is not provable within the formal system XYZ") and purely number-theoretic identities that effectively creates a barrier between levels of description that is as impenetrable as the barrier between our thoughts and the patterns of neuronal firings. In the same manner, Hofstadter suggests, our ability to construct symbols and statements that are about these symbols and statements creates the "strange" reflexive loop of the book's title out of which our sensation of "I" emerges.

Bathsheba Grossman's sculpture *MG*. A self-intersecting, figure-eight knot.

This ambitious program aimed at a deconstruction of our consciousness is not without peril. For example, if we posit that our consciousness is an illusion created by our thoughts "watching ourselves think" [as the philosopher of mind Daniel Dennett had previously suggested (*2*)], we might ask "Who watches the watcher?" Or, if I am hallucinating an "I," who is hallucinating it? However, an infinite regress is avoided because on the level of the neuronal circuitry, the impression of having a mind is just another pattern of firings—something consciousness researcher and neuroscientist Christof Koch of the California Institute of Technology calls "the neuronal correlate" of consciousness.

In fact, Hofstadter's book and Koch's recent *The Quest for Consciousness* (*3*) make for an interesting juxtaposition. Each addresses the same problem but entirely on different levels. Yet both authors reach some of the same conclusions, sometimes using precisely the same metaphor (as when they compare the activity of "making up one's mind" in terms of a voting process). In the end, both authors could have profited from peeking at each other's arsenal: Hofstadter would probably be delighted to see some of the putative neural underpinnings of consciousness, to peer underneath the strange loop as it were, at the inordinately complex firework and the neuroanatomy that supports it. For his part, Koch would no doubt appreciate the computational trick that Gödel incompleteness plays on us, as well as the developmental aspect of consciousness that Hofstadter advocates.

I believe that Hofstadter's views on consciousness will play an important part, on at least two levels, as we go forward in exploring our mind. First, Hofstadter implicitly provides a blueprint for how one should go about constructing a conscious machine, because no less is implied by these ideas. When constructed, we should not expect that such a machine would be conscious from the get-go: after all, Hofstadter's "I" is an outcome, not a starting point. We should give such a machine a good decade or so to form its own personality, as we ourselves are afforded that much. Second, the Gödelian construction suggests a tantalizing hypothesis, namely that a level of consciousness could exist far beyond human consciousness, on a level once removed from our level of symbols and ideas (which themselves are once removed from the level of neuronal firing patterns). Indeed, Gödel's construction guarantees that, while statements on the higher level can be patently

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true but not provable on the lower level, an extension exists that makes the system complete on that higher level. However, new unprovable statements emerge on the next higher level—that is, on a level that maps an improbable jumble of our thoughts and ideas to, well, something utterly incomprehensible to us, who are stuck at our pedestrian echelon. How incomprehensible? At least as inscrutable as the love for Bartok's second violin concerto is to a single neuron firing away.

References

1. D. R. Hofstadter, *Gödel, Escher, Bach: An Eternal Golden Braid* (Basic, New York, 1979).
2. D. C. Dennett, *Consciousness Explained* (Little, Brown, Boston, 1991).
3. C. Koch, *The Quest for Consciousness: A Neurobiological Approach* (Roberts, Englewood, CO, 2004); reviewed by P. Haggard, *Science* **304**, 52 (2004).

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GENETICS

More Means of Regulating Genes

Armelle Corpet and Geneviève Almouzni

What is "epigenetics"? Surprisingly, searching in a dictionary won't tell you much about the word because there is a good chance that you won't find it. Yet the popularity of its use in recent years illustrates the flourishing rebirth of a research area that originated in the 1930s. It is perhaps not so surprising that in our postgenome era people's interest is drawn to phenomena that cannot be explained by classical genetics. Famous examples include paramutation in maize, position effect variegation in the fruit fly *Drosophila*, X chromosome inactivation in mammals, and genomic imprinting. Today, efforts to understand the mechanisms underlying these fascinating phenomena have coalesced into a field of their own, epigenetics.

The expanding interest in this broad field is reflected in the range of topics covered in the volume *Epigenetics*. The editors—David Allis (Rockefeller University), Thomas Jenuwein (Research Institute of Molecular Pathology, Vienna), and Danny Reinberg (University of Medicine and Dentistry of New Jersey)—recognized that, with the pace of epigenetics research, a compilation of expert reviews would probably soon become outdated. So they instead recruited 44 authors, experts in the field, to produce 24 conceptual chapters that highlight a wide variety of aspects of epigenetic gene regulation. Collectively, the chapters provide a reference foundation for both curious newcomers and researchers in the field as well as an effective tool for teachers. The editors, aided by the efforts of Marie-Laure Caparros, have put together a quite coherent volume, one strengthened by the numerous (and relatively consistently styled) illuminating diagrams and figures.

To start off, Gary Felsenfeld offers a brief historical sketch. He reminds us that the word "epigenetics" has its conceptual roots in the theory of epigenesis, which holds that complexity emerges progressively during development. (That view was opposed by the theory of preformation, which held that individuals develop by the enlargement of minute, fully formed organisms, the homunculus; the distinction can be traced back to Aristotle.) Conrad Waddington, in the early 1940s, coined the term epigenetics to describe "the interactions of genes with their environment, which bring the phenotype into being" (*1*)—a fairly broad definition. In its etymological sense, epigenetics refers to additional methods of biological inheritance (the prefix epi- means above or over in Greek) that do not relate to the inheritance of DNA and its mutations.

Epigenetics

C. David Allis, Thomas Jenuwein, and Danny Reinberg, Eds.

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Daniel Gottschling notes that at the 69th Cold Spring Harbor Symposium on Quantitative Biology (2004)—attended by many of the volume's authors—"epigenetics" seemed to have a different meaning for each person. He attributes part of this variation to the dual distinct origins of the word recognized by David Haig (*2*): Waddington's causal interactions and David Nanney's application of the term to the control systems that allowed cells of the same genotype to have different phenotypes (*3*). Gottschling favors a definition [from Robin Holliday (*4*)] that was a major trigger for the explosion in the use of the word during the 1990s: an epigenetic phenomenon is "a change in phenotype that is heritable but does not involve DNA mutation." Gottschling refines this definition by requiring that the change be switchlike (on-off) rather than gradual and that epigenetic inheritance should occur "even if the initial conditions that caused the switch disappear." These concepts encompass most of the important aspects of current views concerning the definition of epigenetics. But the volume's introductory chapters do not adequately recognize the reversible character of epigenetics, which is demonstrated by the capacity to reprogram somatic nuclei. (That topic is, however, addressed in the chapters by Azim Surani and Wolf Reik and by Rudolf Jaenisch and John Gurdon.)

In their own chapter, "Overview and Concepts," the editors offer a modern molecular definition of epigenetics as the "sum of the alterations to the chromatin template that collectively establish and propagate different patterns of gene expression (transcription) and silencing from the same genome." This definition reflects the excitement for chromatin-based mechanisms—a driving force for research on histone modifications and variants, RNA, and nonhistone chromatin proteins. But it leaves aside potential non–chromatin-based epigenetic phenomena such as prions, and it only briefly touches on the aspect of higher-order structures at the level of nuclear organization and gene expression. For these reasons, readers should bear in mind alternative perspectives.

The authors also aim to convey how the study of various model organisms has proven crucial for current epigenetic research. Some of the organisms and their respective phenomena include the budding yeast *Saccharomyces cerevisiae* (mating-type switching), the fruit fly *Drosophila* (position effect variegation, for example), fungi such as *Neurospora crassa* and *Schizosaccharomyces pombe* (e.g., centromeric heterochromatin and the role of small interfering RNAs), ciliates, plants, the nematode *Caenorhabditis elegans*, and mammals (e.g., genomic imprinting). As French readers, we were struck by the fact that frogs did not appear among these models. *Xenopus laevis*, used for the first cloning experiments, is however mentioned in a chapter discussing the mechanisms of nuclear reprogramming of the genome. It is worth remembering that this exotic organism provided useful tools and assays for epigenetics, including pioneering work on chromatin assembly. Of course, still other model systems (such as the callipyge sheep or the planarian *Schmidtea mediterranea*) could have been mentioned had the authors chosen to discuss different intriguing phenomena.

The contributors discuss the substantial progress achieved through studies of covalent and noncovalent modifications of DNA and histone proteins as well as how combinations of these modifications potentially affect chromatin dynamics and epigenetic

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