This article originally appeared in:

Dennett, Daniel. 1995. Hofstadter's Quest: A Tale of Cognitive Pursuit. *Complexity* 1(6): 9-12.

It is not available electronically from the publisher.

This is Daniel C. Dennett's final draft before publication. It has been modified to reflect the pagination of the published work.

Vol. 1, No.6, 1995/6
COMPLEXITY

Hofstadter's Quest

A tale of cognitive pursuit

BY DANIEL C. DENNETT

Daniel C. Dennett is Director of the Center for Cognitive Studies at Tufts University. Among his books are Consciousness Explained (1991), Darwin's Dangerous Idea (1995), and Kinds of Minds (1996). In 1981, he co-authored The Mind's I with Doug Hofstadter.

What Douglas Hofstadter is, quite simply, is a phenomenologist, a practicing phenomenologist, and he does it better than anyone else. Ever. For years he has been studying the processes of his own consciousness, relentlessly, unflinchingly, imaginatively, but undeludely. He is not a Phenomenologist with a capital "P"-with few exceptions, Phenomenologists don't actually do phenomenology, they just write about doing it.

In stark contrast to the Husserlian school(s) of Phenomenology, which advocates the epoche or "bracketing" that excuses the investigator from all inquiry, speculative or otherwise, into the underlying mechanisms, the Hofstadterian school of phenomenology stresses the need to ask-and answer-the question about how it works. Hofstadter's initial phenomenological observations are laced with questions and suggestions about dynamics and mechanisms; he watches his own mind work the way a stage magician watches another stage magician's show, not in slack-jawed awe at the "magic" of it all, but full of intense and informed curiosity about how on earth the effects might be achieved.

In 1979, Douglas Hofstadter published Godel EscherBach:An Eternal Golden Braid, a brilliant exploration of fascinating ideas at the heart of cognitive science: recursion, computation, reduction, holism, meaning, "jootsing" (Jumping Out Of The System), "strange loops," and much, much more. What made the book's expositions so effective were a family of elaborate (and lovingly elaborated) analogies: the mind is like an anthill, a formal system is like a game, theorem and nontheorem are like figure and ground, and Bach's Inventions are like dialogues, to mention a few. The whole analogy-package was wrapped in layers of self-conscious reflection. "Anything you can do I can do meta-" was one of Doug's mottoes, and of course he applied it, recursively, to everything he did.

Then in 1985 came Metamagical Themas: Questing for the Essence of Mind and Pattern, its title drawn from the title of his monthly column in Scientific American,\ which was of course an anagram of its predecessor, Martin Gardner's "Mathematical Games." More word-play, more games, more analogies, more recursion, more self-conscious reflection-all brilliant, but many began to wonder: what, actually, was Hofstadter doing? Was there a serious research project here, or just fun and games and self-absorption? His fans were fascinated, but even some of his colleagues and graduate students-even his friend and co-author (of The Mind's I: myself)-began to worry a bit about his lengthy odysseys into toy worlds (ambigrams, bizarre fonts, curious doodles on long rolls of paper).

This man wanted to be taken seriously, but where was the focused, rigorous investigation of some phenomena, where was the discipline? It was right in front of our noses-

and his. We should have trusted him. He knew what he was doing, and in his new book, Fluid Concepts and Creative Analogies: Computer Models of the Fundamental Mechanisms of Thought, he explains and justifies all those curious practices; and shows that while many of the rest of us were rushing off half-cocked on various quests for one cognitive science grail or another, he was patiently, systematically, brilliantly building up an understanding of a foundational area of cognitive science, doing a job that only he could do. And in the end, he and his team tested their hunches by building working models that can simulate the particular conscious processes they have been studying (and their semiconscious, subconscious, unconscious penumbra). Can they get realistic performances? If not, back to the drawing-board.

Fluid Concepts and Creative Analogies is an anthology of the work of Hofstadter and his graduate students at FARG, the Fluid Analogies Research Group, which he formed first in Ann Arbor in 1984, and then moved to its current home at Indiana University. His fellow "Fargonauts" are given the role of co-authors, both on the title page, and in the individual chapters, but these are his versions, by and large, of their joint projects. It is entirely appropriate for him to produce a volume of his own versions, since it is his idiosyncratic vision of how to do cognitive science that is in need of a full-scale overview and demonstration, which is what this book provides. (His co-authors are very good at grinding their own axes-see their articles listed in Hofstadter's bibliography, and their books: Melanie Mitchell, Analogy-Making as Perception, MIT Press, 1993, and Robert French, The Subtlety of Sameness, MIT Press, 1995).

Scattered through the book are stunning autobiographical revelations that shed light on his imperviousness to the impatience and doubt that was inconcealable-indeed often vigorously expressed-by his friends and associates. At the outset of one "reenactment of a discovery," he tells us:

> I am going to be very faithful to my actual discovery process, not to some idealization thereof. This means that what I will show may seem quite awkward and stupid in spots; but that is the way discoveries are often made. After a discovery has been completed and its ideas well-digested, one quite understandably wishes to go back and clean it up, so that it appears elegant and pristine. This is a healthy desire, and doing so certainly makes the new ideas much easier and prettier to present to others. On the other hand, doing so also tends to make one forget, especially as the years pass, how many awkward notations one actually used, and how many futile pathways one tried out.

"Luckily," he goes on to inform us, "having always been fascinated by how the mind works, I have tended to keep careful records of my discovery processes-even back at age sixteen, which is when this particular exploration and discovery took place." Later in the book, he tells of his alphabetic font obsession:

> What ensued was a lengthy period of time during which I designed hundreds of new alphabetic styles, relentlessly exploring all sorts of combinations of gracefulness, funkiness, sassiness, sauciness, silliness, softness, pointiness, hollowness, curviness, jaggedness, roundness, smoothness, complexity, austerity, irregularity, angularity, symmetry, asymmetry, minimality, redundancy, ornamentation, and countless other indefinable parameters....I am sure that to somebody who hadn't thought much about alphabets and visual styles and the idea of pushing concepts to their very limits or just beyond, many of my experiments would have looked mysterious and pointless, perhaps even gawky and stupid. But that wouldn't have deterred me, because I had a stable inner compass that was carrying me somewhere, though I couldn't have said exactly where or why. As the years [!] went by...

So far so good: by keeping a lifetime of notes, and daring to share them with us, he provides himself, and us, with a wealth of data. But data are only as good as the observer and the phenomena observed warrant Other phenomenologists and, indeed, cognitive scientists have scrupulously gathered data on various trains of thought. K A. Ericsson and H. A. Simon's Protocol Analysis: Verbal Reports as Data (MIT Press, 1984) comes to mind as a particularly systematic and reflective effort along these lines. But the phenomena they study, like those studied by almost all cognitive scientists and psychologists, are a cramped subset of human thought processes: solving well-defined problems with clear (if hard to find) paths to the correct solution. Hofstadter has always been interested in the more free-wheeling, creative, artistic, unpredictable sort of thinking, but as a good scientist he has appreciated that one must simplify one's domain, limiting and controlling it in as many dimensions as possible, so that only a few sources of variation are salient, and hence investigatable, at a time.

Every science needs its toy problems; population genetics has its fruit-flies, neuroanatomy has its giant squid axons, developmental biology has its nematode worm, C. elegans, GOFAI had its blocks world, Tower of Hanoi puzzle, chess, cryptarithmetic problems, connectionism has its NETTalk domain of uncomprehending pronunciation, and so forth. Hofstadter and his students have been remarkably successful at creating well-behaved toy domains for exploring the shifty, subtle, quirky processes of analogy-making and metaphor appreciation: the anagrams and words of Jumbo, the alphabet-world of Copycat, the concrete and mundane but conventional and limited furnishings of Tabletop, to name a few of the best. This success has been a hard-won evolution, not the result of a saltation of perfect inspiration. The Seek-Whence domain begat the Jumbo domain and the Copycat domain which begat the Tabletop domain, and so forth.

One of the simplest demonstrations of the power of Hofstadter's approach to analogy-finding is to compare his toy problems to the limited domains others have devised to demonstrate their models. Every practical model must oversimplify ruthlessly, but it is quite possible to leave out all the important phenomena and be left with a nearly trivial model. Which simplifications offer the most insight? In his latest work, Hofstadter contrasts the bounty of variegated and even surprising behavior his models can generate with the single-stunt-in-different-costumes behavior of rival models, which from other perspectives may appear more powerful. Hofstadter has numerous important reflections to offer on "the knotty problem of evaluating research," and one of the book's virtues is to draw clearly for us "the vastness of the gulf that can separate different research projects that on the surface seem to belong to the same field. Those people who are interested in results will begin with a standard technology, not even questioning it at all, and then build a big system that solves many complex problems and impresses a lot of people." He has taken a different path, and has often had difficulties convincing the grown-ups that it is a good one: "When there's a little kid trying somersaults out for the first time next to a flashy gymnast doing flawless flips on a balance beam, who's going to pay any attention to the kid?" A fair complaint, but part of the problem, now redressed by this book, was that the little kid didn't try to explain (in an efficient format accessible to impatient grown-ups) why his somersaults were so special.

So just what have Hofstadter and the Fargonauts discovered? Hofstadter lists eight themes that have been explored and reexplored in the succession of models, and I cannot improve on his list:

1) perception and high-level cognition are inseparable;
2) high-level perception consists of easily reconfigurable multilevel cognitive representations;
3) there are "subcognitive pressures" that probabilistically influence the building and reforming of these representations;
4) many such pressures commingle, "leading to a nondeterministic parallel architecture in which bottom-up and top-down processing coexist gracefully."
5) there is a "simultaneous feeling-out of many potential pathways"
6) making analogies is a central component in high-level cognition.
7) cognitive representations have "deeper and shallower aspects, with the former remaining relatively immune to contextual pressures, and the latter being more likely to yield under pressure (to 'slip');"
8) a crucial role is played by "the inner structure of concepts and conceptual neighborhoods"

Each of these themes rings a bell, and sometimes a familiar bell, already rung many times by others, but what is exciting about FARG is that they have managed to create models that exhibit all these themes at once, and that actually work. I cannot recall any comparable instance in which so many attractive but all too impressionistic ideas have actually been implemented. One of the most impressive features of their architectural ideas is the fact that they provide a more fundamental (and much more biologically plausible) platform from which one can implement the more rigid architectural ideas of their predecessors in AI. The parallel terraced scan, for instance, has the nice feature that it can be tuned continuously in several dimensions between rigid and lax. You can screw the system up and get obsessively rigid problem-solving, with stacks and stack-pointers, or relax the parameters and get quite "chaotic" wanderings. You can get temporary structures reminiscent of Schank scripts and Minsky frames to emerge from the interactions between top-down and bottom-up pressures that are variable in the architecture. This is fine, since it was always clear that Schank and Minsky were on to some important ideas, even if the attempts at implementation (and Minsky knew better than to try back then) were implausibly straitjacketed.

There are prices to be paid, of course, for such success. As with all other AI models of toy phenomena, there is the question of whether they will scale up without combinatorial explosion, and the interfaces that would be needed to incorporate these models into whole cognitive systems, whole agents, are currently unimagined. Hofstadter addresses these issues and other criticisms forthrightly, and offers particularly valuable projections of where the Fargonauts and those they inspire should turn next.

The models occupy a limbo that is biologically flavored but still quite remote from neuroanatomy; no neuroscientist is going to find any easy clues here about how to discover the analogy-making process in the activities of neural networks. There are dynamically connected nodes and spreading activation from node to node, but these are not neurons or simple assemblies thereof. There are broadcast effects that damp or enhance various activities in parallel, but these are not plausibly the discovered roles of neuromodulators diffusing through the interstices of networks. There are functionally defined places where different sorts of things happen, but these are not tied to anatomical locations by any data or even speculations.

The models are thus both mechanical and abstract at the same time. By being mechanical, they amount to a "proof of concept" of sorts: yes, it is possible, by some such mechanism, to get very warm, juicy phenomenology to emerge from the joint activities of lots of very clockworky parts. Good news. We always knew in our hearts it was possible, but it is very reassuring to have models that actually deliver such goods. We can even look at the details of the model for very indirect hints about how the phenomena might occur in a whole live brain. Compared to the GOFAI models of yore, Hofstadter's models are much more than halfway to the brain, but there is still a chasm between them and computational neuroscience.

Hofstadter provides useful comparisons along the way with many other projects in the history of AI, from GPS to ACT* and Soar, from Hearsay II and BACON to such current enterprises as Gentner and Forbus's Structure Mapping Engine, and Holyoak and Thagard's ACME. He is devastating with his criticisms, but also generous in his praise-for instance, in his homage to Walter Reitman's Argus. What emerges from these comparisons is a tempting but tentative conclusion: Hofstadter may or may not have nailed it, but he has come much closer than any other enterprise in AI to finding the right level at which to conduct further inquiry.

Alan Turing got the idea for the stored-program computer from his own systematic introspection into his mental states when dutifully executing an algorithm, the sort of mental activity that is farthest removed from artistic, creative thought. He saw that the restriction to rigid problem-solving was an inessential feature of the fundamental architecture, and predicted, correctly, the field of AI. We've been loosening the straps, widening the von Neumann bottleneck, ever since. Doug Hofstadter has pioneered the systematic introspection of the other end of the spectrum of mental activities, in a way that could not be done by anyone who lacked his deep understanding of the computational possibilities inherent in Turing's fabulous machine. It is not just that while others have concentrated on problem solving and Scientific Thinking, he has concentrated on daydreaming and Artistic Thinking. He has recognized that even Scientific Thinking is, at its base, analogical. All cognition is analogical. That is where we all must start, with the kid stuff.

