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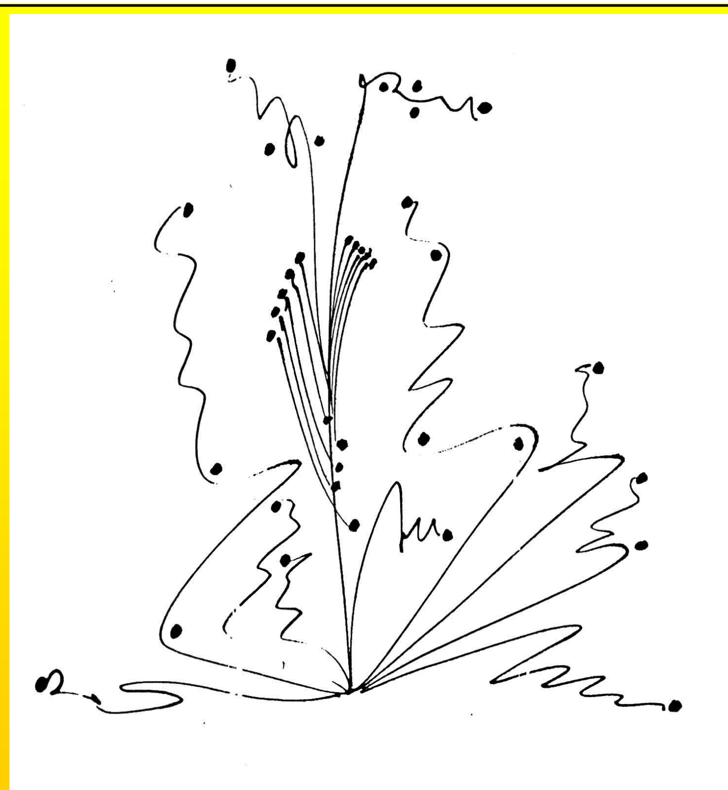
See you in Austin!



Jazz Scribble by Douglas Hofstadter
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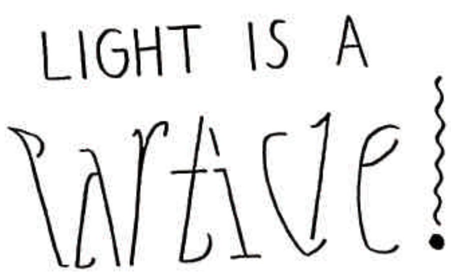
An Eternal Golden Braid:
A Conversation with Douglas Hofstadter

Sonya Bahar

In 1980, recalls Douglas Hofstadter in the preface to the 20th-anniversary Edition of his classic work *Gödel, Escher, Bach: an Eternal Golden Braid*, “when GEB [*Gödel, Escher, Bach*] found itself for a while on the bestseller list of the *New York Times*, the obligatory one-sentence summary printed underneath the title said… ‘A scientist argues that reality is a system of interconnected braids.’ After I protested vehemently about this utter hogwash, they finally substituted something a little better, just barely accurate enough to keep me from howling again.”

In fact, Hofstadter’s best-known book, like his other works and his rich creative life spent in both the arts and the sciences, is far too complex and varied to be encompassed by any simplistic little catch phrase. In the author’s words, *Gödel, Escher, Bach* “is a very personal attempt to say how it is that animate beings can come out of inanimate matter…What is an ‘I’, and why are such things found (at least so far) only in association with certain kinds of gooey lumps encased in hard protective shells mounted atop mobile pedestals that roam the world on pairs of slightly fuzzy, jointed stilts?” His answer is what he describes as “strange loops”: abstract self-referential structures similar to those Kurt Gödel proved to be inextricably folded into the very heart of mathematics, and also akin to the "loopy" processes that give rise to self-replicating molecules, a familiar theme to biophysicists.



Particle/Wave Oscillation. Ambigram by Douglas Hofstadter.

The key to the unraveling of consciousness, Hofstadter writes, “is not the stuff out of which brains are made, but the patterns that can come to exist inside the stuff of a brain.” In this view, form and content circle one another incessantly; indeed, it may be form that gives birth to content. Brains are media supporting patterns that mirror or represent the world. But as parts of the mirrored world, brains themselves are subject at last to an inevitable self-mirroring, and it is here, Hofstadter writes, “that the strange loops of consciousness start to swirl.”

Hofstadter’s interdisciplinary masterpiece, *Gödel, Escher, Bach*, and his subsequent works in the visual arts, in literary translation, and in cognitive science, form a rich golden braid. This intertwining of varied interests, that balance and reinforce each other, may resonate with many interdisciplinary scientists and scholars who feel a dual passion both to understand the world and to express their reactions to it.

Douglas Hofstadter was attracted in his childhood by the beauty of mathematics and physics. He was particularly inspired by the interaction of form and content, a fundamental theme that runs through his adult work. His interest in the arts and in languages also developed early, when he spent a year in Geneva, where his father was on sabbatical. This interest in language led, in turn, to a fascination with the workings of the mind. In high school he was deeply inspired by Ernest Nagel and James R. Newman’s book *Gödel’s Proof*, and began to wonder about the possibility of computers carrying out the same abstract processes as does a human brain, and hence potentially becoming conscious and having their own selves. At 15, a friend taught him to program in Algol, a language he describes as “mathematically elegant”. It was one of the first computer languages to allow the possibility of recursive algorithms, and Hofstadter began to write programs of his own, for several years exploring intricate patterns in the world of numbers, and then branching out to make programs that randomly created syntactically and semantically complex sentences in various languages he had studied, including English, Italian, and Hindi. This led him to ponder further the mysterious connection between algorithms and human thought processes.

As an undergraduate at Stanford, Hofstadter studied number theory, logic, and recursion. It seemed the natural next step to enter graduate school in mathematics, but at the University of California at Berkeley, he began to find mathematics “too abstract, too confining, too arid, and too difficult.” He felt disappointed in his own mind, he recounts. He had always coasted through mathematics before, but now felt himself hitting a wall, like a marathon runner at the eighteen-mile mark.

Frustrated by the internal mental barriers he had run into in his mathematical studies at Berkeley, Hofstadter intensified his involvement with languages, music, and the visual arts, combining all these long-term interests in the creation of abstract “musical shapes” – visual fugues and canons at first, and then all sorts of non-contrapuntal forms – which he improvised in felt-tip pen on scrolls of paper, up to 20 feet long. The curvilinear forms that covered these scrolls were initially inspired by the exquisitely beautiful writing systems of languages from India, but gradually they took on a life of their own. "Are these idiosyncratic visual creations of mine just side projects, or are they central to my life's aims?", he wondered.

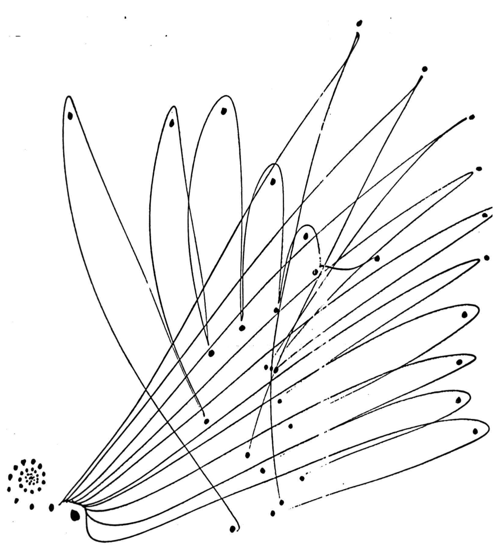
Between the ages of 8 and 16, Hofstadter had sporadically studied piano, playing classical, jazz and popular songs. And as a listener, he had explored classical music in great depth, indulging in what he describes as a “passionate binge of record buying”, which started at age 16 and continued to this day. At 21, he took up the piano again “with an enormous fervor”. He was not aiming at the concert stage, but at building up the technique necessary for musical self-expression, which was a profound internal longing that drove him for many years. In the late 1960's and early 1970's, he composed some 40 pieces for solo piano, and speculated about a professional career in composition. But this would have entailed abandoning mathematics, which he still loved. “To leave mathematics completely,” he says, “would have been to betray too large a core element in myself.”

A. Einstein/ Constant C. Ambigram by Douglas Hofstadter.(Look at it upside-down!)

After much painful soul-searching, Hofstadter decided to switch from math to physics, also moving from Berkeley to the University of Oregon at Eugene. He says he found physics in some ways more difficult than mathematics, its concepts stranger. He initially was interested only in elementary particle theory, driven by a yearning to understand the most fundamental elements of reality’s fabric. But once again, he was bitterly disappointed. Elementary particle theory no longer glowed with the pristine beauty of the work of the thinkers he admired, such as Dirac, Born, Schrödinger and Heisenberg. It had grown unwieldy, even ugly, he felt. The endless speculations that filled the field struck him as absurd. The last straw was an article he was required to read and present to his colleagues, in which feeble group-theoretical arguments were used to posit 132 new particles in one fell swoop in order to explain some tiny and obscure phenomenon. “It was unimaginably ugly”, he says. “I couldn’t understand how anyone could call particle physics beautiful those days. To me it was grotesque, incomprehensible, and hateful.” He went through several advisors, and found himself, after 5 or 6 years of graduate study in math and physics, in a crisis. “I couldn’t do anything”, he recalls, “*because I didn’t believe in it*.” Discouraged and confused, he dropped out of graduate school for a time, doing work on behalf of a social cause which he did deeply believe in: the United Farm Workers.

During the difficult months of the spring of 1972, however, a chance moment of browsing in the University of Oregon bookstore reawakened Hofstadter's fascination with logic, and with Gödel's proof. On the bookshelf he found a copy of Howard DeLong's extraordinary book *A Profile of Mathematical Logic.* He began to wonder again about how thinking was or wasn't governed by patterns related to the subtle mathematical laws of symbolic logic. "Within weeks," he recalls, "all my love for the Gödelian mysteries and all that they touch on was reawakened. Ideas started churning around like mad...." He felt set on fire again. "Algorithms, brains, minds, rules, patterns, recursion, and self-reference – these incredible themes were once again swirling madly about in my head, after having been banished when I dropped out of math at Berkeley several years earlier."

Despite this new excitement, he was troubled and confused about what to do with regard to his still-uncompleted graduate studies in physics. In July 1972, he packed up and headed "vaguely east" in his 1956 Mercury. Engine trouble in Moscow, Idaho left him with time to kill on the University of Idaho's campus. At the university library he xeroxed some of the articles about Gödel's proof listed in the bibliography of DeLong's book. As he continued his eastward travels, he read the papers. "Each night," he remembers, "I would stop and pitch my little tent, sometimes in a forest, sometimes by a lake, and then I would eagerly plunge by flashlight into these articles until I fell asleep in my sleeping bag." It was in the course of this trip, which culminated in one semester of graduate work at New York's City College (CCNY) during which, as a teaching assistant at Hunter College, he tried his hardest to convey the beauties of special relativity to a tiny class of nurses, that Hofstadter began drafting early versions of what would become *Gödel, Escher, Bach,* first in longhand, then on a typewriter.

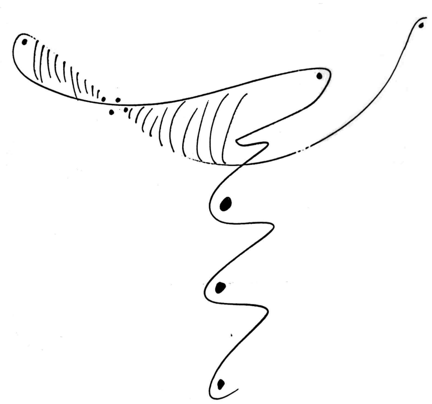


Jazz scribble by Douglas Hofstadter.

He returned to Eugene, still working on his then-nameless book, and to his surprise, as a result of his musings on these many new themes, he found himself reconsidering the way he thought about physics. He began to see higher-level patterns and structures as no less fundamental or mysterious than the elusive nature of elementary particles. His close friend and fellow grad student Francisco Claro convinced him that solid-state physics had great profundity, and another grad student planted in him the magical idea that a crystal is a fancy type of vacuum -- a "discrete vacuum", as opposed to the "continuous vacuum" of empty space. According to this view, the vacuum of empty space is analogous to a mathematical continuum (such as the real line), whereas a crystal is analogous to a periodic set of dots, such as the set of integers distributed along the real line. This radical new perspective on the nature of solids charmed him and opened his mind to the previously unthinkable thought of doing a doctorate in solid-state physics. He found a new thesis advisor (his fourth or fifth, by this time!) who proposed a problem on so-called "rational" and "irrational" magnetic fields. "It sounded right up my alley. I decided to risk it. It turned out, by an amazing stroke of luck, that my years of independent research in number theory when I was a math undergraduate provided exactly the mathematical background that I needed to make a key breakthrough. It was dead center, perfect." The work that followed, described in Chapter 5 of GEB, was in fact based on a discrete version of the Schrödinger equation, and led Hofstadter also to the discovery of what turned out to be a multifractal energy spectrum and a visually stunning graph that he called "Gplot", and that later became known as the "Hofstadter butterfly".

Strangely, however, his thesis advisor, the Swiss physicist Gregory Wannier, was at first opposed to Hofstadter's discoveries, being totally unfamiliar with recursive structures and with the use of either number theory or computers in physics. It took many months before Hofstadter won him over. In the end, Wannier became a champion of Hofstadter's work. It was an ironic twist that capped off Hofstadter's short-lived physics career.

Having defended his thesis, Hofstadter fervidly resumed work on his book, which he had painfully set aside for nearly two years. Thoughts about Gödel's proof were entwined with thoughts about what the soul was, what thought itself was. As he wrote the fanciful, contrapuntal dialogues in *Gödel, Escher, Bach*, he realized more and more clearly that he was not a typical writer of nonfiction.



Jazz scribble by Douglas Hofstadter.

For a while he had considered himself a scientist first and foremost. But by the late 1980s, after the publication and great success of *Gödel, Escher, Bach*, things started to change. "I started to realize," he says, "that my artistic inclinations were equally strong." He found himself creating all the time in artistic domains, designing hundreds of new alphabets and typefaces, as well as translating and writing highly structured poetry.

His fascination with pattern and with language also found expression in the "ambigram", an art form invented by his friend Peter Jones in the 1960s, in which one draws words in a distorted but calligraphically elegant manner so that they can be read equally well upside-down or in a mirror, sometimes saying the same thing, sometimes something completely different. Spurred on by the spectacular ambigrams done by his friend Scott Kim, Hofstadter became very adept at this "strange but beautiful art form". This was related to his subsequent work on the Letter Spirit project, an attempt to design a computer program capable of creating letters in artistically novel styles called "gridfonts", which amount to original new typefaces on a grid. In order to steep himself in this challenge, Hofstadter himself designed some 400 gridfonts over a several-year period in the mid-1980's.

During this time Hofstadter had been teaching and doing research in artificial intelligence at Indiana University. He moved for a time (1984-88) to the University of Michigan, before returning to Indiana. At Michigan he was named Walgreen Professor for the Study of Human Understanding. He laughs, "if only these people who hired me as a fancy titled professor knew that I woke up in the morning and spent hours on end doing nothing but drawing stick letters in bed!" But in truth, his gridfonts were far more than mere stick letters; indeed, they led him to deeper understandings of the mechanisms at the heart of creativity itself.

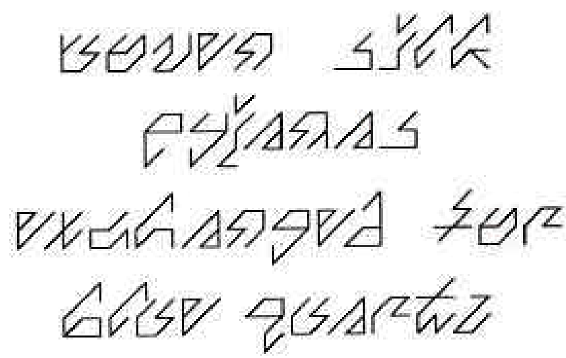
Many years of work on the Letter Spirit project and on related projects in the computer modeling of human analogical thought, artistic creation, and scientific discovery culminated in the publication of *Fluid Concepts and Creative Analogies*, co-authored with the Fluid Analogies Research Group, a team Hofstadter affectionately refers to as the FARGonauts, and which boasts former members such as philosopher David Chalmers and complexity theorist Melanie Mitchell.

Returning in 1988 to Indiana, Hofstadter continued his work both in the arts and in cognitive science. In addition to churning out ever more ambigrams, he developed another curious art form that he self-deprecatingly calls "jazz scribbles", which started as dedications on the flyleaves of his books, and gradually became Jackson Pollock-esque "unpredictable wild things." In 1998, the School of Fine Arts Gallery at Indiana University put up a vast exhibit of many of Hofstadter's long improvised scrolls, ambigrams, gridfonts, and jazz scribbles. Not every scientist, he laughs, has an exhibit of 230 art pieces in a gallery on campus.

Hofstadter's interest in analogy is intertwined not only with his interest in the visual arts, but with language as well, particularly with translation. In the late 1980's, he began to explore the translation of poetry as a model of the creative process, using as his paradigm a charming sixteenth-century poem by Clément Marot, written in French, 28 lines long, with three syllables per line and with rhyming couplets. To translate this into English while respecting not only its content and its tone, but also every aspect of its form, was a task fraught with what he calls "severe pressures". It was like designing a gridfont or like composing a fugue. He wound up translating Marot's poem some 40 different ways. This several-year binge – one of many binges that collectively define Hofstadter's intellectual style – resulted in a long book entitled *Le Ton beau de Marot* (Basic Books, 1997), which starts out quite modestly, telling the tale of Clément Marot and his curious poem, but winds up quite ambitiously, tackling the richly intertwined topics of translation, concepts, words, analogy-making, constraints, and creativity.

Translating from French, a language Hofstadter had learned to speak fluently as a teen-ager in Geneva, was one thing. But then he came under the spell of Alexander Pushkin's novel in verse *Eugene Onegin.* Hofstadter knew very little Russian. What fascinated him was the act of comparing that classic work's enormously different anglicizations. He reviewed and compared four verse translations of *Onegin* for the New York Times Book Review. But that wasn't enough. The beauty of James Falen's translation convinced him to plunge himself into Russian (a lifelong dream) and to read *Onegin* in the original. First he started memorizing stanzas in Russian, and then, on a lark, he translated a few stanzas and sent them by email to Falen, who encouraged him to continue, and eventually, to his own enormous surprise, Hofstadter wound up translating Pushkin's novel-in-verse in its entirety – some 400 intricately rhymed and metrical sonnets – into rhymed, metrical English.

Doing a verse translation of *Eugene Onegin* took roughly a year, and reached its climax on Hofstadter's first trip to Russia. When he boarded the plane in Indianapolis, Hofstadter had five stanzas left to translate. He did two during the flight to Saint Petersburg, and two more in the first few days at his hotel. But the crowning glory last came when, thanks to a friendship with Kenneth Pushkin, a descendant of the poet, Hofstadter was allowed a private visit to the Pushkin Museum, where he was able to sit in total silence in the poet's private apartment – at his desk, even – for two hours on the evening of October 17, 1998, translating the novel's very last stanza. "I got nowhere at first", he says. "I was struggling and struggling, but no rhymes came. I was petrified that I would blow this golden chance, but then, all at once, the logjam broke, and I was able to complete the last stanza in a very satisfying fashion." Hofstadter describes these hours as a magically romantic moment in his life.



An example of one of Hofstadter's gridfonts.

While Hofstadter has found that his artistic side "cannot play second fiddle to [his] scientific side", the opposite holds true as well. He has moved back and forth between his loves of mathematics, the sciences and the arts, "each one enriching the other". This semester, for instance, Hofstadter has been teaching a graduate math seminar at Indiana University called "Group Theory Visualized". His own encounters with group theory in graduate school, as with the elementary particle theory that it permeates, were hugely frustrating. "In those bleak days, I felt group theory was defeating me – it was my enemy."

But last year, which he spent in Bologna, Italy, he took with him, almost by chance, a few group theory texts. "I don't know why," Hofstadter says. "I just grabbed them from my bookshelf and thought, 'Maybe I'll read this in Bologna." He had always found group theory alluring but forbiddingly abstract. "You could prove theorems about groups, but you could never befriend them in the way that you can befriend a number," he says. However, with the aid of Cayley diagrams – "drawings that an elementary school student could understand, but which are never taught in traditional group theory courses" – Hofstadter saw group theory come wonderfully alive. "It was the lack of these babyish diagrams that made me drop out of grad school!" laughs Hofstadter, not without a slight trace of anger.

He deplores the seemingly deliberate obscurantism of many textbook writers in physics and mathematics. "There is a great desire for jargon. Many people who write such textbooks seem to be deeply afraid of clarity," he contends. This obscurantism, says Hofstadter, was raised to new levels in the forbidding tomes of the legendary "polycephalic" mathematician Nicolas Bourbaki, which constituted an attempt on the part of a team of French mathematicians "to rigorize mathematics in the most austere possible manner. It took decades to overcome the Bourbaki pestilence!"

In 2000, Hofstadter was invited to give the Hofstadter Lectures in the Physics Department at Stanford University. The talks are not named for him, but for his father, Robert Hofstadter, 1961 Nobel Laureate in Physics. The yearly Hofstadter lectures consist of two talks, a public evening lecture and a more specialized colloquium the following day. Deeply moved to be able to participate in a lecture series honoring his dad, Hofstadter devoted his evening talk to a description of his turbulent graduate school career. The colloquium he devoted to the key role played by analogy in the process of discovery in physics. Much, if not all, discovery in physics, he says, proceeds by borrowing a concept that worked in one domain of physics and adapting it to another domain, often without the slightest justification except that it "smells right". Hofstadter says that physicists tend to be unaware of the pervasiveness of analogy in their discipline, perhaps because discovery via analogy is not rigorous – in fact, it is usually not even rational.

The use of creative analogy in discovery is one of the threads that bind the sciences and the arts, and it is a crucial thread in the golden braid of Hofstadter's own creative life. There are fundamental differences between the two endeavors: science is a passion for understanding while art is a passion for expression. But then, he muses, "there are so many different styles of each, they form a continuum. An artist who is deeply involved with pattern comes close to doing science." And perhaps vice versa.

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Mentoring: A la carte is better than nothing

Kathy Barker

Fantasies are hard to discard. Although few of us have known the perfect mentor, we still imagine that we might find (or be) that kind, smart, thorough, ideal mentor who will act as a lifetime guide.

When the participants in science were fewer and more homogeneous, there was a good chance that each trainee might, sometime in his or her career, have at least one wonderful mentor. But the face of science has changed. There is an excess of people trained, and there is great competition for jobs and for projects and for attention. And for mentors.

Without a mentor, or some kind of guidance about the politics and realities of research, each new generation of scientists may make the same mistakes as their predecessors, causing many to be far less productive and successful than they expected. Seeing the effect the lack of mentors has had on young scientists, many institutions are scrambling to establish mentoring programs for trainees and starting faculty, These programs have had mixed success, perhaps one mentor is expected to fill too many holes in the training of scientists.

It is hard to give up the dream of the perfect teacher, role model, friend, advisor, instructor, and saint, wrapped into one mentor. But it may not be possible for one person to be the one and only guide to a scientist. If everyone is to have access to a mentor or guide, perhaps each mentor can only do part of the job.

So it is up to you to find your teachers. It is up to you to know what you need, and to find the best person to help you. Seek multiple mentors: define your goals and look for the teachers who can help with those goals.

These are the things that you might need help for: Getting tenure. Packaging experiments to write a paper. Grantsmanship. Finding, hiring, and nurturing good lab members and citizens. Keeping up with current advances in science. Balancing work and home. Establishing collaborations. Figuring out how to get yourself asked to give talks. Dealing with unmotivated students. Job negotiation. Time management. Finding time for teaching and clinical duties as well as research.

Management books will recommend that you ask someone to be your mentor. In general, that doesn't work well in scientific circles. Independence is still an essential part of being a scientist, and many people will not be receptive to entering the kind of commitment being a "mentor" requires. It is a very intimate request that well could be turned down, not because the person doesn't want to help, but because they think they cannot help that much.

Instead, go as a colleague, and ask for advice on hiring that postdoc, or on running lab meetings, as that person does it. If this develops into a classical mentorship - where someone will step out and try to communicate all he or she knows - great. If not, learn what you can and be grateful for the help. Look at it this way: the more connections in science you have, the better.

Even while you are still looking for advice for you own career, others will be looking up to you. You may not feel qualified to be a mentor if you still need a mentor yourself, but you *are* qualified, according to a more practical vision of mentoring. If you are good and have promise, you can show younger colleagues your skills and the steps you are taking to achieve the success your promise demonstrates.

Many starting assistant professors have trouble attracting students and postdocs and residents to their labs. Trainees want to be in a lab where papers are guaranteed, and where the big name of the experienced and famous P.I. can ease a job application through the stacks of applications. But large and famous labs are often Darwinian struggles for the P.I.'s attention, and only a few determined souls will obtain some small bit of mentoring at all.

What a starting P.I. can offer is the opportunity to work side by side with someone who still remembers what is needed to succeed and who is willing to teach it. This advantage is a huge one that savvy trainees are considering more and more when choosing a lab. Sell yourself! Let it be known that you are available to teach the inscrutables of science.

And teach everything! Teach everything you once wanted to learn, and more. Remember what it was like to enter this new culture, looking around for the clues you needed for success, and pass your lessons on. Teach what you can, and advise your people where to go to find mentors for what you can't teach.

Will you offer the same level and quality of mentorship to everyone? This is a tough decision that will evolve as you go. Certainly, it seems easier to mentor the talented, with less work and more return to the lab, than to mentor those with less than stellar promise. But while there is nothing more frustrating than trying to coach someone who just doesn't get it, there is nothing more rewarding than finding the key than turns a once humdrum worker into an enthusiastic scientist.

Many people don't want to mentor those who won't remain in science, some because they can see no payback, some because they just don't know how to give advice on a non-science career. Women and minority P.I.s are sometimes flooded with people of the same background, who want a mentor familiar with their experiences. Potential mentors may feel happily obligated, while others may feel peeved, that they are supposed to come through for a particular group of people.

You don't have to be a saint. You need to know your limits, for you can't rise to everyone's expectations, only to your own. You can't let your career go down the drain while you try to guarantee everyone else's success. Mentoring has to work for you, too.

Good mentorship is still not overtly rewarded by the system. But if you are an effective advisor and teacher, your science will be better, and your life will be richer. For many scientists, the realization of the hidden rewards of a mentoring relationship tends to come later in their careers, when papers and promotions turn out to be less than satisfying. Don't wait too long- pass it on now.

Resources.

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