Honesty to the Singular Object

Roald Hoffmann

What ethical lessons, if any, might emerge from normative science? My nonlinear path to a response begins with a look at storytelling in science. The moral implications of narrative will then quickly take me to an exploration of the ethical considerations that science might (or might not) call forth.

Stories

Science tells some rollickin' good stories. So why are scientists so unappreciative of the necessity of storytelling for the success of their own enterprise? Why do they beatify Ockham's razor rather than the rococo inventiveness of their hypotheses?

Because they are afraid of "just so" stories. The Kiplingesque allusion points to one of science's historical antipathies—to the teleological. Countered by a human proclivity for exactly that, the teleological, in the retelling of scientific stories. Could there be something else astir, for instance, a suspicion of the particularity of language, when scientists are ideologically committed to infinitely paraphraseable universals?

Consider first the marvelous stories that emerge out of science. So many to choose from—the epics of continental drift, or the way one iron atom in hemoglobin communicates with another. Or amusing ones, like how the amount of vanilla claimed to be natural in French ice cream exceeds by a factor of ten the quantity of beans shipped from Madagascar. Which led to a cat-and-mouse game between the forgers of vanillin (the flavor principle here) and the scientific detectives who learned to distinguish between the natural and synthetic form of one and the same molecule.[1] Or take a triumph of molecular biology, the working out of the chemistry and function of the ribosome. In Figure 1 is a schematic illustration—not an atom in sight in this low-resolution representation—of this biomolecular "smart" factory. It is a complex of about eighty proteins and a few RNA molecules that takes a strand of messenger RNA (complementary to DNA) and initiates a process of linking, according to the RNA instructions, amino acids shuttled to site A by a transfer RNA to an already formed piece of the enzyme at another site P. And proofreading the enzyme coming off, at a rate of twenty amino acids a second.[2]

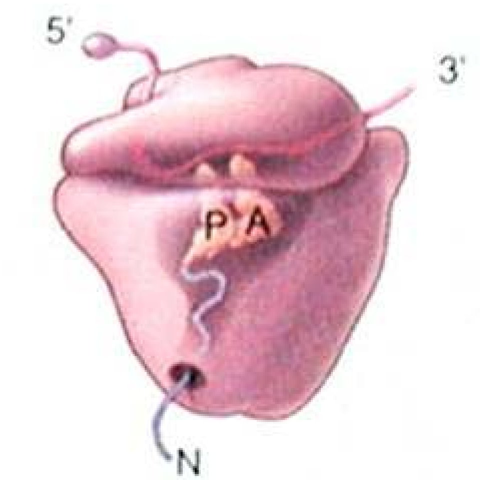

Figure 1. A representation of a ribosome by Graham T. Johnson. Reproduced by permission from Thomas R. Pollard and William C. Earnshaw, *Cell Biology* (Philadelphia: Saunders, 2002). The strand marked 5'—3' symbolizes the messenger RNA, the strand ending in N is the protein being synthesized.

Shall I compare thee to a Rube Goldberg machine (Figure 2)?[3] (In England it would be Heath Robinson.) And is there a gaping trap in this simplistic mechanism of mechanistic visions? Oh, yes. The way we

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[1] Roald Hoffmann, "Fraudulent Molecules," *American Scientist* 85 (1997), 314-317.
[2] Daniel N. Wilson and Knud H. Nierhaus, "The Ribosome Through the Looking-Glass," *Angewandte Chemie, International Edition* 42 (2003), 3464-3486.
[3] Peter C. Marzio, *Rube Goldberg: His Life and Work* (New York: Harper & Row, 1973).

envisage the ribosome is mechanical, linear, and… ephemeral. The representation, thrilling as it is, is transitory. Yet—and this is what some critics of scientific knowledge miss—this most unfaithful representation doesn't hinder us from designing real, functional antibiotics that throw a wrench into the workings of microbial ribosomes.

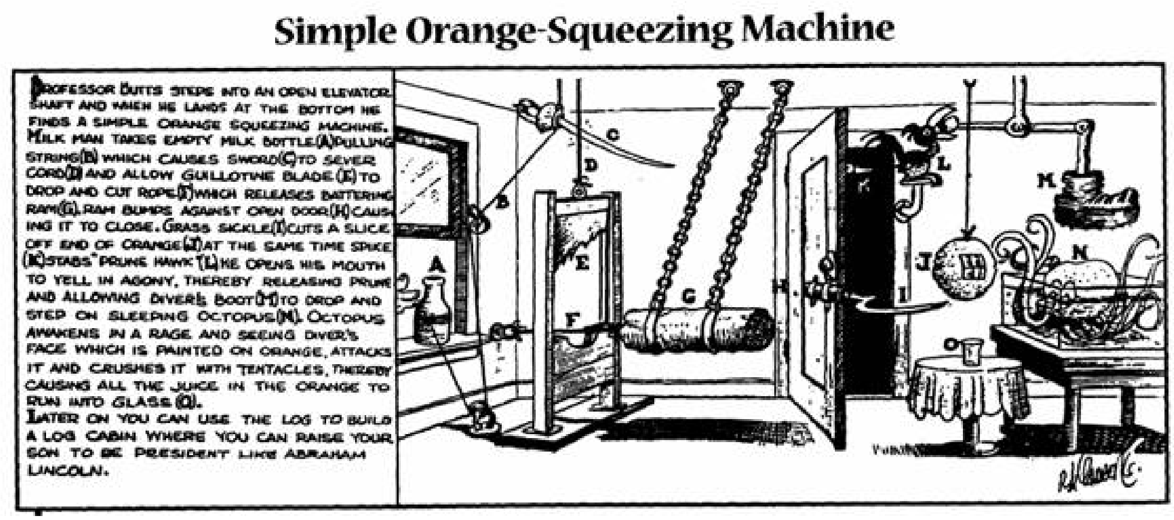

Figure 2. A cartoon by Rube Goldberg, one of the series of inventions by Prof. Lucifer Gorgonzola Butts. Reproduced by permission of King Features Syndicate.

The ribosome story allows me to shift to something much more interesting. This is the utility—nay, the necessity—of storytelling for practicing science.

Why should storytelling be essential for science? Well, every time the simple is proffered, human beings fall for it. So admiration for the symmetrical molecules, exemplified by the ones shown in Figure 3, or for a simple mechanism of a chemical reaction, the aesthetic imperative in physics (if an equation is beautiful, it must be right) seems… natural. And, I would add, related to our falling for political ads, of any persuasion.

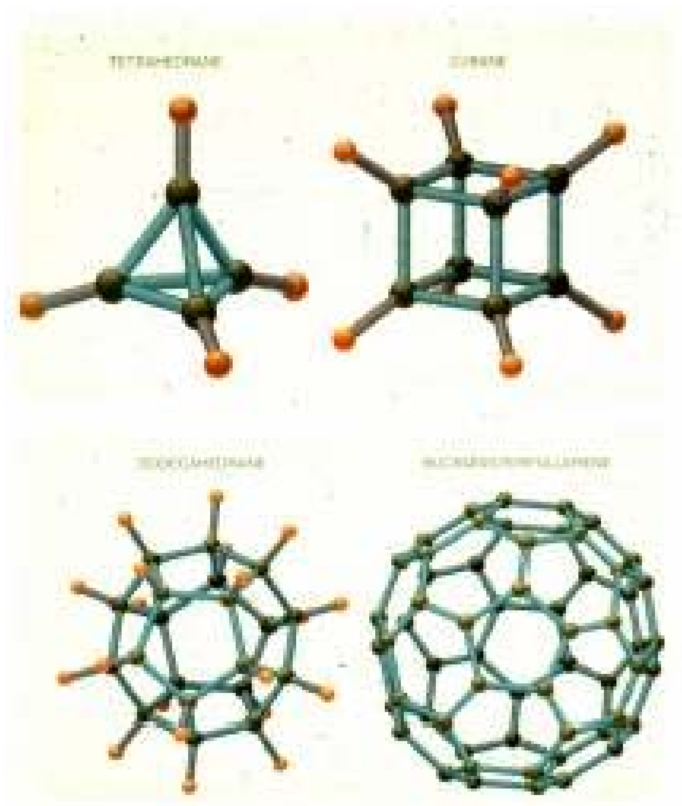

Figure 3. Some lovely symmetrical molecules, beautifully simple, simply beautiful, and… devilishly hard to make (except for *buckminsterfullerene*, the last to be synthesized).

But what if honest investigation of the real world reveals complexity, bound to be discovered in any biological or cultural entity that has been subject to inherently complexifying evolution? Even in a molecule. Take a look at hemoglobin, the oxygen carrier in our blood (Figure 4). This is already a much-simplified representation, omitting the vast majority of the more than 9,000 atoms in this $C_{2954}H_{4516}N_{780}O_{806}S_{12}Fe_4$ molecule. Where, and how, does one then find pleasure in such contorted complexity?

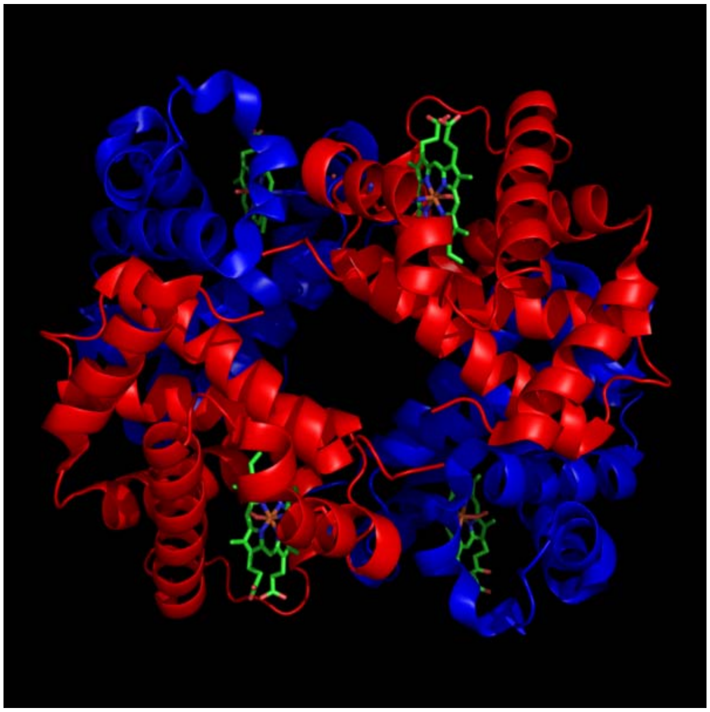

Figure 4. A schematic—“ribbon”—drawing of the structure of hemoglobin. There are four subunits in the molecule, roughly identical in pairs. The ribbon traces the backbone of the biopolymer (note the helices). The oxygen is held at the iron atoms that center the four platelet shapes nestled in the folds of the protein.

By telling a story, weaving one: the story of hemoglobin, of its four subunits, of the α-helices curled in it, of the way an iron atom held in the middle of a platelet-shaped heme molecule binds the oxygen, and in doing so pulls on a histidine group, which… Storytelling seems to be ingrained in our psyche. I would claim that with our gift of spoken and written language, this is the way we wrest pleasure, psychologically, from a messy world. Scientists are no exception. We tell stories because they first satisfy, then keep us going. Stories "domesticate unexpectedness," to use Jerome Bruner's phrase. [4, 5]

A Short Story of the Natural World

Let me tell one such constructive story. Insects are the greatest chemists. They use pretty simple chemicals in communication, mating, defense, and predation. In 1966 R. S. Berger identified the main sex pheromone of the cabbage looper moth, *Trichoplusia ni* (*Noctuidae*), shown in Figure 5 in its caterpillar stage, as "(Z)-7-dodecenyl acetate," a pretty simple molecule related to some fatty acids in all living things. This pheromone is also illustrated in Figure 5.

Figure 5. The cabbage looper moth in its caterpillar stage, and the first identified component of its sex pheromone, wafted by the female moth.

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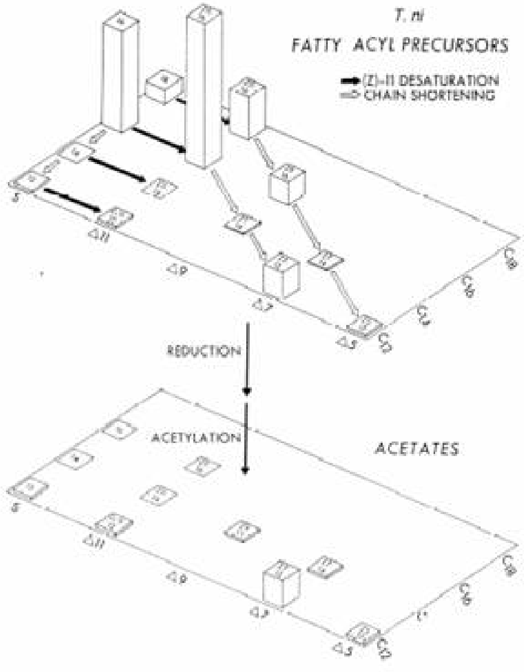
[4] Jerome Bruner, *Making Stories* (New York: Farrar, Straus, and Giroux, 2002), 90.
[5] Roald Hoffmann, "Narrative," *American Scientist* 88 (2000), 310-313. See also Hoffmann, "Why Buy That Theory?" *American Scientist* 91 (2002), 9-11.



Those were the halcyon days of early pheromone chemistry; everyone was happy with one molecule (as they were with one gene for each trait). Thirteen years later, L. B. Bjostad et al. identified a second component, important especially in close-range courtship behavior. Then the same group began to think through the biosynthetic relations between these two components and other molecules observed in the pheromone gland. Obviously, enzymes that do various transformations—shorten molecules, remove hydrogens, add various atoms, all the wondrous machinery of the living—are at work. I show below (Figure 6) a complex graph from one of the Bjostad et al. papers, indicating the biochemical relations between the various kinds of fatty acids in the moth.[6] Here's the story, a biochemical story that moved the authors, which they confide to us. A blend of six components, suggested by their analysis of the way the molecule first thought to constitute the pheromone is made by the insect, elicited complete courting flights against a stiff breeze in a wind tunnel. Clearly one needs six for sex. And would a human master perfumer be surprised?

[6] L. B. Bjostad, C.E. Linn, J. W. Du, and W.L. Roelofs, "Identification of New Sex Pheromone Components in *Trichoplusia ni*, Predicted from Biosynthetic Precursors," *Journal of Chemical Ecology* 10 (1984), 1309-1323, and references therein; Julie L. Todd and Thomas C. Baker, "The cutting edge of insect olfaction," *American Entomologist* 43 (1997), 174-182.

Figure 6. Biosynthetic clues to pheromone mixture. One axis is the length of the carbon chain, the other specifies the position of the double bond in the chain. This drawing is reproduced from Bjostad et al., ref. 6.

The story is told with sufficient verve in the Bjostad, Linn, Du, and Roelofs paper that even I, an outsider to the field, am pulled in by it. More than just an analysis of pheromone glands, the biochemical relations are clever. I am intrigued by their tale and begin to think of its sequel—how do the females evolve that blend? How do the males evolve the receptors to it? Thomas C. Baker and his coworkers at Iowa State University have actually located separate compartments for the six components (and one so-called antagonist, a molecule that acts to negate the physiological reaction to the pheromone) near where the male antenna input is first processed. Extending the story is life-enhancing. And not just in the *Thousand and One Nights*.

John Polanyi has recently described the close relationship between science and storytelling:

> *Scientia* is knowledge. It is only in the popular mind that it is equated with facts. This is, of course, flattering, since facts are incontrovertible. But it is also demeaning, since facts are meaningless. They contain no narrative. Science, by contrast, is story-telling. That is evident in the way we use our primary scientific

> instrument, the eye. The eye searches for shapes. It searches for a beginning, a middle, and an end.[7]

The power of stories may indeed exceed that of facts. As Walter Benjamin has written:

> The value of information does not survive the moment when it was new. It lives only at that moment; it has to surrender to it completely and explain itself to it without losing any time. A story is different. It does not expend itself. It preserves and concentrates its strength and is capable of releasing it even after a long time.[8]

In telling the story of scientific discovery, we form a praiseworthy bond with literature and myth, all the other ways that human beings have of telling stories. Yes, there are times when the story has to be told simply, the fire engine sent the shortest route to the fire. But a world without stories is fundamentally inhuman. It is a world where nothing is imagined. Could a chemist be creative in such a world?

Moral Endings

Almost every story has a moral, explicit or not. As Hayden White asks: "When it is a matter of recounting the concourse of real events, what other 'ending' could a given sequence of such events have than a 'moralizing' ending?"[9] Emily Grosholz notes perceptively that "when we hear a story, we evaluate the agents and the action. Maybe this is because of the irrevocability of human action (it only happens once, so it better be good), and intentionality (we always do things for an end or reason)… The very choice of beginning and ending confers meaning."[10]

In the endings I have seen, more often in scientific seminars than in fragmented papers, there is a curious mixture of celebration of the human

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[7] John Polanyi, "Science, Scientists and Society," *Queen's Quarterly* 107 (2000), 31-36.
[8] Walter Benjamin, "The Storyteller: Reflections on the Works of Nikolai Leskov," *Illuminations*, trans. Harry Zohn, (New York: Harcourt, Brace & World, 1968).
[9] Hayden White, *The Content of the Form* (Baltimore: Johns Hopkins, 1987), 23.
[10] Emily Grosholz, personal communication.

achievement with serendipity co-opted to serve design. And there's a double re-sacralization of the mundane, of what has just been demystified. In a spiritual process that I find refreshing, awe is expressed at what happens in nature or what human beings (okay, usually the author) can do. And the mysteries yet to be resolved are articulated. With complete faith that they will be resolved.

Ethics Growing Out of Science?

The significance of storytelling in science, and the attendant morality, leads me to think of the potential of the process of science for constructing ethics. Here I follow, half a century later, Jacob Bronowski's path. My landsman in more ways than one was much less tentative than I will be when he said, "the practice of science compels the practitioner to form for himself a fundamental set of universal values."[11]

Can ethics grow out of science? The very question may seem ludicrous to two communities of scientists: those who really believe that science is ethically neutral, and those who believe that scientists are inherently ethical. So let me first contend with these, as provocatively as I can.

To claim that science is ethically neutral ("I just worry about the technology of cloning; someone else can decide if it's good for people") puts scientists squarely in the company of anti-gun-control activists ("Guns don't kill, people do"). By contrast, I believe, and there is some philosophical tradition that supports this, that in any action by a human being, the instrument of that action (a gun, a molecule synthesized, yes, even a mathematical equation or a poem) must be accompanied by a moral judgment. The judgment is: "Will the use of that instrument by me (or by others) hurt people, or not?" The invention or implementation of a tool without consideration of the consequences of its use is deeply incomplete.

[11] Jacob Bronowski, *Science and Human Values* (New York: Harper & Row, 1965), xiii.

As for the claim that scientists are born with ethics—well, that's just as likely as their being born with aesthetics or logic. That the latter is not true, you learn from reading the "peer review" referees' comments on your paper. We scientists are people who have opted to engage in a remarkable social system for garnering reliable knowledge, that knowledge being of great practical and spiritual value. The critical components of that Western European social invention, science, are (a) normal, curious people, some of whom like mathematics; (b) people not afraid of getting their hands dirty—experimenters; (c) an open system for dissemination of what one finds, and a communal urge to do so; and (d) a method that encompasses frequent dipping back and forth between approximations of reality (gauged by our occasionally misleading senses and our tools) and flights of imaginative fancy in hypothesis formation and theory building.

So… is there something in the practice of science that can enhance the ethics brought to it by scientists, or that possibly can engender an ethical outlook? As the above makes clear, I do not come to this because I think scientists are "better" than other people—far from it. Nor do I dare presume that a relatively late social invention, science, could provide a broad rationale for a human quality as fundamental as ethics. (Or is ethics itself a social invention? If so, it is older than science. But not as old as curiosity.)

When goods collide, where do we get our criteria for deciding among them? From the usual sources, like them or not: our socialization at home and in our schools, i.e., from our parents and teachers. Perhaps from our genes, though not as much as E.O. Wilson would like us to believe. From churches and religions. From reading—novels are especially strong moral instruments. Not a tad diminished by deconstruction. By the time science enters a young person's moral consciousness, he or she is usually a pretty well-defined moral human being. Yet the web of life has a way of generating new quandaries; one's personal sense of what's right, how to act in difficult times, evolves even as it is moored in the past.

Two of the components I gave of science, publishing and the nervous motion twixt theory and reality, depend on texts, talks, and conversations.

These generate narrative. And, even forgetting the moralizing endings, such acts of communication inevitably confront scientists with ethical choices—to be faced, evaded, negotiated. Let me expand on this.

Writing It Down

An important part of the system of science is publication, with the potential of replication. How reproducible scientific findings are (and whether the reality of reproducibility is essential to belief) is a matter of contention.[12] It took several years for public questioning to surface of the all-too-novel measurements, a multitude of them, of Hendrick Schoen in solid state physics.[13]

Could it be that the primary emotional motivation for a scientist who does not falsify a synthesis or measurement is simply fear, rather than the psychoethical drive to report facts honestly? Perhaps, though I find definite positive value in fear in making us behave righteously. To a point. And fear of damnation, big and small, is certainly important in Christian ethics. It may be painful for most of us to see others, never ourselves, "do the right deed for the wrong reason," as T.S. Eliot says in *Murder in the Cathedral*.[14] But I accept the way we are: The "habit of truth," as Bronowski called it, is formed in many ways.

Ethics is like a limb that needs exercise to function. The importance of publication is that it provides exposure to potential testing. Time and time again. Fraud in science is ultimately unimportant. There is much prurient interest in it, for sure. With the same origins as our fascination with the sexual misdeeds of our ministers. Priests of the truth have a longer way to fall. But fraud is unimportant because the psychopathology of its perpetrators is such that their fear of being proven wrong is somehow

[12] Robert G. Bergman, "Irreproducibility in the Scientific Literature: How Often Do Scientists Tell the Truth and Nothing But the Truth?" *Perspectives* 8.2 (1989), 2-3.
[13] Leonard Cassuto, "Big Trouble in the World of 'Big Physics,'" *Salon*, 16 Sept. 2003: ww.salon.com/tech/feature/2002/09/16/physics/print.html.

[14] T.S. Eliot, *Murder in the Cathedral*, Part I (New York: Harcourt, Brace & World, 1963), 44.

abrogated, and they never forge the dull, only the interesting. Thus, the normal workings of the system ensure that others—out to prove the makers of the startlingly new wrong, not right—will repeat the experiment.

So the system works, but is the individual scientist motivated by loss of reputation if proven deceptive likely to become more ethical? A cynical viewpoint is that he or she will learn to sanitize, embroider, and manicure just enough to get away with what he can. And pile on the hype. A more charitable viewpoint is that we learn that data are not only not to be trusted, but that they are mute and inherently conservative. That a human being must interpret them—yes, tell a story about them. And that it is all right (within a self-correcting system such as science) to risk an imaginative, ornate hypothesis that does an end run around Ockham's razor.

Something salutary takes place in the writing of an experimental part of a scientific paper. I have trouble in picking one of my own to show you, for, sad to say, I'm just a theoretician. But here's a piece of a mixed experiment/theory paper in which I am a co-author, *ergo* in part responsible:

> *Crossover Experiments. In a 25-mL reaction flask was placed 0.050g (0.094 mmol) each of* $Cp_2{}^*Th({}^{12}CH_3)_2$ *and* $Cp_2{}^*Th({}^{13}CH_3)_2$*. The vessel was evacuated, and then 10 mL of* Et_2O *was condensed into the flask at -78°C. The suspension was stirred at this temperature until all of the material had dissolved and a colorless solution was obtained. The flask was then backfilled with 1 atm of CO and the solution stirred vigorously. After 4 h at -78°C, the solution was allowed to warm to room temperature whereupon a colorless solid (*$[Cp_2{}^*Th(\mu\text{-}O_2C_2\text{-}(CH_3)_2)]_2$*) precipitated. Next, 2 mL of degassed 1 M* H_2SO_4 *was added to the reaction mixture via syringe under a flush of argon. After*

the resulting suspension was stirred for 15 min, the mixture was centrifuged to remove a colorless, flocculent solid.[15]

Basta! You see a report of what was done, almost in iambic pentameter. Not the average run, but the best that was done, to be sure. It's there, this experimental part of a longer paper, for historical reasons: as evidence that it was done, that it can be done, with details reproducible by anyone (well, maybe). But why give the evidence? Isn't there trust in the community, aren't we all gentlemen? Or were, now that 38% of Ph.D.s in chemistry in the U.S. are women…

In citing another's experimental (or theoretical) work, there's a similar wrestling match on. To cite is an act of trust. Which can also be viewed as an act of mistrust, for by citing someone else without questioning the result, one is protected should it be faulty. To say that the mistrust complicit in the statement of conditions of an experiment, or citing someone's work, negates the trust overtly expressed by using the work, and that that's all there is to science, is to miss the fertile, tilled orchard of science—the creation of molecules as well as frameworks of understanding.

This is the essential tension of which Thomas Kuhn wrote, between trusting and not trusting.[16] I think writing an experimental part of a paper, or reading it in someone else's text, not once but many times (I have written 500 such, not atypical) is an ethically productive action. One in which both subconsciously and overtly the issues of trust and mistrust are negotiated by chemists. The important word here is *negotiation*: The web of habitual description and citation subconsciously (and explicitly) forces the creator to confront the other. It is an inherently social web, built out of real and imagined interactions with other human beings. In it are the makings of a gift economy. And of empathy.

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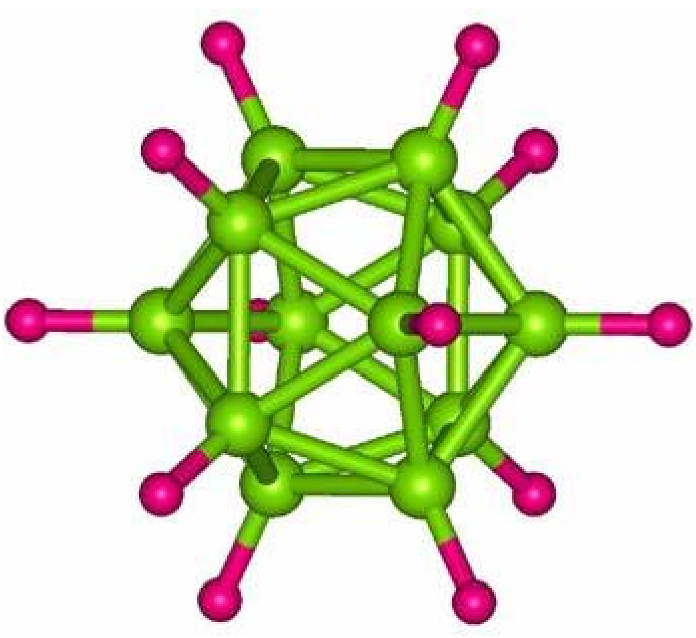
[15] Kazuyuki Tatsumi, Akira Nakamura, Peter Hofmann, Roald Hoffmann, Kenneth G. Moloy, and Tobin J. Marks, "Double Carbonylation of Actinide Bis(cyclopentadienyl) Complexes: Experimental and Theoretical Aspects," *Journal of the American Chemical Society* 108 (1986), 4467-4476.
[16] Thomas S. Kuhn, *The Essential Tension: Selected Studies in Scientific Tradition and Change* (Chicago: University of Chicago Press, l977).

First-time Narratives

I see two other places where ethics emerges in an interesting way from normative science. The first is the responsibility taught by first-time narratives, first-time representations. I remember for instance, when Fred Hawthorne—now at UCLA—came one day in 1961 to Harvard, where I was a graduate student, and told us how he had made $B_{12}H_{12}^{2-}$, a molecule shaped like an icosahedron (see Figure 7).[17] Nothing like it had been seen before; he described its properties with evident and appropriate excitement. Hawthorne knew instinctively that there was a story to be told of $B_{12}H_{12}^{2-}$, that it sufficed to tell it straight. *Das Ding an Sich* was indeed beautiful enough; it was sacred even as it came to be in his profane hands. In another day, another time, Fred would have said that it was given to him by the grace of God. In 1961 he called it serendipity.



[17] Anthony R. Pitochelli, and M. Frederick Hawthorne, *Journal of the American Chemical Society* 82 (1960), 3228-3229.

Figure 7. The structure of the $B_{12}H_{12}^{2-}$ ion synthesized by Pitochelli and Hawthorne, ref. 17.

There was no more question of Hawthorne making up a fib around $B_{12}H_{12}^{2-}$ than of Haydn writing a dissonant section in one of his piano trios.

Representation as Furniture

Much of what we do in science is to represent reality. Those representations, whether in language or not, are murky mirrors. But, as Emily Grosholz says, "representation is also generative: we say more than we know we are saying, and we induce order by our orderings, and good representations, as intelligible things, add to the furniture of the world. So representations are both more and less than what they represent. By misrepresenting, they also allow us to know, and to create."[18]

Speaking of language and veracity, Oliver Sacks tells an interesting story in a film he made in *The Mind Traveller* series. In Eureka, California, he met a family of deaf Mexican farm laborers. Among the five children, the three older brothers, who did not sign, were suspicious of their younger siblings, who were learning sign language. Because they would learn to lie, the older ones said.[19]

When you see something for the first time, you don't know what it is. When you describe it for the first time, language will fail you. You grope for meaning. But there is no lie. Would that we were given more such moments!

Honesty to the Singular Object

[18] Emily Grosholz, personal communication.
[19] Oliver Sacks, personal communication.

A second experience is one shared by poets and scientists. Something is seen, felt, then described. Now not for the first time, but for the umpteenth. So love has fled, and it hurts to remember what was good. It has happened to others, though that thought seems not to comfort at all. A poem needs to be written—one is in the Luberon, in winter. One walks out in the morning into the vineyard; it's sad to face that beauty alone. But then there's a grape cluster, like no other grape cluster. It must be described:

RAISINS FOR BEING

They left small bunches
on the vine, green late-
comers; the farmers

knew the day to pick,
sugar rising in the
berries, rain offshore. But

four sunny days broke
the pattern; the vines free
of their luscious burden

filled out the stragglers.
And then I came, just
before pruning,

and walked out in
the morning frost, the sun
clearing the Luberon,

and a thousand droplets,
on a grape cluster,
muscat pavé, told me

that I had a latecomer's
right, to live life out
reflecting, free albeit

tethered, at an angle
to the sun, sweet to you.[20]

I describe, and I am not sad any longer. For a while.

Elsewhere there is a molecule I see in a journal (Figure 8).[21] I talk about it to one of my graduate students, Pradeep Gutta. It has at its center a ring, with two tins and two nitrogens in it. But as you see, the environments of the two tins are strikingly different. Why? Could it be because of their different substituents, the chemical shrubbery hanging off the tin atoms? No, for the molecule with all substituents identical is calculated to have exactly the same geometry. "'Tis a puzzlement," as Yul Brynner said. And could one exchange the environments of the two tins, as shown in Figure 9? We calculate the way the electrons move in this molecule, their orbitals, orbits writ large. And we reason out a reason, because… that's our *métier*. There's a story to be told. I tell it, as well as I can.

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[20] Roald Hoffmann, "Raisins for Being," *Soliton* (Kirksville: Truman State University Press, 2002), 28.
[21] Soheila Chitsaz, Bernhard Neumüller, and Kurt Dehnicke, "Synthese und Kristallstruktur des gemischt-valenten Komplexes [Sn2I3(NPPh3)3]," *Zeitschrift für Anorganische und Allgemeine Chemie* 626 (2000), 813-815. English translation: "Unusual Geometries and Questions of Oxidation State in Potential Sn(III) Chemistry," trans. Pradeep Gutta and Roald Hoffmann, in *Inorganic Chemistry*, in press.

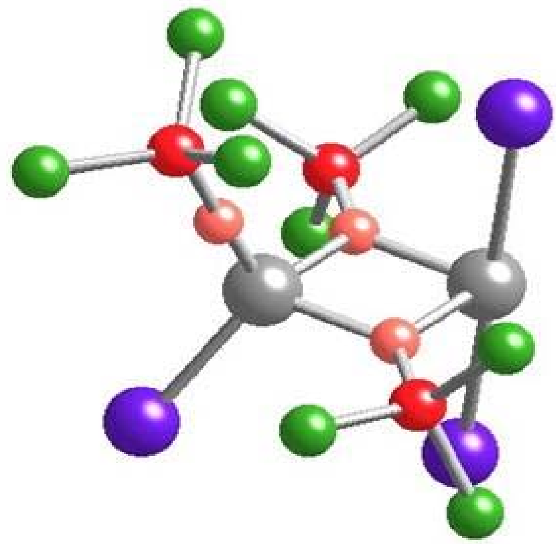

Figure 8. The structure of a molecule made by Chitsaz et al., ref. 21. Gray spheres = tin, orange = nitrogen, blue = iodine, red = phosphorus, green = C_6H_5 group.

Figure 9. A drawing of the same molecule as in Figure 8, now pruned to its geometrical essentials. The sequence of molecules, left to right, indicates a hypothetical way that the environments of the two tins could interconvert—a set of steps in a molecular ballet.

The language I use to tell my story is that of science, which is not the language of poetry, at least not much of the time. There is no premium on ambiguity in science. That a word can mean two things and sound like three other words, *that*... is the stuff of poetry. What science and poetry share, even though they parted company, it seems centuries ago, is an honesty to the singular, determinate object. We tend to think science is after universals—the infinitely paraphraseable—to use again Guenther Stent's idea.[22] But science is not one thing, and maybe chemistry is different—we build shape, motion, and reaction on specific, variably persistent groups of atoms. Trends matter, general theories less. And individual molecules, examined up close, most of all.

Craving understanding, we circle around the object of our affections. In love with the particularity, the "thingness," of this powder, just this shade of turquoise, we study it. Here is what William Blake said:

He who would do good to another, must do it in Minute Particulars:
General Good is the plea of the scoundrel hypocrite & flatterer:

For Art & Science cannot exist but in minutely organized Particulars.[23]

And the theme is voiced masterfully by A.R. Ammons, the American poet for whom art and science were not separated, in a section of his "Hymn":

> And I know if I find you I will have to stay with the earth
> inspecting with thin tools and ground eyes
> trusting the microvilli sporangia and simplest
> coelenterates
> and praying for a nerve cell
> with all the soul of my chemical reactions

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[22] Guenther S. Stent, "Prematurity and Uniqueness in Scientific Discovery," *Scientific American* 227 (1972), 84-93.
[23] William Blake, *Jerusalem: The Emanation of the Giant Albion* (Princeton: William Blake Trust/Princeton University Press, 1991), 219.

and going right on down where the eye sees only traces

You are everywhere partial and entire
You are on the inside of everything and on the outside

I walk down the path down the hill where the sweetgum
has begun to ooze spring sap at the cut
and I see how the bark cracks and winds like no other bark
chasmal to my ant-soul running up and down
and if I find you I must go out deep into your
far resolutions
and if I find you I must stay here with the separate leaves [24]

Fifteen million of the twenty million compounds known are white crystalline solids. I give you four vials, all white powders: One is sugar, another salt, the third penicillin, the fourth tetrodotoxin, the poison of the fugu or pufferfish. Will you play Russian roulette with these? Your body knows the difference. The difference, and its definition by the fallible powers of our mind and hands, is as beautiful as it is essential. The description of difference is one task the scientist does as well as it can be done.

Does the ethical bent inherent in the precision of language sought by scientists and poets make scientists and poets better human beings? No, no more than it improves those who professionally lead the considered life. The ethical impulse is strong, inherently human. It can be suppressed, most alarmingly by crowds and power, to use Canetti’s phrase. And, remarkably enough, it can be suppressed by the flush of first creation. I’m thinking of the susceptibility to this of the saints: Sakharov and Bethe in science, Lowell and Sexton in poetry. Ethical thinking can be awakened; it needs to be reawakened, by consideration of whether a molecule can harm, of advances in reproductive technology, and… of just what one can invent in a historical play or whether a poem hurts a lover. Even a soap

[24] A.R. Ammons, “Hymn,” *The Selected Poems* (New York: Norton, 1986), 9.

opera can teach ethics. We should be grateful for these little (or big) prods to ponder ethical choice.

The First (Fruitful) Intersection of Science and Ethics

I want to make a final point that returns to our cultural roots. The tree in the Garden of Eden in our primeval religious narrative was the Tree of Knowledge of Good and Evil. I take the *etz hadaat tov vera* as… "the Tree of Ethics" (a word not in ancient Hebrew), and the first link between science, narrative, and ethics. Let me bypass the question of why a just God would put ethics out of reach. He did. Or he didn't: If we knew good and evil just like that, the way we breathe, we wouldn't need ethics. Continuing in my disrespectful/respectful *midrash* (similar to that of Zygmunt Bauman, Jean-Pierre Wils, and more recently Leon Kass),[25] is not Adam and Eve's transgression implicit in the tale, serpent or no serpent? Without it there would be no narrative, no story of humankind. We'd still be between the four rivers, right?

Even before eating of the fruit of the tree—and the rabbis discuss whether it was wheat, grapes, or fig, with no apple in sight—Eve makes a decision: "When the woman saw that the tree was good for eating and a delight for the eyes, and that the tree was desirable as a source of wisdom, she took of its fruit and ate."[26]

The science in my mildly sacrilegious *midrash* is manifold. It sparkles in the knowledge that the tree conveys. Of what? Of oppositions and polarities. Of choices, of course—of matter particulate and continuous, of opposites attracting each other or repelling, of analysis and synthesis. Of what is to be hidden and what is to be revealed, of the same and not the same (those four vials).

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[25] Zygmunt Bauman, "What Prospects of Morality in Times of Uncertainty?" *Theory, Culture & Society* 15.1 (1998), 11-22; Jean-Pierre Wils, "Pleasure and Punishment: The Temptation of Knowledge," *Future* (2003), 74-80. See also Leon Kass, *The Beginning of Wisdom: Reading Genesis* (New York: Free Press, 2003).

[26] Genesis 3:6. English translation in *The Torah* (Philadelphia: The Jewish Publication Society, 1962).

The narrative in Genesis 3:6 is so skillful that we rush to the denouement. But the sentence is worth reading again, and in the original Hebrew, so that there is no doubt as to the reasons given for Eve's actions. The verse speaks, directly, of experiment. For this is what Eve hazarded, isn't it? She saw, and thought, and acted. She acted on beauty, for wisdom. Kant would approve. Eve did what had to be done, not to end but to begin a story. In which curious human beings have the choice between good and evil.[*]

[*] *Author's acknowledgments*: Friends helped me a lot in reflecting on the topic of this essay—among them Sylvie Coyaud, Margery Arent Safir, and Emily Grosholz. I am grateful to Jennifer Cleland for her assistance with some research, and to M.M. Balakrishnarajan, Pradeep Gutta, and Beate Flemmig for some drawings.