# The Say of Things

BY ROALD HOFFMANN
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IN SEARCH of a chemical conversation, we are on a farm in Uniow, a little Ukrainian village in Austro-Hungarian Galicia, just before the onset of World War I. In the farm yard we see a big, steaming, lead-lined iron pot. The men have mixed some potash in it (no, not the pure chemical with composition KOH from a chemical supply company, but the real ash from burning good poplar) and quicklime, to a thickness that an egg—plenty of eggs here, judging from the roaming chickens—floats on it.

Elsewhere in the yard, women are straining kitchen grease, suet, pig bones, rancid butter, the poor parts skimmed off the goose fat (the best of which had been set to cool, cracklings and all). This mix doesn't smell good; they would rather toss the kitchen leavings and bones into the great iron pot, but the fat must be free of meat, bones, and solids for the process to work.

They are making soap. Not that we had to go that far, near where one of us was born, for soap was prepared in this way on farms since medieval times well into this century. Fat was boiled up with lye (what the potash and quicklime made). The reaction was slow—days of heating and stirring until the lye was used up, and a chicken feather would no longer dissolve in the brew. One learned not to get the lye on one's hands. The product of a simple chemical reaction was then left in the sun for a week, stirred until a paste formed. Then it was shaped into blocks and set out on wood to dry.

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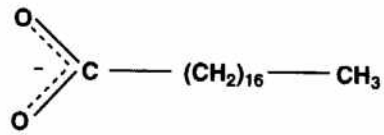
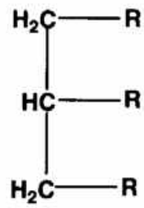
And inside the steaming pot, deep inside, where the fat and the lye are reacting? *There* is the conversation we are after, a hellishly animated molecular conversation. The lye that formed was an alkaline mixture of KOH, $Ca(OH)_2$ and NaOH. In the vat one had hydroxide ($OH^-$) ions, and $K^+$, $Ca^{2+}$, $Na^+$ all surrounded in dynamic array and disarray by water molecules. Contaminants aside, the fat molecules are compounds called esters, in which an organic base, glycerol, combines with three long-chain hydrocarbon chains. A typical chain is stearate:

stearate =

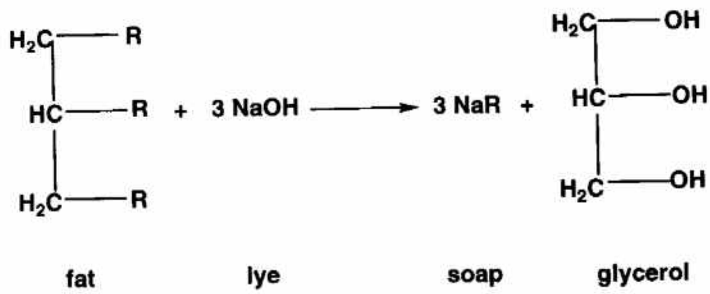


If we call just this ion $R^-$, then the formula for a fat is roughly



The reason we say "roughly" is that animal and vegetable fats are not just made of the esters of stearic acid, but also of other long chains containing fourteen to eighteen carbon atoms and associated hydrogens. Hardly anything in this world is simple (only political advertisements and the aesthetic prejudices of people who believe that beautiful equations must be true), least of all the products of evolution, which include fats and the human beings who invented the craft of making soap without waiting for professional chemists to tell them how to do it.

And what is soap? A typical soap is sodium (or potassium) stearate, NaR, where R is the stearate group. The reaction in the pot is:




It's a mad dance floor inside the pot. Some $10^{25}$ molecules of fat are jiggling around in the viscous solution, moving much quicker (if tortuously) than we may imagine. The molecules collide with each other very frequently, as well as with the $OH^-$, $Na^+$, $K^+$, $Ca^{2+}$ ions and waters. Once in a while a hydroxide nears one of the three central carbon atoms of a fat molecule, the knock is just right (men and women are not that different from molecules as they think) and a C—OH bond forms, while the C—R bond loosens. An $R^-$ ion slides into the murk, picks up some surrounding waters, and is off onto the dance floor, picking up a positive ion partner.

One of the authors [RH] has a fond remembrance of the closest model he has seen for molecular collisions and reaction kinetics. It was outside of Havana, an immense crowd densely dancing as the greatest Cuban band of them all, Los Van Van, played "Muevete."

Lye and fat talk, the triglyceride and hydroxide ions sing this wild riff, entangling, reacting . . . in the dark of the deep, except that sunlight comes in, and other energy in the form of heat, more energy to be released when nearby bonds are productively broken. The conversation becomes more heated, old bonds are loosened, new ones formed.[1] Eventually, the conversation quiets, and we have . . . soap.

Is this an excess of anthropomorphism? Molecules, even though they respond to energy and collisions, do not talk. Human beings do. What business do we have, really, to talk of a molecular conversation? Indulge us for a while, and we shall see. Or hear.

### *Spin to Spin Talk*

Scientists have instruments for eavesdropping on conversations of an ensemble of molecules at the microscopic level. These are totally factual chats, as when we book an airline ticket over the phone and supply the clerk with a credit card number. One particular example is provided by nuclei (or electrons) of atoms informing each other of their spin state.

Hydrogen nuclei, for instance, are allowed by the rules of quantum mechanics two spin states, which are often called "up" and "down," but which, for convenience here, we shall term the blue and the red. Such nuclei can be induced to put up either a blue flag or a red flag (so to say) to signal to us their spin state. The inducement is application of one magnetic field and tickling by another.

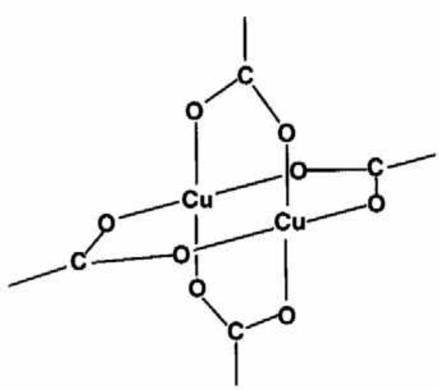
Now imagine two such nuclei (call them *A* and *B*) not too far from each other. There are four combinations of spins possible (flags they can wave): (red *A*, red *B*), (blue *A*, red *B*), (red *A*, blue *B*), and (blue *A*, blue *B*). If those nuclei are ignorant of each other's presence, the four sets would have equal energy. But the nuclear spins do feel each other, just a little, and with the help of a strong magnet we can translate that feeling into a difference in energy between those four sets, and eventually into lines in a so-called spectrum. These lines speak to us, they tell us that there are two nuclei there, sensitive to each other. And not three or five, for those would give rise to a different number of peaks and plateaus. Precious knowledge, and we have gotten it by tapping in, nondestructively, on an atomic conversation.

A version of the technique we have just described is used for noninvasive mapping of the inner parts of the body. Once called nuclear magnetic resonance (NMR), it got rechristened in the age of fear and advertising, ours, as magnetic resonance imaging (MRI).

Spins talking to each other is a productive metaphor within the chemical community. But is it just a metaphor? Real talk is sequential, even if frequently overlapping. At what speed does spin communication take place—is it instantaneous, or transmitted at the speed of light? We don't want to get into the fascinating, active field of decoherence and quantum locality, the ways in which contemporary physicists have made Schrödinger's cat meow (Mermin, 1992). The only way the limited human intellect has of getting a handle on what actually happens in microscopic interactions is to divide the process into sequential steps. In a sense, Cartesian analysis forces a conversation between spins to take place.

There is still another kind of conversation between spins: electrons have spin, just as some nuclei do. If there is an electron on one carbon atom in a molecule with a spin of one type (say, a red flag), then the physics works out so that on the carbon next to it the spin of the electron on the average must be of the other type (a blue flag). Red and blue don't matter—you could switch them here (the first could be blue, its neighbor then red). Alterity, being the other, does matter.

Electrons, detected through their spins, are talking all the time. Imagine a molecule with two metal atoms, as the copper acetate drawn below:



On each copper there is an odd electron. Do these two solitary electrons know of each other? If they do, will they line up with both red (blue) flags aligned (in the trade we call this a high-spin or triplet configuration) or one red, one blue (low spin, singlet)? It turns out that the latter is preferred, by just a little.

Enzymes often do their catalytic magic by shuttling an electron from one part of the protein to another—say from the outside of the protein, where an electron donor docks, to a metal ion in a cleft where the enzyme's appointed action takes place. We think of the conversation between the sites—its speed, for instance. How do these pieces of a large molecule talk to each other? How—through space, through bonds? We tweak the molecules in various ways, through transient perturbations of colored lights, or magnets, and listen, with those marvelous spectroscopies we've invented, to the chatter (peaks, valleys, more peaks) that emerges. We recognize a molecule by its speech in the conversation we have with it.


**FIGURE 1. A drawing by Rick Stromoski, reproduced with permission.**

*Maya-Spectra*

In the *Popol Vuh,* the Council Book of the Quiché Maya, Hunahpu and Xbalanque are the conquering and playful twin heroes. And they are players of the Mesoamerican ballgame, in which a rubber ball is hit with a yoke that rides on the hips. The twins are challenged to a lethal ballgame by the twelve lords of Xibalba, the death-dealing rulers of the underworld, who can be vanquished by the utterance of their real names. The twins are up to extracting those secret names, by stimulating a conversation between the foul gods (*Popol Vuh,* 1986). This scenario has much to do with the way spectroscopy gives chemists a way to listen in to the language of molecules. An as yet unpublished poem [by RH] tells the story:

The bright beam, sent caroming
off four mirrors of the optical
bench, into the monochromator,

penetrates, invisible but intent; like
the mosquito off on his spying
errand for Hunahpu and Xbalanque,

sly heavenly twins of the Popol
Vuh. For that light means to sting
too, inciting the electron clouds'

harmony with a ball, a wave,
to a state-to-state dance; while
the mosquito flies—in dark rain,

the sun yet unformed—down the Black
Road to Xibalba, bites the false
wooden idols, registering their blank

of an answer, on to the first, who,
god-flesh-bit, cries out, jumps
and the next dark lord calls

"One Death, what is it, One Death?"
which in turn the mosquito records;
from the light is drawn energy,

like blood, leaving on a plotter
a limp signature of H bonded to C;
sampling down the row of heart-

reeking gods: Pus Master, Seven Death,
Bone Scepter, Bloody Claws. The row,
stung, name each other, as do

carbonyl, methyl, aldehyde, amine
prodded by the beam, caught in the end,
like the ball in Xbalanque's yoke.

The losers are sacrificed, the twins win
and life is made clear by signals from within.

*Personalization of Nature*

The anthropomorphic turn is *so* natural when we speak of molecules. Why? Personalization of nature is like falling in love: our mind endows the Other with a set of imagined qualities that build on the observed, existing features. Scientists do refer often to nature affectionately. They see it as a good friend, a little bit of a tease on occasion, as someone to respect and certainly not to try and assault, as some fancy us doing routinely!

"As someone to respect," we wrote: this requires a little more elaboration. We respect nature for a number of reasons. We like its good looks; we are awed at all the wonders with which our profligate nature bedazzles us (for instance, when we witness a comet suddenly up in the sky for several months and visible even to the naked eye). Second, in like manner to the strange and difficult Hungarian tongue one of us [PL] was hearing as a child and slowly learning how to decrypt, we project an intelligibility onto nature: it gratifies us by seemingly conforming to rather simple behavioral patterns (or "natural laws" such as the Newtonian mechanics) that our feeble brains conjure up.

This second feature, intelligibility, makes nature personable. Human beings both strive and like to understand things. There is a basic harmony, an almost miraculous consonance between the quickness of our brain in deciphering the say of nature, and the goodwill of nature, who is willing to tell any careful listener what it is made of and what it went through.

Thus, personalizing nature tends to provide it with an intellect. We get to believe that the laws of nature form a language, that only some intelligent being (or Being) could ever have so ingeniously contrived. For instance, Maxwell's laws of electromagnetism appear (and appeal) to us in their splendid simplicity as a monumental architecture built by a genius. Such a personalization of nature may account for the crazy mix we perceive in the naive philosophy of scientists (none but ourselves): deep-seated realism about the existence of a complex outside world, together with an intellectualizing and idealistic bent, hell-bent on simplicity.

### *Meaning and Nonsense*

One might start with the following proposition: "our brain learns using language acquisition as model." This assertion would apply, not only to learning a second language, but more generally yet to our learning about the world.

A scientist puts himself in a position quite a bit similar to that of an infant learning a language (Hungarian, say). Hearing speech, the young child starts identifying, in what sounds very much like random noise, some recurring features. Its brain attaches itself to those signals and yearns for their reappearance, for the attendant comforting sense of a coherence. These isolated signals, that the child strives to hear again, start to regroup themselves and to form patterns in its mind. Children very early on start connecting those patterns with their context: the facial expression of the speaker, intonation, speech volume, body language, and so on.

The scientist, in his effort to understand a phenomenon, may feel at times very much like the infant, too dumb at first to understand what nature is trying to tell it . . . the say of nature.

So, one way to think about science is as a conversation with nature: not only do we listen, as if nature were talking to us, explaining very patiently what s/he does and how she does it; we also most definitely ask experimental questions of nature, and we try very carefully to pick up the meaning from the responses that our questioning elicits. Just as remarkable as the fact that two people conversing about the last World Cup game in sentences that are imprecise, unfinished, and overlapping understand each other, is that scientists can make consensual sense of a few poorly defined bumps in a spectrum.

Such conversations with nature go quite a way toward explaining why scientists tend to personalize nature, to the extent that they refer very often to it, both in speech and in writing.

Aren't there differences between learning a language and doing science? On the surface, the distinguishing features could not be more obvious. A language is a means by which people communicate, while doing science is an attempt to gain reliable knowledge about the world and to raise new questions about it (why is the sky blue, how can we test our explanation, how long has it been blue, does it need us to see it as blue, and so on . . . ).

Yet, there is a deep-seated similarity between learning a language and doing science. Both activities rely heavily on interpretation. Crucial to our growing understanding of any new language is parsing, that is, the ability to segment a train of audible frequencies into discrete units (sentences, words, syllables, phonemes). Conversely, the ability to link together discontinuous utterances, the related aptitude to translate a "poorly" uttered phoneme (the speaker has a foreign accent, perhaps) mark competence in a language (Laszlo, 1993).

Likewise, it is crucial to the scientific enterprise that the research worker be able to parse the physical world into pieces simple enough for examination, thus restricting his attention to the "system under study," to resort to a phrase commonly used by scientists. Conversely, it is equally important for the scientist to convert by interpolation a set of discrete data points into a continuous curve, which at a later stage he or she may try to express with a mathematical equation.

Indeed, the interpretative skill of a scientist is one of the reasons why science—by contrast to what some historians and philosophers appear to believe—goes beyond, way beyond merely the following of a prescribed procedure, that would lead anyone well-versed in the "scientific method" from observations to conclusions. Leaps of the imagination do occur, and they are as important to the scientist as they are to the artist.

### *"My Nature in Me Is Your Nature Singing"*

Not only scientists have conversations with nature. The trope is well established in poetry; a striking exemplification is given by the greatest contemporary natural philosopher poet, A. R. Ammons (1986), in his poem, *Classic:*

I sat by a stream in a
perfect—except for willows—
emptiness
and the mountain that
was around,

scraggly with brush &
rock
said
I see you're scribbling again:

accustomed to mountains
their cumbersome intrusions,
I said

well, yes, but in a fashion very
like the water here
uncapturable and vanishing:

but that
said the mountain does not
excuse the stance
or diction

and next if you're not careful
you'll be
arriving at ways
water survives its motions.

*Now, Live from the RSC Congress in Durham*

*Roald Hoffmann Reports:*

I am at the annual meeting of the Royal Society of Chemistry in Durham, England. The cathedral, visible from every angle, dominates the town. At breakfast in the college dining hall, I see an old friend who is also an invited speaker there, Arndt Simon from the Max Planck Institute for Solid State Research in Stuttgart. Simon is one of the world's foremost solid state chemists, his clarity of mind is unparalleled, and he has an ability to bridge (as the name of his workplace implies) chemistry and physics. He also publishes on old watches, and is very proud of having discovered one of the few one-minute "repeaters" ever made.

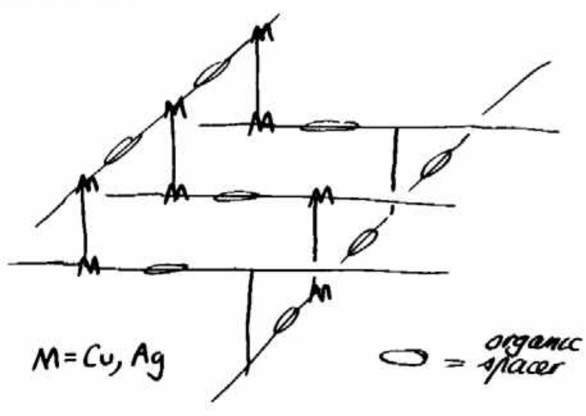
I steer my way to sit with Simon. We both decide to try some dry oatmeal cakes, with mixed results. We talk of a brilliant young Russian who just finished his Ph.D. in my group, now a postdoctoral research associate with Simon (the many ties that bind . . . ). Arndt says he is very pleased with Grisha. I say that was to be expected. We speak of Simon's lecture—he asks me how I found it, because he knows I know the field and the audience and care about presentations. I say it was superb, but perhaps had too much material in it for the non-solid-state-chemist audience. Arndt mentions some new solid state compounds he had made, containing nitrogen, called nitrides. They are related to the new inorganic superconductors, copper oxides. He looks around for a napkin to draw the structure of the molecule; I grope in my back pocket for a folded sheet of paper that I usually carry around for just such purposes; I can't find it, the napkin will have to do.

Arndt draws a picture of the molecular lattice he has made, in a few strokes. I see it, I am used to seeing these; I reconstruct the three-dimensionality of the molecule from his suggestive strokes. We share a semiotics honed by years of practice.

I mention to Arndt an idea I once had, of forming nitrogen-nitrogen bonds in the solid. We know of nitrides (compounds with isolated nitrogen ions) and azides (very explosive, three nitrogens in a row bonded to each other), why then not other extended structures with nitrogen-nitrogen bonds? I say (certainly not as grammatically as this): "The way to make them is to look at some existing nitrides, find those with the closest N . . . N contacts and with very electronegative transition metals around, and then apply pressure to them, maybe along the preferred bond-forming directions of the crystal." Simon notes this mentally, we go on to talk about his theory of superconductivity in carbides, a class of materials he has been studying; we talk of the new appointments at the Max Planck Institute, or at Cornell, of some research projects of mine. There's a lot to talk about between friends; we are late for the first lecture.

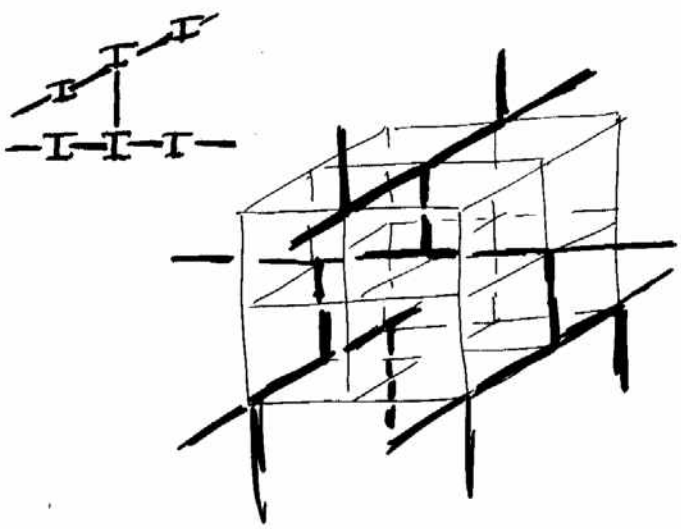
A week later Simon calls with a query, and mentions in a verbal postscript: "I found our conversation very interesting; we are going to try to do something about those nitrides." I say "I hope they don't explode." We laugh. This is chemistry.

Later in the day, I meet Norman Goldberg, a former postdoctoral associate, now carrying out research (for his habilitation) at the University of Braunschweig. Norman, a former graduate student, Greg Landrum, and I had done several papers on a kind of unusual bonding called electron-rich three-center bonding, or sometimes hypervalent bonding (perhaps an intrusion of hyper this or that, "postmodernist" hype, into chemistry?) These young guys should be left alone to work on problems of their own choosing, but here I had just been at Arizona State University, and Omar Yaghi there had told me in the course of conversation (and had shown me a model) of a new kind of extended structure or polymer he had made with T-shaped junctures at a copper or silver atom; the top of the T was formed by two organic units going off linearly, while the vertical part of the T was a bond to another copper atom. Now that's pretty interesting by itself, I told Norman (actually I had held that part of the conversation in a preceding letter and now I was reminding him of the story), as I sketched the Yaghi network:



"What it made me think of," I said, "is an infinite network of T-shaped hypervalent atoms." Why? Because the T shape is typical of such molecules; it occurs in $BrF_3$. "Could we do a calculation on this?" In the usual way of bosses in research groups, by "we," I meant "you."

Norman said "I like the problem; I think we can do it." He continued "But what would be the best system to try?" He meant to try calculations on . . . "Iodides?" I wondered, and drew this chain of iodides, with T junctions. As I did, I began to wonder if that was realistic, or if the atoms in the chains were too close to each other (not a good thing for a realistic chemical structure). "I'm worried, Norman," I said, as I began to draw a simple cubic structure, Escher cubes wandering off to infinity, and thickened some of the lines (I didn't have a colored pencil at hand), "if this is just a coloring of a cubic lattice; that won't work, we need a bigger spacer." But then I drew the structure more carefully, as below:



It turned out the structure was fine; only every second cubical site was occupied and the atoms well spaced. We ran out of paper, but I don't think either Norman or I will forget.

*The Chemical Place Setting*

That so much human conversation takes place around eating might surprise a visitor from another planet—after all, isn't the primary function of visiting restaurants to replenish the chemical feedstocks of this factory of ten thousand chemical ways of breaking down and building up? The mouth should stick to its primary task. Being thus otherwise engaged, there shouldn't be much talk.

But eating is a social activity for humans, as well as a biological one. We eat, and we relax, and we talk. And, especially if we are chemists, we *draw* as we talk. Notice has been taken of the importance of Chinese restaurants, especially a small one near Columbia University, in the development of modern physics. One of the coauthors [RH] can introduce a further piece of evidence of the magic of Columbia University, and one illustrative of the sheer quantity of visual information that is communicated by chemists, by showing two sides of a paper place setting he saved from a visit to Columbia (Figure 2). The dating of this artifact is not easy (who dates napkins?), but there is circumstantial evidence in the gendered faculty club name, the chemistry on the napkins, and the reasonably good trip files of the coauthor. It is likely that this conversation took place thirty years ago, in March 1968.

Do chemists draw more than other people? And if so, why? The answer to the first question is clearly "yes." You just have to take a look at any page of a chemical journal. On the average, 40 percent of the printed page is covered with visual material, and that does not include chemical or mathematical equations. To be sure, there are graphic representations of the results of experimental measurements, but the greatest part of that 40 percent consists of iconic representations of molecular structures. Chemistry was and is the art, craft, business, and now science of substances and their transformations, but in the last two centuries, and especially ours, we have learned to look inside the innards of the beast, and to think of the persistent groupings of atoms that are molecules, and of their transformations. Chemists navigate in macroscopic and

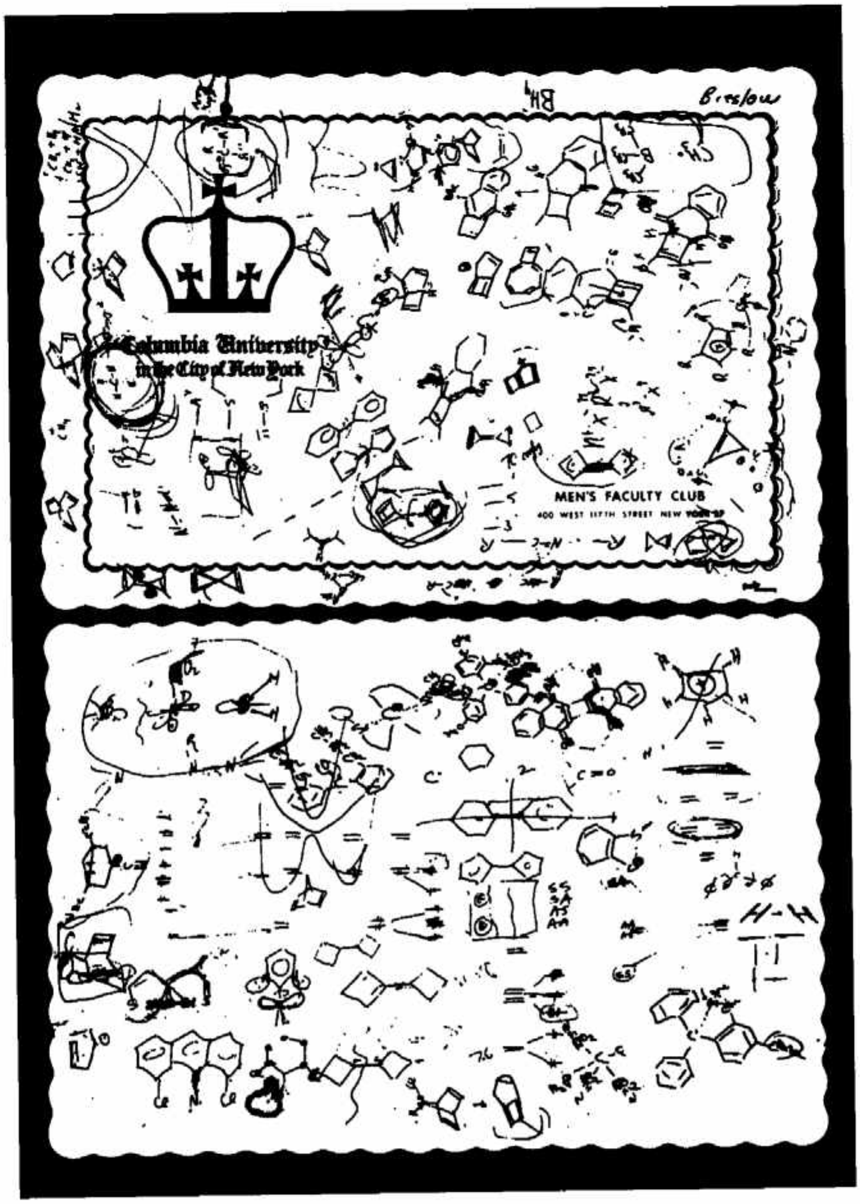



**FIGURE 2. A place setting (front and back) that served Roald Hoffmann and his Columbia University colleagues well in the course of a meal at the Men's Faculty Club of Columbia University in March 1968.**

microscopic worlds, using a necessary mix of symbolic and iconic languages (Grosholz and Hoffmann, 1998). Chemical structures are the latter, and they just flow across the page.

And from the pens and pencils of chemists engaged in conversation, for it is impossible to talk of molecules without drawing them. So chemists talking to each other immediately gravitate to a blackboard, or place a pad of paper between them, or, in places not amenable to either of these, go through a familiar shuffle of probing all of their pockets for a paper scrap or a Paris Métro ticket. *Ergo* that Columbia Men's Faculty Club place setting.

We have written elsewhere of representation in chemistry (Hoffmann and Laszlo, 1989). Three-dimensional information of the shape of molecules is critical, often literally a matter of life or death in the activity of a drug molecule. Communication of that information takes place just as you see, through little drawings on two-dimensional surfaces. But the group of people to whom this task devolves (chemists) are not talented at drawing! Now comes the quotidian miracle: untalented as we are, we not only cope, we communicate three-dimensional information effectively and creatively.

Chemistry is not just still substances or molecules, but molecules in transformation. How does one communicate essential change? In the iconographies of Klee-like arrows and bond-sundering wavy lines. And chemistry is microscopic, and at the level of atoms and electrons there are limitations to architectonic principles derived from the macroscopic structures (or the billiard-ball dynamics) of the macroscopic world. Down there, as mentioned already, quantum mechanics rules. How is that shown? Through another set of icons, little figure-eight shapes indicating in this case where the wave/particle electrons in the molecule are. See if you can spot these "orbitals" in Figure 2. One of us has gotten a lot of mileage out of them [I'll vouch for that, PL].

So much less would have been said in the absence of that place setting.

*Group Meetings, Posters, and Making the Rounds*

There are times when we are quiet, think, eat, read, sleep, watch Zinedine Zidane as he ties a spiritual bond between the ball and his head. There are times when we speak to ourselves. But most often we speak when we and others meet, in institutionalized settings that facilitate or even demand that a conversation take place.

Science is replete with such settings. Some, such as

- the coffee hour (tea time in the United Kingdom),
- the discussion after a seminar,
- the talk with a prospective graduate student,
- a topical conference, and the discussion at it,

are not peculiar to science. But some are; among them we pick

- research group meetings,
- poster sessions,
- visits to lecture at a university; appointments during such a visit.

Let's look at what makes these settings special.

*Research Group Meetings*

At the end of college, the American twenty-two-year-old chemistry major with a bachelor's degree is probably two years behind the corresponding European university graduate—in chemistry. Five years later, at the Ph.D. level, the two are competitive. Obviously, we must be doing something right in our American graduate education (Laszlo, 1996). Among several factors, we would point to the social structure of the research group and its meetings. The research group is often family-like, at times even more strongly bonded than the real nuclear family. An incredible work ethic infects American graduate students. The time spent in the laboratory is great—F. A. Cotton, America's leading inorganic chemist, recently said:

> I tell the same thing to all my students, "If you're not willing to work 60 hours a week on chemistry even when you're a graduate student or a postdoc, I don't hold out great hope for you" (quoted by Dagani, 1998, p. 42).

Many graduate students work still longer hours—you can recognize the chemistry buildings on campus, because in them the lights burn later than anywhere else on campus, with perhaps the exception of architecture drawing rooms.

What goes on at group meetings? Here is how RH tells it, for his group:

> We meet twice a week, for two to three hours each time. After some banter I ask if someone has something from the literature. Anything interesting is game for us, whether we can do a calculation on the molecule or not. It's just a matter of making a couple of transparencies, and then one talks around them. I take the opportunity to provide some background for the problem, if I have some experience with it. Since the people in the group are not only students but also postdoctoral associates and some visiting scholars who are older (we are six to nine people in all, what would be a medium-sized group; some research groups may have as many as thirty people in them) they will chime in.
>
> We digress, all the time: In what order are Vietnamese names written? What is the significance of single author papers of German origin? We stop when someone uses slang, and look at every sports metaphor, for there is only one American in this group. When a graduate student is months away from a critical Admission to Candidacy oral exam I pick on (torture?) him or her by calling them to the board to explain something.

On other days someone presents their research at an intermediate stage. My own strategy is actually to defer personal discussions on science with people in my group, and say "Why don't you talk about this to the group?" I push for such presentations, for they give desperately needed rhetorical experience, teach presentation methods, and engender planning that is needed for writing papers.

While there is substantial variation in the success of what happens, much depending on the interpersonal dynamics of the group (and how much sleep they got the previous night), what transpires is much of the time conversation. Yes, there are also formal presentations, my minilectures as well. But most of the time it is talk, free and unfettered in the way that a family discussion can be. People are not afraid to say foolish things. They know I will jump on them if they are unclear, but if I am lucky I make them feel that their understanding is what I care about.

Some conversations are better than others.

*Poster Sessions*

This is a relatively recent way to present material at a national or regional scientific medium, and it has spread like wildfire. It is also a means of presentation that engenders scientifically pregnant conversation, in ways that surpass all other modes of presentation.

In a poster session there is a space with, say, typically thirty to one hundred often rickety poster boards. Each poster presenter is given about a meter by a meter and a half, and can paste or pin up anything in that space. There is tremendous variation in the quality of the visual displays—from a dismal pinning up of pages of tightly packed numbers, to colorful computer-produced integrated posters. Often there is a personal touch—a ribbon, a flag of the country, a photograph of the laboratory.

The posters usually stay up for a day, and the poster presenter is supposed to be at his or her poster at a specified hour, typically for an hour or two. Sometimes refreshments are served in the room. At the appointed hour, the room fills up, and people begin their promenade. The psychology of poster presentations deserves a separate essay, or better still, a play. The viewer tries to keep a distance, so as not to be sucked into a windy presentation of a boring subject; the graphics of the poster should be such as to lure that bashful-to-recalcitrant viewer in to talking distance. Flexibility is important—here the presenter might be in the middle telling the story to some person *Y*, when there swims into view well-known Professor *X*, who might be the source of a postdoctoral position next year—how can the presenter begin the whole story for *X* without being impolite to *Y*?

Curious—a poster is designed to be *read*. But the measure of its success is its ability to engender *conversation*.

Much, much more conversation takes place in the poster setting than in the lecture format. First, more people come by; viewing a poster is less intimidating than raising your hand to ask a question. The format invites one person to ask, the other to answer. You can look at nametags of people. There are many presenters, and a natural empathy among them ("no one is coming around to talk to us!"). They begin to talk to each other. The presenters are often at the same stage of their careers—graduate students or postdoctoral associates—yet they come from different places. In the darkened lecture hall, they do not see each other; here, the bright light necessary for the presentation draws them to cluster into groups, to gossip, to break the social barriers that stand in the way of meaningful communication.

Lewis Thomas describes hauntingly the sound of scientists talking: "it is the most extraordinary noise, half-shout, half-song, made by confluent, simultaneously raised human voices, explaining things to each other" (1974, p. 62). We have often been able, as we wander down a corridor at a meeting, to find the room where the poster sessions are, simply from the hubbub of the talk.

*Making the Rounds*

Like other human groups, scientists tend to ritualize their interactions. If a guest seminar speaker is arriving from another campus, there is a set procedure so that the visitor may become acquainted with some of his colleagues during his stay. Upon arrival, the speaker is given a schedule on which, besides the time and location of the lecture, are shown time slots for interviews (set at intervals typically of a half hour to an hour) with various professors in their individual offices. Each such conversation thus conforms to the Aristotelian Rule of the Three Unities, which was deemed unassailable by French drama writers of the seventeenth century: unity of location, unity of time, unity of action.

As soon as the visitor has settled, and after a few gestures and grunts of hospitality from the host (a cup of coffee, a Coke, and so on), the conversation can start. The worst-case scenario, one all too familiar to us, has the host delivering a well-memorized monologue, that tells the guest in some detail a recent study that is about to be published. In so doing, the host may show a binder with the transparencies serving as visual aids in a standard sell: salesmanship of the most ordinary kind, no different from someone offering insurance or vacuum cleaners.

Usually, however, the interview starts with some effort at communication, at consonance even: "Which story shall I tell you?" says the host rhetorically, fishing for a topic that will overlap a little with the visitor's interests, which are indicated by the title and the summary of the seminar lecture to be held on the same day—unfortunately, often after the meeting.

Such an interactive scenario—by contrast to the first, the commercial—can lead to genuine discussion. The host will then benefit from points raised or from suggestions offered by the guest, perhaps even encouraging the visitor in such a direction at the outset with something like: "I'd like to have your reaction to these results and ideas," or in the catch-all phrase, "I'd like to pick your brain on this."

Making the rounds in a building and meeting with colleagues in the manner described has at least five virtues: educational—in our age of overspecialization we are thus able to broaden our outlook by learning of advances in other areas; olfactory—if our antennas are delicate enough to sense the prevailing atmosphere in the department visited, whiffs of internal warfare included; seminal—if and when the discussion provides mutually beneficial ideas; congenial—in those not infrequent occasions when host and guest take to one another, and their meeting could conceivably even start a friendship; and, last but not least, the virtue of friendliness—indeed if the two know already and like one another's company, their reunion may be pleasant and even festive.

Listening to a colleague talking about his or her work, by contrast with later reading the published paper—often one leaves the office clutching a bunch of "preprints"—has the merits of a focus on the essentials and of learning how the author values his or her contribution, where he or she puts it within the development of a field.

During the presentation, the visitor acquires extraneous information, too. There are all the nonverbal aspects: the seating arrangement, on a scale from distant formality to close informality and geniality; the titles of books on the shelves; little mottos and cartoons up on the walls; the degree of messiness in the office; the personal pictures of family and of hobbies outside work—from skiing or mountain climbing to sailing and scuba diving, not to mention playing the cello, square dancing, or gourmet dining—that hint at more dimensions in the person than is let on explicitly during the meeting.

All in all, such behavior as just described goes back a long time, much before the advent of modern science. Homer's *Odyssey* repeatedly shows us Ulysses being greeted in a city and palace. He tells the story of his peregrinations, and he is treated to some narrative in turn.

*Famous Conversations in Chemistry*

If Mephistopheles were still offering bargains, what would tempt us would be time travel—to hear and see a Greek chorus in a Sophocles tragedy performed at Epidaurus or Segesta. Or to sit in on that Paris dinner in October 1774, given by M. and Mme. Lavoisier, and attended by that remarkable Unitarian clergyman and scientist, Joseph Priestley. Priestley later was hounded out of his home in England for praising the revolution whose excesses took Lavoisier's life, but in 1774 what brought them together was good science.

Priestley had earlier that year made oxygen by forming *mercurius calcinatus per se* (which we would now call mercuric oxide, HgO) by heating mercury in the presence of air. On decomposition (people then spoke of the compound "reducing itself") it gave mercury and a previously unknown gas that supported combustion. Priestley, thinking in the older chemical framework that Lavoisier's experiments eventually demolished, called that gas "dephlogisticated air." Meanwhile Lavoisier had embarked on a careful series of studies of metal-gas compounds *(calxes)* and the processes of combustion and reduction. He was close to discovering oxygen—the gas was in the air in more than one sense. But until Priestley showed up in Paris, it is the considered opinion of most that Lavoisier did not know of the essential piece of the puzzle—oxygen. Here is how Priestley describes the dinner we wish we could relive:

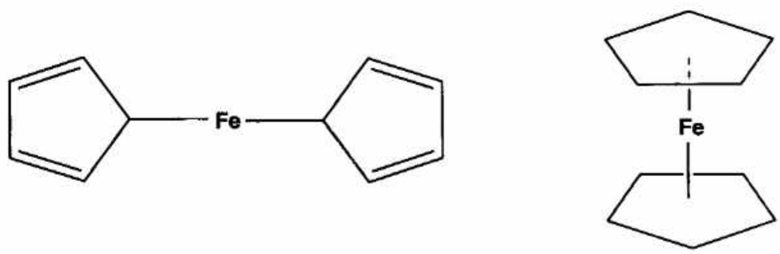
> Having made the discovery some time before I was in Paris, in 1774, I mentioned it at the table of Mr. Lavoisier, when most of the philosophical people of the city were present, saying that it was a kind of air in which a candle burned much better than in common air, but that I had not then given it a name. At this, all the company, and Mr. and Mrs. Lavoisier as much as any, expressed great surprise. I told them I had gotten it from precipitate per se and also from

> red lead. Speaking French very imperfectly and being little acquainted with the terms of chemistry, I said *plomb rouge,* which was not understood until Mr. Macquer said I must mean *minium* (cited by Poirier, 1996, p. 75).

Actually the gas had first been discovered (but remained unpublished—an interesting story), more than two years before, by a modest Swedish apothecary, Carl Wilhelm Scheele. By heating manganese oxide, Scheele got a gas he called descriptively *eld-sluft,* or "fire air." He wrote of it to Lavoisier. On October 15, 1774, Lavoisier received Scheele's letter telling him in substantial detail of the synthesis and properties of oxygen. The letter was found, unanswered, in Lavoisier's files in this century.

October was not an easy month for Antoine Laurent Lavoisier. In the course of his epochal subsequent work on combustion, Lavoisier failed to give proper credit to Priestley for the crucial information in their October dinner conversation. There may have been a flaw of character in the great French chemist.

Let us recount another conversation. One of the great success stories of twentieth-century chemistry is the renaissance of inorganic chemistry, and the development of organometallic chemistry, a borderland between inorganic and organic chemistry. There were hints of the existence of this fertile region, but that's all there were—hints—until the beginning of an explosive growth of the field in the 1950s. This beginning is very clearly defined; it is the report in 1952 of a very simple compound, $(C_5H_5)_2Fe$, or ferrocene. The compound has two five-membered carbon rings, each carbon carrying a hydrogen. Each of the two groups reporting (independently) the synthesis of this beautiful orange compound had the connectivity of these parts of the molecule right, but guessed quite incorrectly about the way the cyclopentadienyl rings (as they are called) are linked up to the iron. They postulated the molecule at left, but the structure is the much more interesting (and simpler) one at right. This is the first of a multitude of organometallic "sandwich" compounds.




Two chemists at Harvard, both good at keeping up with the literature, saw the initial English reports on pretty much the day they came into the library. One of them was a new assistant professor from England, Geoffrey Wilkinson. He had been less than a year at Harvard at the time, just getting his laboratory set up. Wilkinson was still to find his first graduate student. The other Harvard chemist to see the report of the still to be named ferrocene was also young, but already recognized as one of the outstanding organic chemists of the world, Robert B. Woodward. Woodward was that rare person in chemistry, a child prodigy. And while the world thought of him as the shaper of paradigms in the art of organic synthesis, his awesome intellect roamed all over chemistry.

Woodward and Wilkinson saw the English papers with the incorrect structure independently on January 30, 1952.[2] Both felt intuitively the structure suggested was wrong. Woodward had a sizable research group, and in it was a graduate student, Myron Rosenblum (since that time a distinguished professor of chemistry at Brandeis University). Apparently, Woodward told Rosenblum of the problem, and set him to find some ruthenium, so that a ferrocene analogue (Ru is right below Fe in the Periodic Table, and so should have similar properties) might be made. Here is how Wilkinson describes what happened next:

> The first I knew of this [of Woodward's interest in the problem] was on Saturday when Mike Rosenblum came into my laboratory asking if I had got some ruthenium. I can't remember what I said, though I remember being more

> than considerably annoyed, except that I think it was along the lines of "let me tell you what you want that for." However the upshot was that Woodward and I had lunch at the Harvard Faculty Club on Monday and sorted things out. The possibility that the $C_5H_5$ ring in the iron compound could possibly undergo Friedel-Crafts or other aromatic reactions simply had not dawned on me, but after the structure, this seemed to be Bob's main interest, whereas mine was to go to other transition metals (Wilkinson, 1975, p. 276).

The last comment is actually telling; it cuts to one of the very, very few failures of judgment in Woodward's remarkable career. Wilkinson took off in the right direction, for the explosive (productively, not literally) path of organometallic chemistry led to other metal and other "ligands" (organic groups attached). Ferrocene was just the opening, to a new universe. We suspect that Woodward, more than Wilkinson, understood the essence and necessity of the sandwich structure. But this greatest of the century's organic chemists saw ferrocene as an aromatic molecule (he was right), and then got caught up in finding in its chemistry the telltale markings of other aromatic molecules. We think that to Woodward what was interesting was not so much to go on to other metals as to find out how ferrocene was the same and not the same as benzene, the archetypical aromatic molecule.

### *Simulated Dialogues*

Our libraries hold precious few transcripts of actual oral exchanges between scientists, but they hoard a wealth of fictionalized conversations about science. Use of such books, much in fashion at certain periods in history, can be didactic. The two conversants stand for a teacher and a student.

While it is true that science builds up a body of knowledge and that scientists should and do share the specialized knowledge that they have acquired, their forte is not so much to parcel out what they know, but rather to ask questions: unusual, incisive, and radical. The scientific enterprise is a quest for (provisional) truths about nature. It proceeds by raising questions, about anything and everything, including the revision of well-accepted notions. Cavaliere Ripa's early seventeenth-century icon for *Investigatione* (Figure 3) (Ripa, 1618; Ashworth, 1990) is a pretty good one to this day.

The dialogue form is near to being ideal for conveying an *impression* of this questioning, which is so basic to science, a skill in which scientists train themselves for years. To quote Leonard Woolf (1969), "Journey, not the arrival matters."[3] The dialogue format is thus oftentimes couched in questions from one actor, "the pupil," to the other, "the teacher."

Jane Marcet, in a time (early nineteenth century) when women were considered as unsuited to intellectual pursuits, published such a book. Her *Conversations in Chemistry* (1806) introduces to her readership the still-pristine science of chemistry: luminaries with the stature of Lavoisier and Humphry Davy had set it on its course during the previous few decades. She presents both facts and their interpretation. Compared with the contemporary textbooks of chemistry, Marcet's dialogue format endows her text with superior readability.

Such a didactic use of a dialogue goes back to Antiquity. The Book of Job and the Platonic dialogues are the archetypical example of the use of a written dialogue to present ideas. Moving to the seventeenth century, to the time when philosophy and physics parted company, the lively style of Galileo's *Dialogo sui Massimi Sistemi* (1962 [1632]), together with it being written in the vernacular, a major innovation ensuring a larger and different readership, was responsible both for the widespread diffusion of this dialogue and for its author's well-known troubles with the Church. Galileo could not resist putting a Pope's opinion into the mouth of Simplicio.

Bernard le Bovier de Fontenelle was a playwright in Paris when he published in 1686 his *Entretiens sur la Pluralité des Mondes*


**FIGURE 3. A representation of *Investigatione*, from the 1618 edition of Cesare Ripa's *Iconologia*. George Richardson (1779, pp. 85, 86)) writes of this emblematic image: "with wings at her temples, to signify elevation of the understanding, by which this faculty should always be directed. Her garments are overspread with emmets [ants], which, by the Egyptians, were assigned as the hieroglyphick to investigation, they being, of all other animals, the most diligent searchers after every thing necessary for their support. The figure points to a crane in the air with her right hand, and with the left she points to a dog, who is in the action of searching after his prey. The Egyptians understood a crane to be the sign of an inquisitive man."**

(Fontenelle, 1955). This was a time of transition in astronomy, many new discoveries were being made and there was rapid growth of public interest in science. Some necks must still have been strained from the viewing of Halley's comet, an astounding sight, just a few years before (1680), and Fontenelle was able to build on this interest.

Fontenelle was not a scientist, but he made it a point to revise his book and to keep it up to date with contemporary science, especially after his election as perpetual secretary to the Academy of Sciences in 1697. Thus the *Entretiens* well deserved their extraordinary success, they went through dozens of successive editions. They defend Copernican astronomy and also Cartesian physics against Newton. Fontenelle wished to appeal to women particularly. Hence, the *Entretiens* give us dialogues between the author and a lady of the aristocracy, as the pupil intent upon learning astronomy: this marquise has personality and poise.

Some idea of the sheer verve of this dialogue might be obtained from this fragment. Fontenelle begins by enumerating the planets as one goes out from the sun:

> "Finally, Mars, Jupiter and Saturn follow, in the order in which I've named them for you, and you can see that Saturn makes the largest circle of all around the Sun, and takes more time than any other planet to make each complete turn."
>
> "You've forgotten the Moon," said the Marquise.
>
> "I'll find her again," said I. "The Moon turns around the Earth and never leaves her in the circle the Earth makes around the Sun. If she moves around the Sun it's only because she won't leave the Earth."
>
> "I understand," she said, "and I love the Moon for staying with us when all the other planets abandoned us. Admit that if your German [Fontenelle has mistakenly called Copernicus a German] could, he'd make us lose her too, for I can tell that in all his actions he had it in for the Earth."
>
> "He did well," I answered, "to have put down the vanity of men, who had given themselves the greatest place in the universe, and I'm pleased to see Earth pushed back into the crowd of planets."

"Surely you don't believe," she cried, "that the vanity of men extends all the way to astronomy."

During the Enlightenment, Diderot wrote *Le neveu de Rameau* (1959 [1761–74]). This extraordinary piece presents a conversation between intellectuals, of which the title character, the composer Rameau's nephew, runs the gamut of the emotions (at turns sarcastic, witty, incisive, argumentative), and of the modes of expression, from the confessional to the declamatory; and is brilliant throughout. Diderot, in this philosophical essay purporting to report a conversation, refocussed the published dialogue on the personality of one of its participants. This innovation was not lost on subsequent writers: quite a few books by Richard P. Feynman (or by his friends and students reconstructing Feynman), with their unique mix of entertaining fun and artful presentation of scientific concepts, are very much in the same vein.

Today, didactic fictional dialogues continue to serve their useful function of presenting difficult scientific concepts to the layman. The "Mr. Tompkins" books by George Gamow are small gems in this vein. For instance, the first chapter of *Mr. Tompkins Explores the Atom,* first published in 1944 (Gamow, 1958[1944]), opens on a discussion by two main characters, Mr. Tompkins and Maud, of a gambling martingale, which had been published in the January 1940 issue of the magazine *Esquire:* In this first chapter, Gamow brilliantly leads his reader from an elementary presentation of probabilities into one of statistical physics.

We have addressed so far two functions of a written, made-up dialogue, the didactic and the admiring. There is a third as well, as an outlet for an unorthodox writer who wishes to prevail nevertheless (the power of the pen) and to take on the rest of the world, if need be. George Berkeley wrote such a controversial text in 1713 (Berkeley, 1994). Bishop Berkeley, in this dialogue, has Hylas as a representative of materialists while

Philonous is a mouthpiece for his own views. Philonous undertakes to convince his interlocutor that matter does not exist, only representations in the mind.

An equally important fictional dialogue is that imagined by Alan Turing (1950), in one of the few papers he ever published. The dialogue sections form a *gedanken experiment* intended to demonstrate, by way of a questions and answers exchanged by a human being and a machine locked in a closed room, the seeming absence of any distinction between the intelligence of man and that of a computer. This seminal paper by Turing is entitled "Computing Machinery and Intelligence," and lucidly addresses, for the first time we think, the controversial philosophical question of artificial intelligence.

Dialogues persist to this day. The late Jeremy Burdett was one of the most original applied theoreticians of our time. His last book, just published last year, is a wonderfully perceptive *Chemical Bonds: A Dialog* (1997).

### *Taboos*

What cannot enter a scientific conversation? There are certainly things that are excruciatingly difficult to say—to tell a graduate student who announces that he has applied for a job at Cal Tech that you do not think he is good enough for the position, or signal a colleague that he has written a paper that just has too much hype in it, for example. But these are problems faced by all people, not just scientists. Could it be more difficult for some scientists to deal with such problems because of shyness of dealing with human beings? Fortunately, real life is a magnificent corrective, and in the end most everyone, scientists included, learns how to deal with a boss, with love, with a bank account.

Perhaps more interesting are the areas of forbidden discourse special to the scientific enterprise:

- We avoid telling a colleague that we have reviewed his research paper or grant proposal. Research papers are our stock in science, rather than books. These papers typically get sent out to two anonymous reviewers, who (often without coercion) respond in a month or so. Research grants are judged in two ways—either with a large set (seven to ten) of anonymous reviewers, or by a review panel, with one person taking the lead in summarizing and evaluating the work for the other members of the panel. A difficult situation is to hear in a conversation a colleague tell excitedly of his work—when one has already reviewed it, and therefore knows it in unusual detail. No problem if one is equally ecstatic about the work; but what if one has doubts? The conversational setting elicits a response; and the situation provokes inauthenticity at the least, the uneasy feeling that one has not quite said what one really thought.
- To reveal, or to conceal? The first reaction of scientists is, "How can you even ask this question? Science depends on a free and open communication system!" Indeed. But the scientist who responds in this way has simply not been fortunate enough (or misfortunate enough) to be faced with a discovery that has real commercial value. Our societies have evolved a complex system of patents for protecting the economic fruit of invention. Much more can be said about patents than we have space for here—in principle, one has a system of exchanging protection for disclosure. But in practice the art is to claim as widely and to reveal as little as one can get away with.

Chemists in industry are faced with extraordinary constraints on what they can or cannot say, especially when their companies are in the midst of patenting a process. Sometimes our heart goes out to them, for underneath the constraints we see a scientist dying to tell us something new. Sometimes, we have no sympathy, when we see them trying to worm out of fellow chemists (working for a rival company) their precious art.

There is a story to tell here, one that regretfully must be told without specifics, and with some minor changes. Once, in Cold War days, the U.S. Department of Defense supported a major program of classified research in a certain field of chemistry, hoping that it would lead to a new explosive. The program was based, as it turned out to be, on some faulty chemical assumptions. It led to no explosive at all, but instead to some wonderful chemistry, indeed to the synthesis of an entirely new class of molecules. No wonder, for the chemists employed in the program were, as it happened, very creative. Now, it is in the nature of secret programs and the stodgy bureaucracies that surround them that, even when it is perfectly apparent to everyone that on technical grounds there is nothing to hide, nevertheless the secrecy is maintained, and "classification" is not lifted.

Imagine the agony of the chemists who for five years could not publish their work, work that they knew would make a stir. The only thing that would make the stupid bureaucrats declassify the work would be if the Russians published the same research in the open literature! Or if not the Russians, at least another American. Some of the scientists got so desperate that they went around to American academic research groups working in related areas, and dropped broad hints that this area of chemistry was worth pursuing. One of us sat in on such a conversation.

Here is a question we believe probably one should not ask, especially a young scientist should not ask in a scientific conversation: "Do you understand?" On the face of it, what could be more honest and straightforward? The speaker, who may have just presented a difficult concept, or spoken too quickly, has sensed a nonverbal response on the part of his audience/listener, and is stating that he or she is willing to explain things again. But the question, unless asked in just the right tone, and between people of equal status or confidence, may be just as problematic as the question "Do you love me?" If it has to be asked, it may be too late.

*Written Thoughts and Spoken Words*

Conversation may be bad because it can make a human being break a covenant, forget a promise, be lured into an action showing poor judgment, become sneaky and duplicitous. The Bible, as usual, provides us with some pivotal examples. For a comparison between speech and writing, we go to the fascinating parable of the adulteress:

> The *scribes* and the Pharisees brought a woman who had been caught in adultery, and placing her in the midst they *said* to him "Teacher, this woman has been caught in the act of adultery. Now in the law Moses commanded us to stone such. What do you *say* about her?"
>
> This they *said* to test him, that they might have some charge to bring against him. Jesus bent down and *wrote* with his finger on the ground. And as *they continued to ask* him, he stood up and *said* to them "Let him who is without sin among you be the first to throw a stone at her." And once more he bent down and *wrote* with his finger on the ground. But when they *heard it,* they went away, one by one, beginning with the eldest (John 8:3–11; emphasis supplied).

The meaning of Jesus writing on the ground—the Apostle does not give us a clue as to what he may have been scribbling—has intrigued theologians for centuries. The dominant interpretation has Jesus making reference by his gesture to Jeremiah 17:13:

> Those who turn away from thee shall be written in the earth for they have forsaken the Lord, the fountain of living water.

The reference to Jeremiah has the merit of mirroring—also in the *testing* and in the attendant judicial-like *charge* as well—the first conversation in the Torah, that of Eve and the serpent "the shrewdest of all the wild beasts that the Lord God had made" (Genesis, 3:1–5). The well-known consequence was for Adam and Eve to know henceforth the distinction between good and evil, to be cursed in no uncertain language and cast out of the Garden of Eden.[4]

The Bible thus endows speech with the riches and risks of seduction and treachery, while writing records (as a scribe does) such transgressions. Commenting upon Jesus's enigmatic action in John 8:3–11, Schnackenburg, summarizing centuries of exegesis, writes

> Jesus refers (the questioners) to the judgment of God, before whom all men are sinners. They are all fit to be "written in the earth" . . . a sentence upon the guilty who know their guilt (Schnakenburg, 1980, p. 166).

Thus writing inscribes names of the sinners, while speech is what incites a person to sin. What a pessimistic appraisal of those two modes of human expression, oral and written, that have given us masterpieces of narration and of lyricism!

The opposition we might put between the two, for the purpose of this paper, has speech being the medium for reports to others, and writing being the tool for thought; it separates the collective and the social, on one hand, from the personal and the private on the other. Such a tension between the personal and the social dimensions animates the opening line of one of Dylan Thomas's (1946) poems:

The conversations of prayers to be said
By the child going to bed and the man on the stairs,
Who climbs to his dying love in her high room,
The one not caring to whom in his sleep he will move
And the other full of tears that she will be dead.

*Fecundity out of Repression*

The scientific article ossified in mid-nineteenth century. Take away Asian coauthors and computer graphics, and what you have today is pretty much the same format, governed by similar conventions, to what was there one hundred and forty years ago—an ordered layout, the scholarly apparatus of endnotes and/or footnotes, a neutered third-person diction. "Please, no emotions allowed, we're scientists." Underneath the surface (now as before)—we have impassioned, curious, and fallible human beings engaged in the search for reliable knowledge—and forced to at least express themselves like dispassionate "gentlemen" (Hoffmann, 1988).

The mechanisms of repression are certainly institutionalized here. But the id will out; if not in the most tangible product of scientific activity, the article, then maybe in the dark, hidden places—in the referee's reports, the reviews of proposals. Also in those nooks of society where repression is loosened by licit drugs or by informality. In these settings, often in speech—uncontrolled, unrecorded, in plain talk, not subject to strictures of order and good behavior—in the *Nachsitzung* after a seminar at a German university; in the long drinking evenings of a Gordon Research Conference. . . .

So what's new about this? People are people—they use informal conversation for gossip, innocent or malevolent, for *Schadenfreude,* for eliciting pity, claiming power, stoking the insatiable demands of some guilt. Is there anything in the free talk of scientists that is of *value,* over and beyond normal letting go?

Thinking about real value, if conversation is compensatory of repression—more open just because the written product of scientific work is so constrained—could it be that much more real discovery and creation takes place in conversations? We think so! It is the first place where one expresses understanding outside of the private confines of one's mind. The research group presentation is probably next, the writing of the paper the last, very important, place. The conversation—with a colleague, student to student—is where the ideas get expressed. And until they are expressed, in some way they are not real. The conversation reifies the idea; it selects in the mind of the researcher one possibility of many, it is *the first existential act in science.* All the stronger because the talk is free.

## Notes

1. For a good introduction to chemical change, see Atkins (1991). See also Hoffmann (1995), Chapters 29–36.

2. Wilkinson tells his version of the story in a published paper (1975); Woodward (deceased 1979) never wrote of the matter. The sandwich structure for ferrocene was independently suggested by Fischer and Pfab (1952).

3. See also Cavafy's wonderful 1911 poem, "Ithaca" (Cavafy, 1976).

4. In a recent book, Quignard (1998, our translation) writes:

> "Tertullian said 'Even in Paradise one needs to dissimulate. Even in Eden, it would have been better for the first woman to have been secretive. Even God is secretive: he is inscrutable to our sight. He is impenetrable in his designs. He is forever silent to Himself.'
>
> Eve should have shut up. This was the thesis to which the schismatic theologian from Carthage kept returning. What the serpent had whispered to her in the shadow of the tree, she ought to have kept locked away in her heart."

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