Roald Hoffmann

Roald Hoffmann was born in 1937 in Zloczow, Poland. Having survived the war, he went to the U. S. in 1949, and studied chemistry at Columbia and Harvard Universities (Ph.D. 1962). Since 1965 he is at Cornell University, now as the Frank H. T. Rhodes Professor of Humane Letters. He has received many of the honors of his profession, including the 1981 Nobel Prize in Chemistry (shared with Kenichi Fukui). "Applied theoretical chemistry" is the way Roald Hoffmann likes to characterize the particular blend of computations stimulated by experiment and the construction of generalized models, of frameworks for understanding, that is his contribution to chemistry. The pedagogical perspective is very strong in his work.
Notable at the same time is his reaching out to the general public; he participated, for example, in the production of a television course in introductory chemistry titled "The World of Chemistry," shown widely since 1990. And, as a writer, Hoffmann has carved out a land between science, poetry, and philosophy, through many essays and three books, *Chemistry Imagined* with artist Vivian Torrence, *The Same and Not the Same* and *Old Wine, New Flasks: Reflections on Science and Jewish Tradition*, with Shira Leibowitz Schmidt (translated into six languages).
Hoffmann is also an accomplished poet and playwright. He began writing poetry in the mid-1970s, eventually publishing the first of a number of collections, *The Metamict State*, in 1987, followed three years later by *Gaps and Verges*, then *Memory Effects* (1999), *Soliton* (2002), and most recently, in Spanish, *Catalista*. He has also co-written a play with fellow chemist Carl Djerassi, entitled *Oxygen*, which has been performed worldwide, translated into ten languages. A second play by Roald Hoffmann, *Should've*, had its initial workshop production in Edmonton, Canada in 2006.
Unadvertised, a monthly cabaret Roald runs at the Cornelia Street Café in Greenwich Vilage, "Entertaining Science," has become the hot cheap ticket in NYC.

Making sense of the image in the nanoworld

With a title like *Blow-up*, one cannot escape thinking of Michelangelo Antonioni's 1966 film, made just a few years after Feynman's prophetic talk on "There's Plenty of Room at the Bottom." The film is an existentialist mystery, in which a fashion photographer, desensitized to life itself, is inadvertently drawn into a murder mystery. In a visually stunning sequence, the photographer enlarges a snapshot of two lovers in a deserted park. And enlarges the photo again. In the grainy magnification (we begin to see the silver halide crystals) he sees a man and a gun. Or does he really see them?

Blow-up, the film, to me Antonioni's best, is art. It is artifactual, human-made, and unnatural. The remarkable images in this *Blow-up* book show real things, blown-up for sure. But... "image," "show," and "real" in our context are fuzzy words, even for a dyed-in-the-wool (now there's an image!) realist like me. Let's explore what we see here, and the meanings we attach to what we see.

IMAGE, SHOW

We are so used to photographic images, on film and now digital, that we process mentally the other-worldly mountain landscape of a gold tip of a near-field scanning optical microscope (page 53), or the "stacked sheet" picture of a layer of fat molecules (page 83), as photographs, perhaps taken through some microscope.

But they are not photographs. Oh, they do share with (digital) photography the eventual recording of an electronic signal on a detector. But the representations of the gold tip and the fat bilayer are not generated by reflected light impinging on an electronic sensor or a silver salt. In the case of the gold tip image they come from a scanning electron microscope, essentially a beam of electrons passing through, the beam recorded electronically. In the case of the stacked bilayers, the process is still more complicated. This is an atomic force microscope image, where a cantilever scans a surface, the force between tip and surface converted by a piezoelectric crystal into an electrical signal.

Is a "real" photograph any more a faithful image than these outcomes of a sequence of interactions of electromagnetic irradiation and electricity with matter? Any one who has developed and printed an image, or tinkered with it electronically in a computer, knows that the answer is "no". The standard photographic processes allow a human being to modify the image, in a process that could at one extreme be termed "deceptive," and at the other, "creative."

There is an underlying reality in the kind of images we are discussing. That reality is transformed by the interaction of a sensor of some sort into an electronic signal (in the classical photographic processes some neat chemistry intervenes), that is manipulated and amplified, eventually to print an array of black or colored dots on the paper before you. Off of which light reflects, to be transformed by molecular receptors in retinal cells into another electrical signal. That your brain processes into an image. What a journey, what a set of transformations!

REAL?

So why do some of these images seem "real," and some "other-worldly?" The mind is a complex bioprocessor that takes one piece of a visual image and compares it with another, as well as with fragmentary similar images stored in the brain, or their abstractions. We just feel that the way the light bounces off a rounded object in a 2-D image corresponds to a real orange, while in another 2-D image, perhaps less well rendered, we sense the object was made by a computer. What's interesting is that a Cézanne orange, when seen in the artistic context, is as real, perhaps more real than real. Even though when it is isolated as a visual object, stripped of its bowl and our knowledge that it is art, that luminous shape may be analyzed to be a "less successful" representation of an orange. Hollywood, or rather the humming, air-conditioned, programmer-studded rooms of Pixar or DreamWorks, have shown us something else. If the interest (read "profit") is to make us believe something is real, then these wizards of modern animation can do it. Most of the high seas in the movie *The Perfect Storm* were computer generated. Those terrible seas!

The images you see here were not intended to fool you, or to impress you with their quotidian naturalness. They were taken in the first instance to allow scientists to "see" something informative, in the second instance to communicate to other scientists what was found. And, in the context of adorning the cover of a scientific journal or this book, the images evolved into aesthetic objects.

To simulate reality for profit, to blend in, to deceive – that is not the scientist's aim. So naturalism is not on the agenda. Some of the images (e.g. page 83, the fat bilayer sheets) look "realistic" to me, just like the edge of the hazelnut-filled wafer I have just bit into. Many look unreal – the gold tip, the nanocantilever on page 31. Some are in-between, parts that we feel comfortable with, parts not of our ken. So in the image on page 49, the $Cu/SiO_2/Si$ multilayer with a hole precisely carved into it by ions, the rectangular orifice seems to me realistic, shadowed so well. But the way the light comes off the edges of the jumbled small films in the cavity doesn't feel right.

What makes things less than real? I am not an expert on rendering, but it seems that differences in surface texture, in smoothness and roughness, matter. They are compared in our brain with memories of tangible objects. So it matters the way light comes off edges – too bright, almost luminescent edges, as in the nanocantilever image and parts of the $Cu/SiO_2/Si$ multilayer image. Cézanne, unencumbered by being faithful to an orange before him, yet faithful to the essence of all oranges, would know how to fix that up. So would Antonioni.

COLOR AND FORM

The raw electronic image has no color, only intensity, shades of grey. Wavelength information (color) may be communicated as well, but most of the images before us were not interested in color. But they are "colorized." And immediately, in the choice of color(s), hue, and intensity one is led to artistic decisions.

The choices offered by the software packages scientists use are simply garish, replete with fully saturated colors. What's sad when people just push a button is that the outcome of a sophisticated experiment, with ambiguities of interpretation (not a weakness) and real achievement comes out looking like the cover of a thirties «Astounding Science Fiction», or the Italian comic books which Umberto Eco interleaves in *The Mysterious Flame of Queen Loana*.

Not the images before you. Lucia Covi taught the scientists that less is more, and that a palette with gentle pastels and browns can be very, very effective.

We enter here the matter of form. No one is born with a feeling for harmonious arrangement, for the relation of the center and the periphery, for what visually makes for repose and what for tension. Certainly not scientists. But principles of form can be taught, indeed are part of the standard education of artists. No painter wishing (or commissioned) to portray a chess game would paint it dead on from the side, one player at the left in a pose identical to his opponent on the right. So the image of Garcia and Pellegrini's quantum dots in this show (page 59) is not centered, of course, nor are its rows or columns horizontal and vertical. How dull that would be!

STYLE

The visual style of any age is set by the images that have taken hold in our minds. These come from artists, from "realistic representations" of the period, such as newspaper photographs or videos. And from scientists. A look at the advertising in «D» or «Vogue» reveals out-of-focus images, David Hockney type cubist photomontages, surrealism, and computer iconography.

Blow-up, the movie, in fact placed the anomie of the protagonist photographer, Thomas, in the world of high fashion, a world in which feeling comes only through pictures.

Do the images in our *Blow-up* break new stylistic ground, will they shape future style? Some of the design elements and the way they are posed can be related to a past. Or several pasts: So the SnO_2 nanowires (page 103) call up the importance given to foreground and background in classical Chinese painting. And to a bamboo-like feeling coupled with the tension of Japanese calligraphy. And a Jackson Pollock drip painting. That's a lot of artistic allusion for a few nanowires, but little that will shape a new sensibility.

The black and white signifying of the nanocantilever (page 31), and the gold tip (page 53), is, to me, different. These images border on the alien – the starkly illuminated softness that seems to hide something, the too sharp peaks, ridges like teeth. I find these images scary, the stuff of nightmares, what Antonioni might well use. Given their emotional impact, and a consistent coolness to them, I think there is a chance that these, or like images, will enter our stylistic universe.

ART OR SCIENCE?

The images before us are separated from their scientific source, in several ways. First they depict the very small – 500 nanometers (nm) across is the typical size. A baby's hair might be 25,000 nanometers thick. The objects portrayed are blown up. And they definitely contain secrets. But could it be that they seem almost too small to be real?

The images are also homogenized in scale. Some are nanometers across, some microns (1 micron=1000 nm). The medium, be it museum or book, pushes the pictures to one rough size.

And then these beautiful and startling images are printed on fine paper, neatly framed. All these unintentionally distancing maneuvers invite us to contemplate the images of real objects as art.

But we are "connoisseurs of chaos," patterners. So we look for resemblances to things in our experience, to other art we have looked at. All the associative power of linked human neural pathways is set loose. I see Valbusa's glass surface bombarded with Ar ions (page 99), and I see sand dunes. That happen to be blue. No matter, the image has already sent me off to another planet, to Frank Herbert's novels, and I look for signs of the Shai-Hulud in the valleys. The gold tip (page 53) is a digital Tower of Babel, or a wedding cake. And a fractal set, and the electron microscope image I once saw of a small worm's mouth.

I build multiple stories around that blue image. And it is OK, for it is in the nature of human beings to make up stories. In fact, narrative is behind the most important part of science, its imaginative part. For what are alternative hypotheses but stories?

But aren't these images also science, emerging from serious experiments? There are some scientists (do I set up straw men?) who would look askance at this twin departure – to art and storytelling – of a serious scientific investigation. Or they would see it just as window-dressing.

Relax, my friends. An object can have multiple uses, both material and spiritual.

That stepped surface of silver indeed needs to be "characterized" in great detail, perhaps to see if the 50x50 nm terraces on it are necessary for its catalytic activity. Yet within that professional study you need to imagine stories, of indexed planes, or row and step defects, being more reactive. Surfaces, rows, defects – innocent words, aren't they, just labels for structures? But actually these are all metaphors, productive and potentially misleading. We need the metaphors, as unmathematical as they be, to think of the next experiment to try.

And if the surface be interesting, and if that visual interest can be enhanced by turning the image, cropping it, coloring it not the hue of macroscopic silver – that is just fine. The image of the surface is beautiful. That beauty is complemented by the intellectual beauty the scientist perceives in the surface, as he or she thinks hard about it. Beauty resides, as Kant said (in a fuller and more involuted way, you can be sure), in the interplay of cognition and imagination.

The nervous motion between art, narrative, and science - taking in visually the formal qualities of the image, letting it please or disturb us, setting the associations loose, thinking about the underlying microscopic structure and function and how a scientist discerns and creates it – all of these make for a richer life, for understanding. For art, and just perhaps, for better science.