Aesthetic cognition and synosia

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Over many years, I have come to the conclusion that aesthetic considerations are in and of themselves ways of thinking about scientific ideas and that sensual experience is the basis of the intuition we bring to our work. I have recently introduced the concept of 'aesthetic cognition' as a way to talk about such sensual and aesthetic thinking (Root-Bernstein 2002). Following in the footsteps of physical chemist Michael Polanyi, I firmly believe that we each develop a kind of 'personal knowledge', or intuition, about how nature works that comes from our own, sensual and intimate interactions with it (Polanyi 1958). The result is that we each develop two types of understanding: formal knowledge of things that we learn through books, lectures, conversations, and other forms of communication; and equally important, intuitions that we develop through our sensory interactions with materials in experiments and other forms of play. In addition, we bring to everything we do a sense of aesthetics that we develop in part through our professional activities (what is an elegant experiment) and our hobbies (why is this painting or poem or song more beautiful than another?). Combine the intellect, the senses, and aesthetics and one gets what I call 'synosia', from the root words 'synaesthesia' (using all one's senses interactively) and 'gnosis' (Greek for knowledge). Synosia, in short, means 'synthetic knowing' that melds objective and subjective ways of knowing. One knows what one feels and feels that one knows (Root-Bernstein & Root-Bernstein 1999). Aesthetic cognition results from the fact that there is a 'meta-logic' to the intuitive responses that is embedded in what we call scientific aesthetics. From the examples given above, it must be clear that aesthetic cognition precedes and is distinct from formal logic, nonetheless yielding insights that are amenable to logical development and analysis. In sum, aesthetic cognition combines knowledge and feeling into synosic intuition that is the basis for creative scientific thinking.

The concepts of aesthetic cognition and synosia unexpectedly integrate two outstanding problems in the philosophy of science. One problem is the division made by Karl Popper and many other philosophers of science between the 'logic of research' and 'psychology of research'. Logic, in this formulation of the philosophy of science, is applicable only to well-formulated ideas that have already been expressed in mathematical or verbal formulations by scientists. How such well-formulated ideas come into being is relegated to the realm of 'psychology of research', which most philosophers have placed beyond the consideration of their field. The other problem that aesthetic cognition and synosia bring into the fold of the philosophy of science is the consideration of aesthetics itself. While there is a very strong tradition of philosophical discussion about aesthetics in the arts that can be traced at least to the ancient Greeks, the role of aesthetic considerations in science is a relatively new and undeveloped field. My contention is that understanding the role of aesthetics in science requires consideration of sensual and emotional responses to nature similar, if not identical, to those involved in considerations of aesthetics in the arts (McAllister 1996). Understanding how these individual and subjective sensual and emotional responses underlie the urge to do science – that is to understand nature itself – gets us directly, via philosophical considerations, into novel areas of cognition. Thus synaesthesia, as a basic concept within aesthetics, turns out to be a form of cognition – hence, aesthetic cognition.

The view that sensual and aesthetic considerations are a way of thinking about science should not, for all the reasons I have summarized above, be a surprising conclusion, but I suspect that for many people it will be. Science is often described in textbook formulations of the scientific method as being distinguished from the arts by being objective, intellectual, analytical, unemotional, and verifiable. The arts, in contrast, are supposedly subjective, sensual, synthetic, emotional, and idiosyncratic. Recognizing that all scientific insights originate in highly subjective, sensual, and aesthetic ways suggests that this science-art distinction does not hold water. The interesting philosophical issue becomes the problem of how emotional, sensual, and

idiosyncratic intuitions can form the basis of objectively verifiable analytical results. The connection involves how scientists perceive problems and patterns. What is an hypothesis or theory but a pattern that we recognize within diverse sets of data; and what is a problem but the breaking of a pattern or our inability to perceive how some data fit into any known pattern?

The fact is that we *feel* what is right and wrong about scientific ideas. Thus, the importance of aesthetic cognition is that it makes intuitional understanding comprehensible and useful by showing us how sensual ways of knowing are connected to rational ways of knowing. Our feelings tell us whether what we are learning or observing or theorizing fits with the somatic and sensual understanding of nature that we call intuition.

Thus, I have found that the bodily feelings, emotional responses, and visual images that I had when I looked at the drawings of the DNA double helix and imagined unwinding it like a rope are not uncommon among creative chemists. Some, indeed, go much further than I did, actually imagining themselves to be the objects of their study (Root-Bernstein 1990). Thus, Peter Debye (Nobel prize, 1936) said that the key to his insights was, "to use your feelings – what does the carbon atom *want* to do? You had to […] get a picture of what is happening. I can only think in pictures" (Debye 1966, p. 81). Cram was similarly visual: "I have always felt that I understood a phenomenon only to the extent that I could visualize it. Much of the charm organic chemical research has for me derives from structural formulas." (Cram 1990, p. 122) For Cyril Smith, chemistry involved all of his senses: "In the long gone days when I was developing alloys I certainly came to have a very strong feeling of natural understanding, a feeling of how I would behave if I were a certain alloy, a sense of hardness and softness and conductivity and fusibility and deformability and brittleness – all in a curiously internal and quite literally sensual way, even before I had a sensual contact with the alloy itself." (Smith, 1981, 353) He goes on to say similarly, that his later work, "on interfaces really began with a combination of an aesthetic feeling for a balanced structure and a muscular feeling of the interfaces pulling against each other!" (*Ibid.*) The mathematical physicist Wolfgang Pauli (Nobel Prize, physics, 1945) also maintained that scientific thinking begins within the "unconscious region of the human soul," where, "the place of clear concepts is taken by images of powerful emotional content, which are not thought, but are seen pictorially, as it were, before the mind's eye" (Heisenberg 1974, pp. 179-180; Chandrasekhar 1987, p. 146). Karl Popper has gone so far as to actually recommend such empathetic thinking as the basis of creative scientific thought. "I think the most helpful suggestion that can be made […] as to how one may get new ideas in general [is …] 'sympathetic intuition' or 'empathy' […]. You should enter into your problem situation in such a way that you almost become part of it" (Krebs & Shelley 1975, p. 18).

Intuition developed through careful attention to feelings, sensual and aesthetic, are therefore at the basis of chemical knowing, not the antithesis of rational thought. When Mulliken wrote that he "smell[ed] various compounds […] to look for resemblances or differences in the odors of similar or related compounds," (Mulliken 1989, p. 20) this was a process that differed in no way from the chemist who examines tables of data or chromatographic charts in search of patterns of properties. Each approach yields information useful for thinking about chemical properties. The fact that one is sensual and the others analytical does not alter their utility as ways of thinking about chemistry. Thus feelings are a way of thinking just as intrinsic to science as logical analysis.

A necessary corollary to my concept of aesthetic cognition is that ideas arise in individual minds in private terms that must be translated in an explicitly secondary process for communication with other people (Root-Bernstein & Root-Bernstein 1999, chap. 1). We discover in very personal ways using private 'mental languages' such as emotional feelings and sensual images that only we understand. These need to be transformed into publicly traded forms. Lipscomb, who like Debye is very visual, has addressed this translation process directly: "My language is my visualization of what molecules are doing either in their structure, their transformations, or their reactions, and I translate that either into chemical language or into mathematics, but not into English. It's surprising how little one uses English in the actual working out of science. Most people who are not scientists believe that they think in terms of language. I'm not quite sure

that they do. I know that I don't. I later put it in English, but it's the third stage of the process." (Curtin 1982, pp. 134-135) Smith has written similarly that, "before publishing anything I tried to put it in respectable scientific terminology and it was fun to do so, but the stage of *discovery* was entirely sensual and the mathematics was only necessary to be able to communicate with other people" (Smith 1981, p. 353). Perhaps it is the fact that insights are always developed through such private forms of thinking that has hidden the crucial roles that sensual images and aesthetics play in discovery processes in favor of the public forms of discourse that scientists employ between one another. In any event, it seems to me that this translation process is another aspect of the 'scientific method' that is badly in need to formal study and instruction (Root-Bernstein 2002).

Sensual Chemistry

Aesthetics as a Motivation for Research

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