"Elegant Solutions: Ten Beautiful Experiments in Chemistry"
by Philip Ball, Royal Society of Chemistry, 2005, 212 pages, $39.95

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"Beauty is truth, truth beauty"---that is all
Ye know on earth, and all ye need to know.
(Keats, *Ode on a Grecian Urn*)

If that's really all ye need to know, then all experiments that yield truth are beautiful, and ye shouldn't waste your time trying to assess relative beauty. But people do it anyway, despite Keats. A few years ago (Aug. 25, 2003), C&EN published a list of the ten "most beautiful experiments in chemistry," along with fifteen runners-up, chosen from nominations submitted by ACS members (in response to a challenge from then-editor Madeleine Jacobs) by a panel of eminent chemists and historians of chemistry. Independently, around the same time, noted science writer Philip Ball was invited by the Royal Society of Chemistry to come up with his own list. This book is the outcome of that project.

Ball's stated goal is not so much to achieve a definitive list as to highlight the importance of experiment to the historical development of the chemical sciences, with particular emphasis on "the gap that sometimes exists between the popular notion of how they [the experiments] happened and what they meant, and (as far as it can be discerned at all) the historical reality." He is largely successful in that effort, although he does not always respect his disclaimer about the possibility of determining "historical reality." For example, his chapter on Pasteur draws heavily on the work of historian Gerald Geison, an unquestionably valuable counterpoint to the traditional accounts of Pasteur's life and work. But Geison's account has in turn been challenged, by critics as diverse as Max Perutz and Bruno Latour. Calling it "the real story," as Ball does, may be a bit of overreaction. Nonetheless, both chemists and non-chemists will find plenty of entertaining and informative material in this attractive and well-written book.

Ball further hopes his work will stimulate discussion, because "there is nothing like a list to provoke comment and dissent." I'm more than willing to provide some dissent — not so much about the particular choices made, but rather on the whole idea of ranking experiments as more or less beautiful. Both Ball and the C&EN panel acknowledge that identifying standards of beauty that might attract broad (let alone universal) agreement is problematic. In fact, the two lists are far from identical. Ball did consider the C&EN list, which appeared while his work was in progress, but in the end included only three of its top ten (Pasteur's manual separation of enantiomeric crystals — number one on the C&EN list; Bartlett's preparation of the first xenon compound; the Curies' isolation of radium) along with two more from the next-best group (Cavendish making water from its component elements; Urey and Miller's production of amino acids by zapping a model prebiotic atmosphere). The remaining five include two from the realm of nuclear chemistry (Rutherford's identification of alpha particles as helium ions; Seaborg's generation of transuranium elements) and two from organic synthesis (Woodward's B_{12}; Paquette's dodecahedrane). For the tenth, see below.

While none of these choices is objectionable as a beautiful experiment, neither the lists themselves nor the similarities and differences between them offer much insight into what criteria — in particular, what *aesthetic* criteria —might be used to evaluate beauty. The subtitles for each of Ball's chapters suggest specific characteristics of beauty, but most of them are not very helpful. They include a pair of apparent opposites ("detail" for Cavendish, "simplicity" for Pasteur); a couple that do not stand out as obvious properties of beauty ("patience" for the Curies; "simplemindedness" for Bartlett); and at least one ("elegance" for Rutherford), that stands as much in want of definition as "beauty" itself.

Indeed, several of the C&EN panelists pointedly eschewed *any* aesthetic evaluation in favor of historic importance. According to Arnold Thackray, "by beautiful, we mean holding profound significance to us today." While Ball questions that conflation of concepts, noting that "there is no real reason why we should demand that a beautiful experiment also be an important one," he acknowledges that all of his chosen examples *do* pass the significance test. It would be interesting to see what (if any) experiments these pundits consider significant but *not* beautiful; perhaps that could point to some absolute criteria of beauty. Ball does observe that Perkin's synthesis of mauve (ranked 5th in C&EN) was messy, inelegant, and accidental to boot; but he lets it back in (though not to the top ten) because it produced a beautiful outcome — the purple dye itself.

Another issue, which receives little attention in either list, is the question of what counts as chemistry. Ball's tenth selection — van Helmont's 17th century "demonstration" that the increase of weight of a growing tree comes from the water used to moisten it, not the earth in which it is grown — is included as a very early illustration of the power of quantitative measurement; but is it a good example of a *chemical* experiment? (It also reached an erroneous conclusion, of course: the weight increase comes mainly from the air.) Conversely, if I were making my own list of beautiful experiments in chemistry (which, it should be clear by now, I would do only with the greatest reluctance), I would definitely

include the Meselson-Stahl experiment — determining the mechanism of DNA replication by isotopic labeling — which has been called "the most beautiful experiment in *biology*." (For an excellent account, see the eponymous book by the late historian of chemistry Larry Holmes). It would surely get very high marks on any of the aesthetic criteria offered (elegance, simplicity, etc.) as well as that of significance; does it not qualify as chemistry? For me it does.

Returning, finally, to the focus on significance: one unfortunate consequence is the complete absence of anything of recent vintage. Only the two syntheses (B_{12} and dodecahedrane) from Ball's list, and nothing at all from the full C&EN list, are less than fifty years old; the large majority (22 out of 30 in the combined lists) are pre-20^{th} century. I would bet that any chemist could offer at least a few examples of newer work that rival any of the chosen ones for elegance, but apparently nobody did so. Clearly the latest experiments have not yet withstood the test of time, but this absence may well reflect unconscious preferences at least as much as any explicit appeal to historical significance as a standard for beauty. Psychologist Norbert Schwartz has recently (*Daedalus*, Spring 2006) described experiments that show that subjects are more likely to find beauty in a familiar object. That may suggest that the selections in these lists just represent the most often-told stories of our chemical heritage, the best efforts to justify them on aesthetic grounds notwithstanding. Schwartz further observes that judgments of truth also depend heavily on familiarity. It looks like Keats was right all along.