The Advancement of Science, and Its Burdens

Gerald Holton
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In this thoughtful book, Gerald Holton considers both blades of our sword of Damocles, the thought-provoking advancements and the concomitant burdens of science. Holton, a renowned historian of science, takes the philosophical and historical high road on his trip from the past glories of Albert Einstein, Werner Heisenberg and Robert Oppenheimer to the burdens of the broader societal implications that scientists must consider – the bad along with the good. It is pedagogically wise for our graduate students to have this book to bridge the river of human events from those glorious achievements to the other side of burdens, at once less precise and less logical. Holton's approach works extremely well when addressing the "achievements" side of the coin, but is less satisfactory for the flip side because the burdens are more complicated than nature itself.

First, the "advancement": Both experimenters and theorists suspend their disbeliefs to jump creatively to their solutions based on intuition. Holton has examined data books to discover that Robert Millikan ignored data with "larger errors" because deep down he wanted electrons to have a unit charge. This bold, controversial stroke eliminated the fractionally charged electrons that had some support in other laboratories. Alternatively, theorists suspended various disbeliefs to create the discreteness of quantum mechanics and a relativity where time is suspect.

By using fundamental presuppositions containing elements of symmetry, causality, completeness, continuum and invariance, Einstein concluded that "the noblest aim of all theory ... is to make these irreducible elements as simple and as few in number as is possible without having to renounce the adequate representation of any empirical content." Holton contends that the two-dimensional approach of combining physical phenomena and mathematical analysis must be expanded to include a third, orthogonal axis that folds in the presuppositions of symmetry, causality and so forth. This type of right-brained thinking is not strictly linear and logical in that it can require suspending disbelief and tolerating ambiguity, but it often has led to the "truth." The first two thirds of the book contain a number of interesting quotes and insightful revelations, such as the image of Max Planck, the creator of the quantum concept, fighting its corpuscular implications in 1927 by saying, "Must we really ascribe to the light quanta a physical reality?" Or consider Wolfgang Pauli's statement in 1925 that "physics is decidedly confused at the moment; in any event it is much too difficult for me and I wish I ... had never heard of it."

Second, the "burdens": From the well-defined high ground of achievement, Holton is forced to descend into the less precise regime of burdens, where we do not have the friendly guideposts of symmetry and invariance to help us find our way. Linear, logical thinking will need more than a third axis if we are to succeed here because issues such as the arms race are driven by vague, less clearly defined driving forces such as mirror imaging, deterrence, marginal cost, countermeasures, hidden agendas and governmental debates that often are too politically pragmatic. However, Holton gets very high marks for leading the deeply philosophical into thinking about the responsibility of being a scientist. Certainly Einstein felt his burdens in his own end game, the manifesto he wrote with Bertrand Russell in 1955, in which he

encouraged us to consider our burdens by stating: "We have to learn to think in a new way. We have to learn to ask ourselves, not what steps can be taken to give military victory to whatever group we prefer; for there no longer are such steps." These words stimulated the establishment of the Pugwash movement, through which the international science community has considered its collective burdens. My guess is that Einstein would consider the Pugwash legacy equivalent to his trio of papers from 1905. The real question is, how can we do better to ensure the good uses of science and to avoid the bad uses of science? One possibility that has occurred to me is a science court – with penalties for errors of commission and omission. Holton suggests the use of "combined mode" research to expand the study of basic concepts along with their implications. In fact, this approach is the hallmark of studies produced by the Congressional Office of Technology Assessment, but unfortunately only a few universities have really taken up this call since professional rewards come from digging deep rather than broad. I was encouraged to read in Jan Beyea's letter in PHYSICS TODAY (October, page 152) that he is drawing up a list of possibilities for physicists who wish to devote 10% of their time to applying physics to societal problems-much in the manner of lawyers doing *pro bono* work. With some hard work, we might yet agree with Einstein and remove some of the dice-playing in our universe.

In summary, Holton's book on the advancements and burdens of science is a good supplemental and broadening text for first-year graduate students (as well as more mature practitioners). By staying on the philosophical high road, Holton avoids the politization of discussing specific burdens, thus making it more likely that his book will be used as a starting point in graduate courses.

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