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Pseudohistory and Pseudoscience

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Abstract. The dangers of pseudoscience – parapsychology, astrology, creationism, etc. – are widely criticized. Lessons in the history of science are often viewed as an educational remedy by conveying the nature of science. But such histories can be flawed. In particular, many stories romanticize scientists, inflate the drama of their discoveries, and oversimplify the process of science. They are, literally and rhetorically, myths. While based on real historical events, they distort the basis of scientific authority and foster unwarranted stereotypes. Such stories are *pseudohistory*. Like pseudoscience, they promote false ideas about science – in this case, about how science works. Paradoxically, perhaps, the history of pseudosciences may offer an excellent vehicle for remedying such impressions.

> *Characteristically, textbooks of science contain just a bit of history, either in an introductory chapter or, more often, in scattered references to the great heroes of an earlier age. From such references both students and professionals come to feel like participants in a long-standing historical tradition. Yet the textbook-derived tradition in which scientists come to sense their participation is one that, in fact, never existed.*
>
> –Thomas Kuhn, *The Structure of Scientific Revolutions*

1. Introduction

Every science teacher, it seems, knows the dangers of pseudoscience: parapsychology, astrology, new age healing, creationism, UFOs and the like. While defined variously, pseudoscience essentially tries to claim scientific authority where there is no science. Individuals may ‘conjure’ science using the emblems of its authority (Toumey 1997), or they may mislead their audience by using evidence selectively. Science teachers often endeavor to teach the nature of science, so that students will not succumb to the illegitimacy of pseudoscience.

Here I discuss a variant of this syndrome: *pseudohistory*. Pseudohistory, like pseudoscience, uses facts selectively and so fosters misleading images – in this case, about the nature of science. I refer, in particular, to stories that romanticize scientists, inflate the drama of their discoveries, and oversimplify the process of science. They often use rhetorical devices that, literally, give them mythic status (Allchin 2003a). While based on real historical events, they are deeply misleading.

They contribute to unwarranted stereotypes and false ideas *about how science works*. Science educators especially, I fear, perpetuate many such stories. But they are also ideally positioned to remedy such misperceptions. Here, I provide an extended example of pseudohistory offered for science teachers (Section 2), then distinguish between pseudohistory and false history (Section 3), and elaborate on pseudohistory as pseudoscience (Section 4). Ironically perhaps, placing pseudosciences in their historical context may deepen understanding of the nature of science for students (Section 5). I conclude by summarizing some simple strategies for the science teacher who faces the challenge of assessing history without historical expertise (Section 6).

2. Appropriate History | *Appropriating* History

Distinguishing between history and pseudohistory is essential for the teacher in the classroom. To begin, then, I show just how the difference can matter – not about the historical details themselves, but about how those details shape perceptions of the nature of science. I also want to highlight how someone unfamiliar with history might recognize an account as possibly misleading. I illustrate the problem with a recent example: a discussion of William Harvey's discovery of the circulation of the blood presented to a wide audience of biology teachers.

Harvey was certainly a prominent figure in the emergence of modern science (Pagel 1967, 1976; Frank 1980; Hamburger 1992). A physician to royalty, he claimed that the blood did not move on its own to its 'natural place', but was propelled by the action of the heart. Moreover, blood is not merely used up in the extremities. Rather, it continues to flow as in a natural cycle. Harvey's peers certainly recognized his conceptual achievement, although some disputes arose. Harvey also epitomized early efforts in experimental investigation in the 1600s. He thus prospectively serves as a model for introducing students to these concepts and to the very methods of modern science.

Indeed, in the treatment I am considering, Harvey – along with four other historical cases - was presented explicitly to exemplify 'The Generality of the Hypothetico-Deductive Method' (Lawson 2000, quoted below). Thus, it seems at first glance to offer a valuable synopsis of history and material for classroom lessons. But the persuasive context is an important clue. The case is introduced:

> Let us start with early theories of blood flow and the classic research of William Harvey to see how his thinking can be cast in the form of hypothetico-deductive arguments. (p. 482)

Note the phrase '*can* be cast'. The primary aim seems to be fitting the history into a predetermined philosophical mold. History interpreted through an ideological lens can be misleading, of course. Thus, a historian would demur here. And justly so. As I will show, some facts were misrepresented and other relevant facts were omitted, with powerful rhetorical effect. The fundamental approach was echoed later:

> The hypothetico-deductive reasoning behind his experiment can be reconstructed as follows ... (p. 483).

Reconstructions are easily shaped by retrospect. They can fail to capture the original historical context and the process as it happened *prospectively* (Allchin 1996). To understand the nature of science, one wants to understand how Harvey actually reasoned, not how he *might* have reasoned according to some idealized scheme. Anything less trivializes what contributed to his very real achievement. Thus, the careful reader may hesitate at the very outset. Indeed, this case was ultimately about appropriating history, not appropriate history.

First, this reconstruction distorts Harvey's investigations. It makes deductive logic seem central and his method seem much simpler than historical evidence indicates. In his 1628 book, Harvey reported numerous demonstrations by which one might observe his claims. He encouraged the would-be skeptic to trust his own observations, rather than the authority of a text. The most famous demonstration is portrayed in an oft-reproduced diagram of a ligatured arm. Harvey adapted it from one that his teacher, Fabricius, used to illustrate the presence of valves in the veins. Harvey exhorted his reader to see the evidence for unidirectional flow in veins: 'But that this truth may be made more apparent ... '(Chap. 13). However, when this was reconstructed for teachers, it became *Harvey's own* decisive investigation. It was treated as his *planned test* based on a *theoretical prediction*. The implication was that Harvey accepted or rejected his theory based on the results of this bold test, as in a Popperian ideal. The persuasive context of Harvey's text was completely ignored. Moreover, Harvey's work was cast according to the standard rhetoric of a *modern* scientific paper. The account discounts the role of Harvey's many years of observations and vivisections, well before he developed any explicit theory of circulation. The account for teachers seems to show, through Harvey's example, that scientific discovery occurs through a very deliberate, unproblematic and quite formulaic method. Success in science seems guaranteed by simply following the rules.

Harvey's imagined if-then reasoning is 'reconstructed' in other cases. Most notably, the account parades what it portrays as Harvey's greatest triumph: the prediction of capillaries (pp. 483, 484; also see Lawson 2002). Although no one could observe them at the time, Harvey supposedly boldly saw the implications of his theory:

If ... the blood flows away from the heart in the arteries, and
If ... the bloods flows towards the heart in the veins,
Then ... the arteries and the veins must be connected by unseen capillaries.

Harvey's impressive 'if-then' reasoning, we are told, later inspired Marcello Malpighi's observations, which ultimately proved the theory. This is certainly how we might reason today, knowing that capillaries exist. When I began teaching biology many years ago, I encountered this myth about Harvey – and believed it uncritically. I had not yet been alerted to think about bias in history. Would that I had been inspired then to read Harvey's original work, which is eminently accessible. In his classic *De motu cordis*, Harvey describes how blood percolates in the lungs and is collected as though *from a sponge* (Chap. 7). Blood *permeates the* *pores* in the flesh, he said (Chaps. 10, 14). In a later publication he echoed that it is *absorbed* and *imbibed from every part* by the veins (*A Second Disquisition to John Riolan*). Harvey had dissected many 'lesser' animals that have hearts but no blood vessels (open circulatory systems, in our terminology). He had observed directly that connections were not needed for circulation. *Harvey did not predict capillaries* (Elkana & Goodfield 1968). Nor were Malpighi's investigations guided by Harvey's work (Allchin 2003b). But it is not the historical misconceptions that matter so much as how they are used rhetorically. This account instructs teachers that the non-existent prediction is 'an excellent example of how theory generation and test directs observations – rather than the other way around'. It lauds Malpighi's discovery as 'very impressive' just '*because* the theory led to the *prediction* that capillaries should eventually be seen' (p. 484, italics in original). The error functions explicitly in promoting a specific image of scientific thinking. It seems to result from reading a modern methodology into Harvey's 17th-century perspective.

Harvey's reasoning is contrasted especially against the conclusions of the Greek physician Galen centuries earlier. Galen knew that blood entered the left chamber of the heart and had supposed that blood not only seeped in from the lungs but that some also permeated the septum of the heart from the right side. Here, we are told how theory guided Harvey, absent any prior observation, to infer that no holes exist there – a deduction that he then tested (p. 483). We do not learn that Andreas Vesalius had criticized Galen on this very point decades earlier. Vesalius, of course, did not use any theory or elaborate reasoning process. It was simply a 'brute' anatomical observation. Vesalius does not fit the philosophical model and is not mentioned all too conveniently. Moreover, Harvey quotes extensively from Galen himself in trying to persuade his readers that blood flows from the right to the left side of the heart via the lungs (Chap. 7). As in the case of the ligatured arm, Harvey's 'test' on blood flow through the septum functions more as a persuasive demonstration than as inquiry towards discovery.

These three elements of the reconstructed account confirm the initial suspicion that the history might be misleading due to conceptual shoehorning (Allchin 2003b). Far more important, however, is understanding how they mislead. An essential principle for historians is respect for historical context. Failing this principle, by reading the past in terms of current norms or standards, earns its own label: *Whiggism*. This perhaps odd term derived from the practice of a political party in Britain to cast history as substantiating their own eventual power (Butterfield 1931). The history functioned as a political device for legitimizing authority. One element was erasing historical contingency, making it seem that the outcome was inevitable. It cast historical actors as acting for anachronistic reasons. Histories of science, too, may exhibit Whiggism when they cast a particular theory, now deemed correct, as proven from the very start. Other ideas, for example, are framed as opposing it, rather than as alternative trajectories in a blind process of trial and error. The historical uncertainty is suppressed. The reasons scientists might have supported an alternative is regarded as due to psychological or sociological *inter-*

ference, rather than based on evidence or proper scientific judgment of the time. To portray the history of science otherwise may seem to threaten the legitimacy of the final outcome and, with it, the ultimate authority of science. Of course, historical scientists could have reasoned scientifically, yet still, ultimately, been 'wrong'. Whiggish history of science eclipses that possibility. It blames all errors on unscientific factors and credits all success to proper method alone. The account of Harvey reflects the tendency to make the past conform to a present ideal. It tries to ensure progress through logic. It also reflects how an appeal to history may function ideologically. The strong Whiggish perspective is thus a clue for the reader to interpret the account's relative reliability.

The science teacher not deeply informed about history might not be able to notice or articulate the particular errors noted above. But the tendency towards Whiggism is evident there and in other ways as well. For example, critics of Harvey are portrayed as persons who 'held fast to prior beliefs' 'regardless of an impressive amount of both qualitative and quantitative evidence in favor of circulation theory' (p. 484) – that is, as irrational. (Waiting for the proof of Harvey's presumed prediction, ironically, is portrayed as critical here.) Harvey's critics seem to obstinately impede the inevitable. One never learns how they might have interpreted Harvey's observations differently, or why they might have *reasonably* considered them irrelevant, misleading or flawed (Gregory 2001, pp. 115–136). Even the non-historian may notice the Whiggish omission and wonder. The teacher should always *strive to understand context*.

Consider, again, Harvey's analysis of Galen's claims about the septum of the heart. The observation seems so obvious that one may feel like blaming Galen for missing it. This, too, contributes to the Whiggish sense of correcting Galen's ancient beliefs and 'imagined' blood flow (p. 482). Progress seems to depend on the power of Harvey's style of reasoning. If one is interested in scientific reasoning, however, one might also wonder how *Galen* reasoned. As Harvey himself mused at one point, 'I wonder what would have been the answer of that most ingenious and learned man?' (Chap. 5). Galen was a pioneer in dissection. He hardly would have advanced a claim foolishly, absent any observation. One would never guess, for example, that Galen remedied earlier misinterpretations about arteries. Arteries, meaning 'air ducts', had been so named because they had been empty in cadavers. Through his own observations Galen was able to assert, however, that blood indeed flowed through them. As Harvey himself acknowledged, Galen also understood how the valves of the heart ensure one-way flow. Galen's ideas were respected for over a millenium, yet this account does not address why. Again, the truncation of context is itself a telling clue.

Finally, context is missing in the treatment of how Harvey developed his theory. Namely, how did his new ideas originate? 'Harvey's guiding analogy', we are told, 'was . . . circular planetary orbits and the belief that large-scale planetary patterns should be echoed in smaller-scale physiological systems' (p. 482). This is the microcosm-macrocosm concept of the chemical philosophy, exemplified in the writings of Robert Fludd, a friend of Harvey's. The analogy also extended to chemical distillations, strengthening the analogical resonance. Harvey expounded this image throughout his book. He referred to the heart as the sun of the microcosm, giving warmth and life to the body. In a Whiggish view, this is very strange – perhaps 'unscientific'. It may seem counterintuitive to us now that the microcosm worldview could have led Harvey to discover something we now regard as true. Historians concur, however, that the analogy was *integral* to Harvey's very *reasoning* (Pagel 1967, Frank 1980). In this account, however, the analogy quickly becomes peripheral. After all, *we* cannot justify it logically or empirically. What seems to matter, then, are only logic-driven tests, which can contribute to a Whiggish framework of legitimation. The creative element of scientific thinking is thereby obscured. In Harvey's case, the microcosm analogy was not an incidental inspiration soon abandoned after empirical study. His text presents it as a further argument. Other later cited it as a *reason* to accept Harvey's conclusions. One cannot regard the analogy as peripheral if one wants to understand Harvey's reasoning and thus portray science faithfully to students. In the history for teachers, the discussion of Harvey's thinking is incomplete. The context is missing. Hence, the perceptive reader may consider the account suspect – even without knowing the historical significance of the microcosm analogy.

The problem of Whiggism is primarily one of elided content. Yet stylistic clues may betray a misleading account, as well. Historians question, in particular, accounts that tend to romanticize scientists as saint-like heroes. Such *hagiographies* mislead by hyperbole and/or by reporting only what reflects favorably on the scientist. Consider, for example, the dramatic introduction of Harvey as a character in the story:

> Galen's theory of blood flow was virtually unquestioned for nearly fifteen hundred years until 1628 when the English physician William Harvey (1578–1657) published a book . . . (p. 482).

The statement may seem harmless enough. But it casually discounts others who, before Harvey, had introduced new ideas about circulating blood flow (e.g., URL: www.timelinescience.org/resources/teacher/blood.htm). For example, the 'pulmonary transit' had been recognized by Michael Servetus in 1553, Realdus Columbus six years later, and Andreas Cesalpius in 1603, although each for different reasons. All three questioned Galen's authority. Moreover, Ibn al-Nafis discussed pulmonary blood flow in the 1200s, during the Golden Age of Arabic science. The statement collapses contributions from several physicians over at least a century into just one person: William Harvey. Now, set aside again the historical details and any cultural slight. The rhetorical effect of the omissions is unmistakable. Harvey's genius is inflated. In the same way, Vesalius's earlier commentary on Galen is missing. Harvey's amplified achievement contributes to seeing him as a landmark authority, or model scientist. The implicit lesson is that Harvey seemed to exercise some extraordinary skill that his peers did not. This primes the following discussion, which reconstructs Harvey's work to promote science as 'largely hypothetico-deductive in nature' (p. 482). The monumental, virtually superhuman Harvey may clue the reader to the myth-like hagiography (Allchin 2003a).

As noted earlier, the account of Galen is incomplete. This has significant consequences narratively, as well. That is, Galen represents the ideas which Harvey must disprove. In the hagiographic perspective, then, Harvey must be completely 'right' and Galen completely 'wrong'. Galen becomes a competitor, or adversary, like a villain in a melodrama. Knowledge and ignorance conflict. Dramatically, Galen's theory is 'finally dealt a fatal blow' (p. 384). Harvey's stature as 'hero' is amplified. But because Galen is virtually a caricature (Gauld 1992), he is hardly more than a straw man, here. There is no real sense of intellectual encounter, because only reasoning supporting Harvey is included. The asymmetry of perspective is another clue that this account does not illuminate the process of science, but again uses Harvey only for authority.

A final hagiographic element is *how* the (false) story of the prediction of capillaries is presented. Harvey's impressive 'if-then' reasoning, we are told, was ultimately vindicated. But only fourteen years after Harvey's death (p. 484). The tragic irony, here, evokes sympathy for Harvey and charges the lesson with emotion. Harvey is not only a hero. He is almost a martyr, apparently having never enjoyed the full glory he was due. Of course, one can celebrate scientific achievement without romanticizing it or relying on falsehoods. The inflated drama is another signal that the reader should not regard the history as reliable.

As detailed above, the account of Harvey I have analyzed includes *numerous* historical sleights: omitting antecedant thinkers, vilifying Galen, imagining that Harvey predicted capillaries, mistaking rhetoric for investigation, suppressing the role of the microcosm analogy. The individual errors are not as important as their common therme: everything is shoehorned into an idealized model of scientific reasoning and genius. While misrepresenting history, they also misrepresent *the nature of science*. This is not just a streamlined account that omits needless detail. By eclipsing historical context and romanticizing the scientist as hero, it actively misleads. This is not appropriate history for understanding science. Rather, it is *appropriated* history for promoting a particular notion about how science works. When historical integrity suffers, so too do the lessons about nature of science.

Note, too, the role of the history itself. A perspective inscribed into history tends to garner the semblance of naturalness or authority. The strategy is, essentially: 'Observe how great science was done historically'. But the history here does not function as an idle illustration. History may seem transparent. For some, it may seem only a matter of describing plain historical facts. Yet selective use of such facts, like selective use of facts in science, can mislead. An incomplete or biased history that obscures the original historical context can *lie*.

Whiggish history and hagiography misrepresent history. While drawing on some authentic elements of history, they are ultimately *pseudohistory*. Fortunately for the novice, one can typically recognize the basic errors *stylistically* and through *telltale omissions* (Figure 1, Section 6). Equipped with the proper analytical perspective, a reader may recognize when a history is probably untrustworthy. One need not know the actual history in detail.

3. False History | Pseudohistory

Not every science teacher can become a professional historian, of course. While teachers should certainly be concerned about historical accuracy, my primary focus here is not false history. For example, many popular anecdotes are apocryphal: the apple falling on Newton's head, Galileo dropping balls from the Leaning Tower of Pisa, Archimedes shouting 'Eureka!' as he ran from the baths naked through the streets of Athens, among others. These seem relatively harmless. Some such stories are still debated by historians, who can't seem to document conclusively whether some historical figure's remark is trustworthy. We need not be unduly preoccupied with inconsequential infelicities.

Other false stories can be misleading. For example, Darwin did not deduce natural selection upon seeing the finches on the Galapagos Islands. The Church during the time of Galileo *supported* astronomical investigation and many challenged Galileo's claims *scientifically*. When Columbus set out on his voyage, educated persons did *not* believe that the world was flat. The photoelectric effect did not inspire Einstein's concept of the photon (Whitaker 1979). While many science teachers have promulgated such false stories, I think most treat them with caution once they learn otherwise. Science teachers tend to respect historical fact, I think. They seek to avoid historical error as much as scientific error – when they know the history. Thus, historians do have an important role in publicizing their findings and in informing science educators.

My concern, however, is not false history per se, but *pseudohistory*. Pseudohistory conveys false ideas about the historical process of science and the nature of scientific knowledge, even if based on acknowledged facts. Fragmentary accounts of real historical events that omit context can mislead, even while purporting to show how science works. For example, a romanticized tale of discovery may overemphasize the contributions of one individual, minimize the role of accident or errors, simplify the investigative process, disguise less than noble motivations, hide the effect of personal or cultural values, as partly illustrated in the Harvey case. They turn real science into an imaginary idealized science. Such a misleading selective history masquerading as responsible history is justly called *pseudohistory*.

Michael Shermer and Alex Grobman (2000) have recently used the term pseudohistory to describe Holocaust denial. One may regard such denials, however, as simply blatant disregard for documented history: another case of demonstrably false history. The concept of pseudohistory underscores the role of the implicit historical lesson, even when many of the basic facts are reliable. Robert Todd Carroll, in his online *Skeptic's Dictionary* (2001), echoes this dimension of pseudohistory:

> Pseudohistory is purported history which ...
> is on a mission, not a quest, seeking to support some contemporary political or religious agenda ...

is selective in its use of ancient documents, citing favorably those that fit with its agenda, and ignoring or interpreting away those documents which don't fit.

The bias or agenda may surely also be philosophical or cultural, not always blatantly ideological. Also, pseudohistory need not be deliberate or intentional. It may result from negligence or even naivety. One cannot suppose that this account, despite its flagrant errors, was intended to misrepresent science. Still, suppression or omission of relevant facts can be as misleading as outright falsehoods. Pseudohistory may be as much what the history is not, as what it is.

A few more examples may illustrate. Consider a teacher who reconstructs Galileo's arguments for Copernicanism. The lesson plan omits Galileo's theory of the tides (from Day 4 of the *Dialogue*). It was ultimately wrong, after all: no need to confuse the students. Here, one has subverted what *Galileo* considered most critical. He thought he had physical not just mathematical or circumstantial proof. Without seeing the basis for criticizing Galileo, of course, students are impressed by the 'resistance' to his ideas. One enthusiastic student encounters the tides argument independently and poses a query in class. The teacher explains away Galileo's error: knowledge was simply inadequate at the time; Galileo was right about everything else; and, well, the Church was unwilling to admit to the plain facts. Here, the casual dismissal again discounts the basis for contemporary criticism. 'Plain fact' was not so plain at the time. One cannot understand science fully without appreciating the controversy. And one cannot understand the controversy if some evidence is missing. Here, addressing all Galileo's evidence except the tides is pseudohistory.

As a second case, consider Ignaz Semmelweis, whose innovation – handwashing – dramatically reduced puerperal fever in a maternity ward in the mid-1800s (Colyer 2000; Leinhard 1988–1997). Although we hail the discovery now, Semmelweis was harshly criticized by his peers. Critics, we are told, were wrong. All wrong. They exhibited personal prejudice and social ideology, even xenophobia. It is hard to imagine that Vienna was then viewed as 'the Mecca of Medicine'. In fact, if one probes the contemporary intellectual context, one finds that therapeutic caution was correcting earlier excesses of bloodletting and purgatives. Modern practices of diagnostics and loose bandaging of wounds emerged here. Many found Semmelweis's results empty because he could not identify what caused the disease. Without knowing the cause, one could easily err – and be diverted from searching for the real cause. Semmelweis's peers may thus have responded to his conclusions cautiously *for good reasons* (Allchin 2003a). A Whiggish history where results are measured only by the outcome is pseudohistory.

Cases may be compounded. For example, two conventional heroes of the Scientific Revolution, Isaac Newton and Robert Boyle, each pursued alchemy (Dobbs 1975; Principe 1999), now viewed as unscientific. This small detail deeply transforms how one interprets their roles in establishing modern science and, indeed, what makes science science. A century later, many chemists supported phlogiston even after the discovery of oxygen (Allchin 1994). According to conventional stories of the Chemical Revolution, these two concepts were mutually exclusive. Here, the polarized story obscures how late phlogistonists reasoned, a clue to understanding how new scientific ideas emerge. Finally, when Bernard Kettlewell popularized his now landmark research on the evolution of the peppered moth, his story was largely 'black-and-white'. He did not mention that some forms had intermediate coloration. His edited account affects how students, in turn, will conceive the role of crucial experiments (Allchin 2001). In all these cases, the 'textbook histories' eclipse relevant information, while perpetuating a caricature of science (Gauld 1992). Embarassing examples of pseudohistory even haunt the pages of this journal (Lawson 2002 and in press). Pseudohistory may not include any outright falsities. But this does not mean that the resulting story cannot 'lie'.

4. Pseudohistory *as* Pseudoscience

No one will dispute, I think, that everyone, including every teacher, has a minimal responsibility to respect historical fact. By contrast, pseudohistory may seem like a subtlety relevant only to historians. But as portrayed above, pseudohistory is more than just a historian's parallel to pseudoscience. Pseudohistory of science is pseudoscience. Like pseudoscience, it conveys false ideas about science. But unlike pseudoscience, which typically deals with facts or concepts, it concerns misleading ideas about the *nature of science*. Pseudohistory misportrays *the process of science*, rather than its content. The science teacher should thus be as concerned about pseudohistory as about well-worn pseudoscience topics. Hagiography and Whiggism in science should join the ranks of the Loch Ness monster and cataclysmic planetary alignments.

Histories are not 'just' stories of science. They are 'just-so' stories of science. Like Kipling's fables – such as 'How the Leopard Got His Spots' (1902) – they are explanatory. They explain through narrative. The events of the story and the outcome are intimately linked. Every history – every story – has an implicit lesson, or moral. Historical tales of science inherently model the scientific process by showing how a series of events *leads to* a certain result, such as a famous discovery. They identify what is relevant to scientific discovery. The narrative thereby explains how science works. When the narrative is biased, the explanation falters.

Many educators may use historical stories strictly to teach science content, in a narrow disciplinary mode, apart from any intended overtones or lessons about nature of science, in a cultural mode (Gauld 1977). They may feel, therefore, that they can escape or minimize the dangers of pseudohistory (Matthews 1994, pp. 79–80). But every narrative of science is *implicitly* explanatory. Every history of science teaches nature of science. The pseudoscience of pseudohistory is thus always a concern.

Science classrooms, and indeed popular culture, are replete with scientific myths (Allchin 2003a). Literally. Some educators refer to myths of science in the generic sense of entrenched misconceptions (e.g., McComas 1998). I mean myths in the sense of literary form and narrative structure. Many pseudohistories share a rhetorical architecture with ancient myths. Common elements include, briefly:

(1) monumentality,
(2) idealization,
(3) affective drama, and
(4) explanatory function.

The account of Harvey exemplifies all these elements. And it is these *rhetorical* features that help transform history into pseudohistory. Collectively, they package the nature of science into a simplistic just-so story of 'How Science Finds the Truth':

- Science unfolds by a special method, independent of context or contingency.
- All experiments are well designed and forestall any mistakes.
- Interpreting evidence is unproblematic, and yields yes-or-no answers.
- Achievement relies on the privileged intellect of extraordinary persons.
- Scientific method thus leads surely and inevitably to the truth, with no error.

Scientific myths, then, are designed to explain and justify the authority of science. However, they often rely on distorting history. Students cannot truly understand the warrant and limits of science if educators promote such 'myth-conceptions'. That is why, again, pseudohistories of science are ultimately pseudoscience, as well.

5. *History of* Pseudoscience

Educators, then, should purge science classrooms of pseudohistory of science. But the reverse may be true for *history of pseudo*science. Indeed, history of pseudoscience offers an ideal opportunity for teaching nature of science. That may seem paradoxical. If teaching pseudoscience is reprehensible, how can teaching its history be any better?

Consider, first, that many of today's pseudosciences were yesteryear's sciences. Astrology, alchemy, craniology and others were once pursued by notable scientists. For example, Johannes Kepler, renowned for finding that planets trace elliptical orbits (not circles), was committed to astrology, which indeed fostered many of his discoveries. Robert Boyle, of Boyle's Law fame and co-founder of the Royal Society, pursued alchemy (Principe 1999). So, too, did Isaac Newton, otherwise known for his three laws of motion and his monumental achievements in gravitation, calculus and optics (Dobbs 1975). Paul Broca, who identified a language-processing region of the brain now known as Broca's area, advocated craniology. He engaged members of the Anthropological Society of Paris in a sustained debate over the size of George Cuvier's brain, defending its importance in measuring intelligence (Gould 1980, pp. 145–151). Given the pursuits of such distinguished scientists from history, teachers certainly might pause before disparaging students who themselves entertain such topics seriously.

When teaching the nature of science, therefore, one might appropriately begin by acknowledging how pseudoscientific claims *seem* entirely plausible or reasonable, at least at first. If one follows constructivist pedagogical strategies, eliciting such views is preliminary to transforming them into something more sophisticated. Here, the educational exercise is also historical: to recover the (good) reasons once advanced for what is now pseudoscience. For example, consider again Robert Boyle and his views on the healing power of gems. Boyle believed that the salubrity, or healthiness, of the air was due to 'subterraneal Effluvia', which carried the distinctive mineral properties of a region (1699, Book III, Vol. 2, pp. 275–299). The effluvia would explain local epidemics, for example. Further, when gems crystallized, they were 'imbued with Virtues by subterranean Exhalations and other steams' (1672, p. 166). That is, in solidifying, a gem could trap particles of, say, the healthy vapors. Later, rubbing the gem would release them, just as rubbing amber excited its electrical attractions (1672, p. 108). The gem's 'virtues' would 'exert their power by the copious Effluxions of their more agile and subtle parts' (p. 122). It was no different than deer leaving behind subtle effluvia that hunting dogs sensed (1699, Book II, p. 249; 1673, Chap. V), or perfume causing people to faint, or odors causing headaches (1673, Chap. VI). Here, Boyle explained a commonly known 'fact': namely, that certain gems have specific types of healing powers. Now, to our ears, this sounds dangerously 'new age'. But for Boyle it expressed his corpsucular philosophy. Indeed, what had once been attributed to some transcendental 'sympathy', he reconceived as mediated by the mechanial properties of minute particles. Now we tend to regard that as a scientific achievement, not pseudoscience. If Boyle was wrong, it was not because the idea was intrinsically unscientific. One can only say that further study of gems did not bear out their healing power. The historical transformation holds the critical lesson: the difference between science and pseudoscience.

Consider, too, the notorious history of craniology. For several decades in the nineteenth century anthropologists, such as Paul Broca, tried to use skull measurements to prove sexual and racial differences in intelligence. Science would interpret and validate why social power and privilege had developed as it did (Gould 1981). Now, the whole enterprise is a blemish on science. At the time, however, craniology seemed like a straightforward application of the principle of structure and function: 'if mental functions take place in the brain, then the brain's size should reflect mental capacity or ability'. Likewise, the brain's shape should reveal significant features of specific, localized mental functions, such as personality, rational faculties and emotions. This would naturally affect the size and shape of the skull, as well. Phrenology, the study of cranial shapes and proportions, thus also seems eminently plausible. As it does to many even today (Cordingley 2001). Moreover, craniology was *quantitative*, following one oft-cited hallmark of science. Craniologists used over 600 instruments and 5,000 measurements. For historian Elizabeth Fee, it was a 'Baconian orgy of quantification' (1979, p. 419) . Of course, the prospects of craniology and phrenology went unfulfilled. When women eventually entered the field, they challenged claims earlier deemed acceptable by men. Standards of evidence rose. The whole field soon dissolved. In retrospect one can see that the community of (white) European male researchers was culturally biased (not that any practitioner recognized his own bias). Now the episode is a persuasive example of how diversity in a scientific discipline can contribute to its objectivity. Here, a historical perspective makes the pseuodscience seem a little less ‘pseudo”. Substantive data showed that the plausible approaches were, ultimately, unfounded. Craniology is wrong, not misguided. History thus offers complementary lessons in science and pseudoscience. It helps reveal vividly how science works and why, sometimes, it errs.

A historical perspective highlights that many topics typically branded as pseudoscience are not *self-evidently* pseudoscience. That status of understanding is the outcome of historical investigation. Identifying error in various claims or assumptions involved work, *scientific* work. Claims characterized as pseudoscientific reflect *negative* scientific knowledge. Such negative knowledge continues to be important (for example, in ending the search for a perpetual motion machine, or in deferring from astrological inquiries). Negative discoveries generally raise the standards of evidence or interpretation. Indeed, scientists disregard past error at their peril, lest they repeat it. Just because something ‘is known’ does not mean that each individual automatically knows it. Therein lies the very rationale for education. So: every generation must re-learn what is scientific, what pseudoscientific. The evidence shaping knowledge of pseudoscience historically must be reinstantiated in each student. The history itself, of course, may be a valuable tool (for results on the effectiveness of one classroom lesson on historical error, see Allchin 1997).

By advocating a historical approach to pseudoscience I do not endorse, of course, succumbing to pseudohistory. Turning to history merely to bash pseudoscience with today’s ‘obvious’ conclusions achieves nothing. History is valuable, rather, for showing students how they might *challenge* the ‘obvious’. Educators may help them probe evidential claims and show them how historically, with further evidence, later scientists found them ultimately to be without merit. Indeed, the very understanding that something may appear reasonable until it is considered more deeply, is a powerful lesson worth offering to anyone.

6. Conclusion: Strategies for Educators

Concerns about pseudohistory or ‘quasi-history’ in the science classroom are not new (e.g., Klein 1972; Whitaker 1979). Yet most such concerns address preserving the integrity of *history*. My focus, by contrast, is preserving the integrity of *the nature of the process of science*(Section 2). That is, while many accounts may be historically misleading, or false (Section 3), my argument highlights how they can be *scientifically* misleading (where science is construed as the enterprise, not just its ideas). When past science is reconstructed on some idealized model, it becomes *pseudohistory* of science. When a narrative of scientific discovery verges on myth, it becomes pseudohistory of science. In both cases, pseudo*history* of science is also pseudo*science* (Section 4).

One might approach such claims as threatening the role of history in science teaching (Matthews 1994, pp. 77–81). Indeed, Stephen Brush (1974) once asked, ‘Should the history of science be rated X?’. He voiced a possible concern that ‘the way scientists behave (according to historians) might not be a good model for students’ (p. 1164; but also see Brush 2002). Recent reforms in science education seem not to have heeded this caveat. They recommend more history of science, in the spirit of Brush’s alternate profile for the humanities-oriented student (p. 1172). But neither more history nor less history is the problem. History already permeates science classrooms, I contend. However, much of such history, as exemplified in the case of Harvey above, is *pseudohistory*. As such, it is really *pseudoscience* trying to borrow illicitly the authority of historical narrative. We need, instead, *different* history. My concern, in contrast to Brush’s, is that Disneyfied, G-rated pseudohistories of science (Sterling 1994, Wallace 1994) promote role models undesirable for a very different reason. The idealized scientists of romanticized myths provide unrealisitic models for what citizens can expect of scientists in our society. They distort the nature of scientific knowledge by concealing its limits and oversimplifying the nature of evidence and interpretation. How can students schooled in pseudohistory of science ever make informed decisions where complex science is involved – for example, in cases of global climate change, genomics, cloning, alternative energies, or biological and chemical weapons? By graduation, *all* students need mature views of science.

Without historical expertise, how is the typical science educator to proceed? First, educators should understand pseudohistory, Whiggism and hagiography, perhaps just by a few clear examples. They must recognize and be alert to their warning signs, exemplified in the case above (and summarized in Figure 1).

Ideally, they learn more about analyzing texts rhetorically. They also learn about the architecture of myth – monumentality, idealization and affective drama in an explantory fable – and appreciate how myths work culturally to shape views of science (Allchin 2003a). Second, educators should master at least one historical case study in-depth (e.g., Matthews 2000; College Board 1999; Hagen et al. 1996). A single well developed case study can be far more valuable in profiling the nature of science than, for example, a comprehensive ‘greatest hits’ survey course in the history of science. Likewise, brief vignettes and tangential sidebars rarely convey the context so essential to a full, integrated picture. Teachers will then adapt this case for their students. Familiarity with its complexity will allow discussion and probing it in depth. Ideally, it can illustrate how simple stories can be misleading. Finally, as teachers gain experience, they broaden into other cases. They underscore resonances between them. They highlight the questions that lead to deeper understanding and the clues that should occasion such questioning. They guide students in exploring and analyzing cases on their own. Remedying pseudohistory in science education is not difficult. It begins with simply recognizing it for what it

Warning Signs of Pseudohistory

romanticism
flawless personalities
monumental, single-handed discoveries
'Eureka'-type insight
'crucial' experiments only
sense of the inevitable (plot trajectory)
rhetoric of truth-versus-ignorance
absence of any error
unproblematic interpretation of evidence
general oversimplification or idealization
ideology-laden conclusions
author with a narrow agenda

Context is missing:
- no cultural or social setting
- no human contingency
- no antecedent ideas
- no alternative ideas
- uncritical acceptance of new concept

Figure 1. Several 'warning signs' may alert science educators to possible pseudohistory. No symptom is absolute, but each should signal the teacher to question and check a source's reliability.

is – and thereby changing the standards for what history is deemed appropriate in the classroom.

In some cases, science teachers need better history. In other cases, they need, far more importantly, to abandon the mythic structure of science and its history. If the aim is to present students with a genuine portrait of science, not of pseudoscience, educators need to be wary of pseudohistory, as well. At the same time, the history of a pseudoscience may well be a vehicle for helping students develop a mature understanding of the nature of science – and of claims that only purport to be scientific.

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