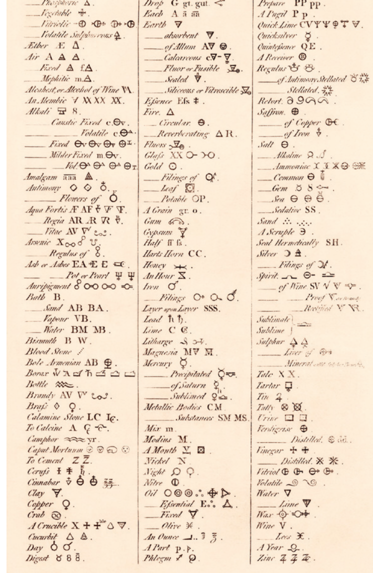
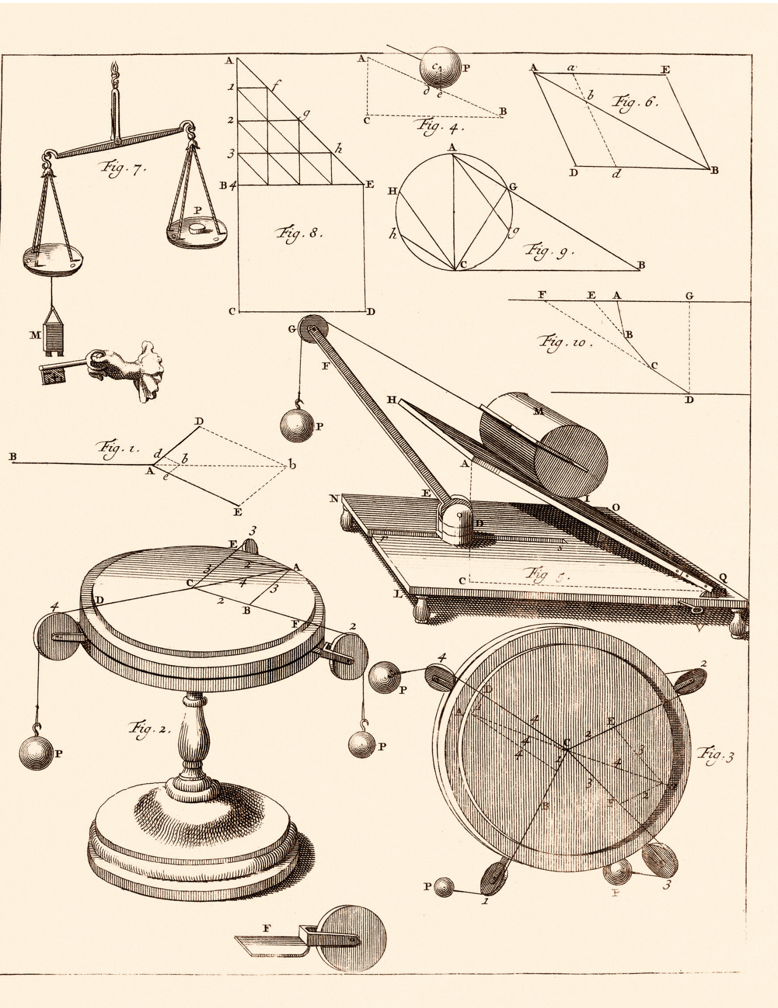


Incorporating HISTORY into the Science Classroom

— David W. Rudge and Eric M. Howe —



History can be used to promote a deeper understanding of the nature of science

Many science teachers recognize that teaching aspects of the history of science helps students learn science content and the nature of science (NOS). The use of history can potentially humanize science, help students refine their critical thinking skills, promote a deeper understanding of scientific concepts, and address common student misconceptions that often resemble those of past scientists (Matthews 1994). Reflecting on historical episodes can, in particular, promote a deeper understanding of a host of issues associated with NOS as a process (e.g., the tentative nature of scientific conclusions). There is consensus that history of science should be integrated into science content instruction, but available models are often sketchy when it comes to details (Monk and Osborne 1997; Howe and Rudge forthcoming). The challenge for teachers is how to effectively incorporate history into the science classroom while at the same time being mindful of the multiple constraints that govern classroom practice.

We have been developing an approach to the use of history of science that may provide some insights for instructors of K–12 classes. This article describes the various steps to the approach and includes two examples—one from a classic story of evolution, and another from the history of sickle-cell anemia research.

Step one: Identify and prioritize objectives

Like any curriculum development project, the solution for how to incorporate history of science into the classroom begins with an explicit identification of the educational objectives you have for both yourself and your students. Common constraints include the number of students, amount of time available (both preparation and time in class), and previous background knowledge students can reasonably be expected to have. While use of a historical episode may potentially support multiple objectives, it is not necessary to address all of them. Students do not need to be provided with a complete historical interpretation of the episode, particularly if the details might distract from the educational goals (Allchin 1993).

Step two: Select an episode

The next step is to determine which episode from the history of science to use in the classroom. If you have one in mind, consult the ERIC and Educational Abstracts databases or search the Internet to see whether someone has developed a lesson plan using the same episode. If you do not have a particular episode in mind, it may help to prioritize your objectives to determine which episode to use.

For instance, past experiences led us to recognize that we needed a unit that would directly address misconceptions students often have about evolution. One of us recognized that misconceptions had been previously proposed as explanations during the early history of research on industrial melanism in the classic case of the peppered moth. In this case, the choice of which misconceptions we needed to address led us to which historical episode to use. On another occasion we decided that we needed a scientific phenomenon that had been studied with reference to multiple subdisciplines in biology. Therefore, we developed a unit of study on of the history of research into sickle-cell anemia that incorporates biochemistry, genetics, ecology, and evolution.

Step three: Learn about the episode

With an episode in mind, the next step is to learn enough about it to create a way for students to reason in a manner similar, but not identical, to past scientists. While ideally primary sources should be consulted, such as original research papers, it will also be useful to consult textbook accounts and brief summaries provided in history of science texts to help create a unit for your own classroom. Classroom practice should be thought of in terms of presenting students with a phenomenon for study, eliciting student prior conceptions about this phenomenon, and using these volunteered comments to motivate the activity of the day (e.g., an investigation or a discussion that might allow them to explore and evaluate their ideas). The closing class discussion can be aimed at not only providing understanding of the concept, but also explicitly reflecting on what this particular example reveals about science as a process. By viewing the process in terms of the educational objectives for the lesson, it becomes easier to make decisions about what historical details to omit (as extraneous to the overall objectives) and also what historical details to simplify or otherwise modify to help students learn the science and overcome any misconceptions they may have.

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In our evolution unit on peppered moths, we begin with the introduction of a mystery phenomenon—a rapid increase in the frequency of the previously uncommon dark moths in the vicinity of manufacturing areas shortly after the industrial revolution in Great Britain and continental Europe. Students are provided with photos of pale and dark moths as well as frequency maps, and prompted to consider whether a pattern exists in the distribution of dark moths over time. Students are also asked to provide explanations for what is happening, which in turn are used to motivate a discussion of the ideas of past scientists who anticipated similar views to those our students have shared. We then ask students to consider how they might develop an investigation that would allow them to choose among these theories, and again, use their ideas to motivate a discussion of experiments actually conducted in the past. We invite students to interpret furnished results, and in particular, put themselves in the place of the past scientists who disagreed with one another.

Readers of *The Science Teacher* are no doubt aware of the controversies surrounding Kettlewell's 1950s work on peppered moths and our current understanding of the phenomenon of industrial melanism. For example, it is now known that bird predators see better in the ultraviolet region than previously suspected, so visual camouflage may not be the only important selective factor as was originally thought. These problems actually augment the potential value of discussing industrial melanism because comparing the simplified textbook account with what is now known about the phenomenon promotes greater insight into a host of issues associated with NOS (Rudge 2004). Learning about the ongoing research into the evolution of peppered moths helps students appreciate the tentative NOS and the continual scientific quest for additional evidence. Such readings and discussions set the context not only for reflecting on the experiments and theories specifically related to the phenomenon of industrial melanism, but also an *explicit*, *reflective* discussion of the nature of experiments and theories in general (Abd-El-Khalick and Lederman 2000).

Step Four: Implementation

Effective teaching by inquiry often requires substantial preparation. First, a problem scenario must be developed that provides students with sufficient, but not overwhelming, detail. You also need to think in advance about how best to introduce the problem for the day and then scaffold learning using a set of questions developed in advance. You must consider how students will respond, and how to modify instruction on a moment-to-moment basis depending on their responses to the learning environment created. All of this must be done while keeping in mind the objectives of the day, the unit, and state and national standards.

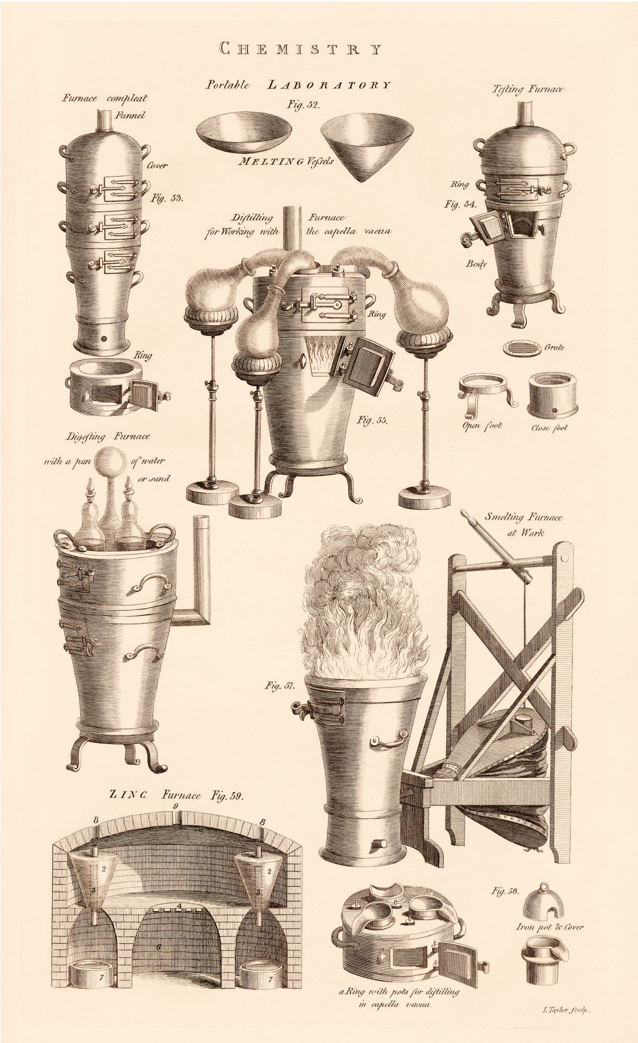
Sickle-cell anemia example

An illustration of our approach with reference to the sickle-cell unit (Figure 1) provides a sense of how we encourage students to explicitly reflect on various NOS issues. After three introductory classes, students on day four are challenged to construct a provisional theory to account for the varying and unexpectedly high frequencies of the allele (gene) associated with the mystery disease (sickle-cell) in

FIGURE 1

Emphases of the sickle-cell unit.

Class	Year(s)	Historical description	Class problem
1	1910	Dr. Jim Herrick first encounters and diagnoses the mystery patient.	Examine histology slides and cellular models to explain symptoms of mystery patient.
2	1923	Using the Emmel Test (*in-vitro* test) to identify sicklers from nonsicklers, Drs. Taliaferro and Huck propose the dominance model of inheritance of the disease from pedigree information they have collected.	Examine pedigree data developed from results of Emmel test.
3	1949	Dr. Jim Neel resolves the distinction between full (homozygous) sicklers and heterozygotes by way of new pedigree information.	Examine pedigree data developed from results of *in-vitro* and *in-vivo* tests.
4	late-1940s to mid-1950s	Hematology work in East Africa uncovers high frequencies of carriers for the sickle-cell disease. Several initial theories are developed.	Examine ethnographic and geographic data from Uganda to explain the high frequencies of sickle-cell heterozygotes.
5	mid-1940s to mid-1950s	Parasitology work in East Africa also examines the distribution of the disease malaria.	Examine *Plasmodium falciparum* life cycle and propose mechanism of inhibiting its growth and development.
6	1952–1954	Dr. Anthony C. Allison proposes theory of heterozygote protection of sickle-cell carriers to the malarial parasite.	Consider how malarial data affects students' earlier explanations for heterozygote frequencies in Uganda.
7	1949, 1957	Linus Pauling elucidates the difference between normal and abnormal hemoglobin forms through electrophoresis. Dr. Vernon Ingram sequences the peptides of hemoglobin and determines the molecular difference between normal and mutated forms.	Examine DNA fragments for hemoglobin proteins from electrophoresis.
8			Review



Working in groups, students examine evidence that strongly supports explanations that the phenomenon is likely due to a combination of selective mutation, gene flow (intermarriage), and racial predetermination.

the country of Uganda (Figure 2, p. 56). From a previous class that addressed the genetics of the disease, students tentatively concluded that the debilitating nature of the mystery disease should effectively result in the near removal of the gene that causes it from a population of interbreeding individuals. As such, when students discover the varying and high frequencies of carriers of the disease existing in the country of Uganda, they recognize it as an anomaly that cries out for explanation. Working in groups, students examine evidence (ethnographic, migrational, ecological, and topographical data) that strongly supports explanations that the phenomenon is likely due to a combination of selective mutation, gene flow (intermarriage), and racial predetermination. Each of these explanations were fervently proposed and defended by leading scientists of that time.

In the beginning of the next class that examines evolution, students are provided supplemental data from hematologic work in the late 1940s that quantified the presence of a related blood disease, malaria (Figure 3, p. 56). When students examine their earlier allele frequency maps in conjunction with this malarial data, they inevitably observe a strong and compelling correlation. Students are also given the results from a study conducted by Anthony C. Allison (1954) in which he collected blood samples from numerous children throughout Uganda and compared the incidence and severity of malaria between children who carried the allele for the mystery disease and children who did not (Figure 4, p. 57). These pieces of supplemental data lead students to propose a new theory that heterozygotes—those who carry a single copy of the mystery disease gene—are in fact protected against the ravages of the malarial parasite. From this, students can predict that one would expect to find higher frequencies of carriers of the mystery disease in those areas where malaria is present in high numbers. This theory postulating the selective advantage of sickle-cell heterozygotes is essentially the same as that historically put forth by Allison as a result of his research in the area, and the now well-accepted explanation for the continuation of sickle-cell anemia genes and the relatively high prevalence in persons of African descent.

At some point while students are engaged in group work to make sense of the various pieces of data given to them, each group is given various "probes" to consider (Figure 5, p. 57). Students are asked to share their ideas with one another with the understanding that each group will participate in a subsequent whole-class discussion about their various explanations to account for the data and their interpretations of the probes. These targeted probes serve as a main vehicle to have students both explicitly and reflec-

FIGURE 2

Frequencies of the sickle-cell allele in Uganda, circa 1949.

Data adapted from Herrick (1968) and Lehmann (1953).

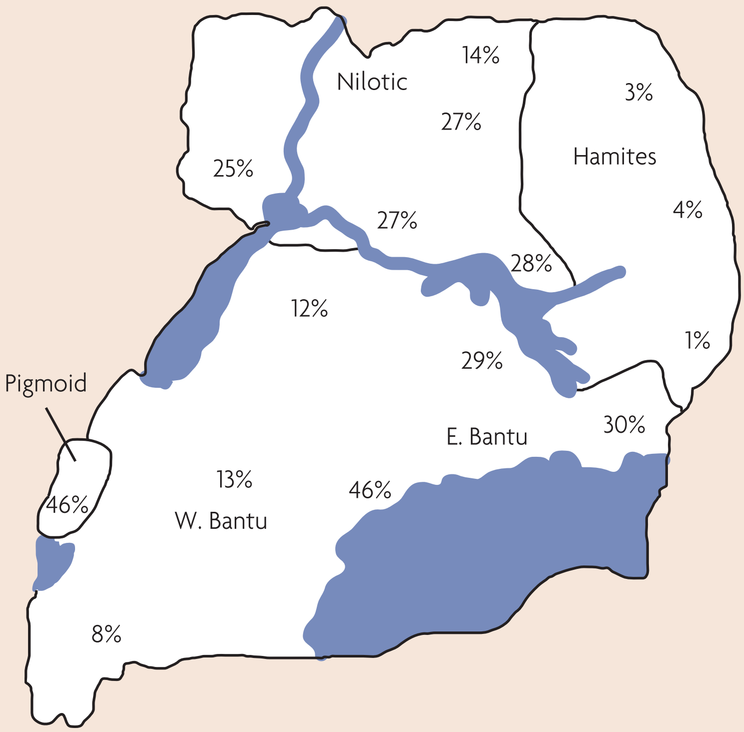
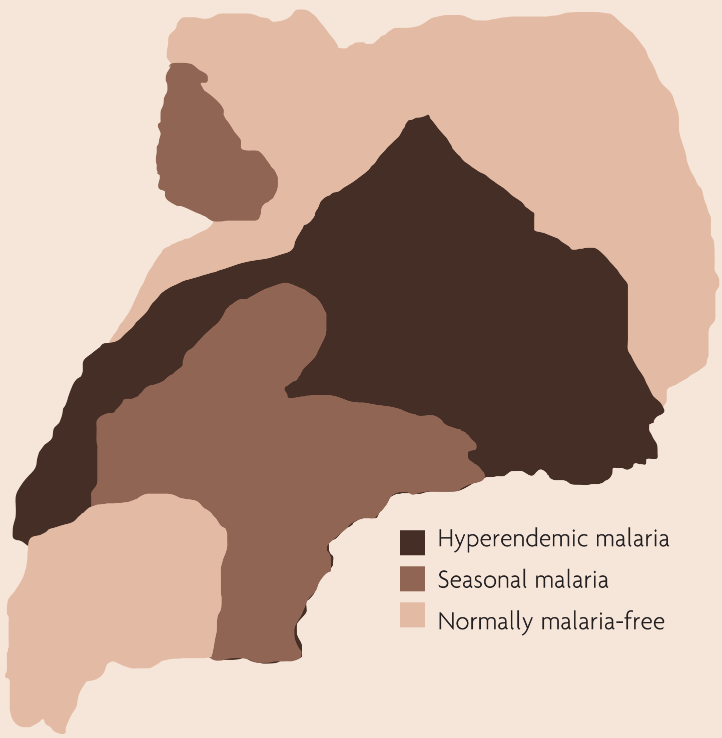


FIGURE 3

Distribution of malaria in Uganda, circa 1949.



tively consider aspects of NOS because they are given the opportunity to connect their work with the conceptual material of the unit to larger NOS ideas.

For example, the first probe in Figure 5 invites students to indirectly consider what is commonly referred to as the subjective (theory-laden) NOS. Students often assume that scientists inevitably all come to similar conclusions when examining the same data (Chalmers 1999; McComas 1996). This is partially because students commonly believe scientists are definitively objective in their work, free from bias and prior theoretical commitment. During the whole-group discussions about this NOS issue, teachers should refrain from "telling" students a more contemporary perspective of subjective NOS. Rather, teachers facilitate students to comment on the strengths and weaknesses of each other's answers. Usually, students come to understand that their differing explanations to account for the high frequencies result in part because of their own disparate perspectives—correlated to their different backgrounds, educational experiences, and personal commitments that influence what they "see" in the data.

The second probe (Figure 5) invites students to consider how their own explanations may have changed between classes. This is intended to get students to think in a rudimentary way about how knowledge in science is subject to potential change or modification. Changes in students' explanation for the frequency anomaly result in part from their ability to reconceptualize the problem in light of the new malarial data. Furthermore, when pressed by the instructor to consider whether or not their previous explanations were "wrong" or have no further utility (i.e., are abandoned), students often recognize that while heterozygote protection offers better explanatory and predictive power, aspects of their earlier explanations are important factors that contribute to the genetics of the mystery disease. The instructor then can ask students whether or not they believe that similar processes of theory comparison occur in the development of robust and long-standing scientific theories.

The main advantage of designing lessons that use history of science in this way is that it is closely aligned with constructivist te-

FIGURE 4

Hematological analysis of children from Uganda, circa 1949.

Data adapted from Allison (1954) and Raper (1959).

Genetic disposition	Total children Examined	% w/falciparum malaria	Parasite density index
Normal ('+/+')	247	46	5.9
Carrier ('+/-')	43	28	4.0

FIGURE 5

Example reflective probes for the Uganda problems.

NOS issue	Probe(s)
The subjective (theory-laden) nature of science	Given that you all had access to the same data, did the members of your group all come to the same conclusion to account for the high frequencies of mystery disease carriers? Why or why not?
The tentative nature of science	Has your theory to explain the anomalously high frequencies of carriers changed from previous classes? Why or why not? If so, what sort of things precipitated your change in theory?

nets, meaning that students use history of science to construct their own understanding both of the important biology concepts and of those issues related to NOS. When students are challenged to assume a problem-solving role similar to that of historical scientists, the experience facilitates student ownership of the conclusions that they themselves develop. Preliminary empirical evidence collected in connection with the sickle-cell anemia unit described here suggests the foregoing approach can indeed help students develop more sophisticated views of NOS (Howe and Rudge, forthcoming). ■

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For additional insight into the history of science, see this month's insert—an excerpt from *The Story of Science: Aristotle Leads the Way* by Joy Hakim.