SHiPS Teachers' Network NEWS

Vol. 9, No. 2 Dec., 1999

A Newsletter for the **S**ociology, **Hi**story and **P**hilosophy of **S**cience in Science Teaching

From the Lipid Bilayer to the Fluid Mosaic: A Brief History of Membrane Models

Phillip Eichman
University of Rio Grande, Rio Grande, Ohio

Membranes are one of the most common features of the biological world. With the exception of some viruses, all living things depend in one way or another on membranes. They surround cells and separate cellular contents from the external environment. Membranes also form special spaces, or compartments, within the cytoplasm that separate various cellular processes. Without membranes, life as we know it would likely not exist.

Today we know a great deal about membranes, but it was not always so. The story of how we came to understand membranes, however, begins not with biology, but with chemistry and the study of lipids (i.e., oils) and how they interact with water.

It has been noted that one of the first to write of the effects of oil on water was Pliny the Elder. In his encyclopedic work, *Natural History,* Pliny observed that ". . . sea water is made smooth by oil, and so divers sprinkle oil on their face because it calms the rough element. . ." (Tanford 1989). In the centuries that followed the idea that oil calmed troubled waters became a part of folklore. *(cont. p. 5)*

We must expect changes in the theory in the future. If a theory is taught and learned dogmatically as it stands, without regard to its origins, then it is in danger of becoming fossilized and of being finally an obstacle to further progress. Science, and even quantum mechanics, is not a body of revealed truth to be piously preserved. We must understand what is essential in the theory and what is not, and the best way to reach such understanding is by studying its history. –Freeman Dyson

---

News of the Network

If you have not already done so, please forward your e-mail address to the Editor, to be notified when future issues are published online and/or when major updates are posted on our website (***please note the modest change in address from the last newsletter!***):

ships@tc.umn.edu

As I assemble each new issue of the *SHiPS News*, I am reminded of the expansion of HPS in mandated curricula, coupled with the increased availability of resources via the internet (see Websights!). Accordingly, SHiPS itself is shifting focus. One change, of course, is our new online Resource Center, a more permanent and widely accessible hub for finding information and centralizing curriculum ideas. I hope that you will find it a convenient reference and source of ideas. Please also encourage colleagues to use it as well. I sense that many teachers now find themselves responsible for teaching "history and nature of science" and are wondering what to do or are feeling ill-equipped. We need to lead the way.

We also need to keep in mind that historical and philosophical research does not stop. New, sometimes revolutionary, findings emerge, just as in science. We would be in dire straits, for example, if we depended on the narrow philosophy and images of science popular a half-century ago. We will continue to provide updates on what is current in these fields, much as *Science News* and other magazines keep teachers abreast of develop-ments in science itself. We will also post information about professional meetings and associations, and encourage teachers to link with historians, philosophers and sociologists of science locally.

Another area of growth is in providing and sharing curricular exemplars for teachers who want or need an introduction to new ways of teaching. Can you help?

Douglas Allchin, *ships@tc.umn.edu*

Commentary: Stories *and* Science

Douglas Allchin

I am holding a small, fragile 5"x7" volume, a mere 32 pages—the September, 1906, issue of *The School World*, the two O's of "SCHOOL" overlapping. The cover boldly reminds the reader that it is published monthly, from September to June, by D•H•Knowlton•&•Co, Farmington•Maine. Art deco flowers border each side. Only 35 CENTS. Above the table of contents, this issue's theme: "Stories of Science."

Here, nearly a century later, one might reflect on why this magazine offered stories to teach science. Surely now we've outgrown such primitive pedagogy at the secondary level. The Discovery Channel and NOVA do not replace school. Still, the narrative format is incredibly powerful, even among adults. (Wit-ness how such TV shows succeed.) Students, too, listen. Indeed, I think this may explain their often favorable response to history of science.

"Stories" cannot substitute for learning about scientific concepts, one hopes. But can stories be vehicles for such lessons? Fables have "morals": is that a model for teaching? Are there also lessons in the narrative itself, as in literature—for example, that scientists err, have personalities, may be motivated by ambition as well as passionate curiosity, apply certain problem-solving strategies, assess puzzling results and try again, etc.? Many indigenous cultures record their natural knowledge in myths or narratives (see SHiPS 8/2 on Science and Culture). What makes stories sometimes as cognitively powerful or memorable as abstract principles?

The topics in the modest *School World* are simple, but provocative. Consider, for example, "The Beginning of Chemistry." We certainly know where most textbooks begin. How often do we consider, though, where chemistry "begins" for our students—as *they* see it? How did concern for chemistry originate historically? How did it become relevant enough to motivate inquiry? Metallurgy, pharmacy, ceramics, mortars, glass-making, dyes, even cosmetics: these are the origins of chemistry. Indeed, many early chemists (well into the 18th century) made their living in one of these trades, where chemistry as a pure theoretical pursuit was adjunct. Yet in teaching, we invert the relation-ship. History reminds us how science connects to our lives—that is, our students' lives. History is a window to "relevance."

Another section details "The History of Air." Nowadays, every school child could tell you that air is not an element, not a simple uncompounded thing. But how many could tell you how we know that? Some students (alas) will point plainly to the periodic table, implying that it's not listed there, so why did you ask? But the concept is not simple, unfolding historically over several decades as the emerging "pneumatic" chemists realized, first, that there could be *different* "airs" (with distinct properties) and, then, that recognizably different gases mixed to form a still transparent air. The notion that air has weight is equally cryptic, and was tied to the story of pumping water from mines (SHiPS 7/2). The history reminds us of how such questions became meaningful and how the answers can be genuinely surprising. Sometimes, historical perspectives—rather than show that "we know better now"—expose common ignorance. That may apply equally well for the next topic, "The "History of Water."

The volume concludes with a biography of Michael Faraday and one of his renowned public lectures. Faraday was perhaps the Carl Sagan or Stephen Jay Gould (or Bill Nye the Science Guy?) of his day—a spokesperson for and promoter of science. Did he succeed in part because, as this excerpt illustrates, he could mix fact, demonstration and story-telling elements into vivid, engaging occasions?

One should not idealize outside the social structure shaping teachers' options and respon-sibilities. How does one cope with prescribed curriculum and an atmosphere of accountability to standardized tests or evaluations? While these contexts are real, I think common perceptions may overstate the limitations. Teachers at alternative schools, for example, seem to help students master the requirements in about 40% of the time. So precedents seem available, if students (even non-academic ones) elect to focus. Where, then, is the place for stories of science in today's classroom?

Bunsen — Without his Burner

Colin Russell

This year marks the centennary of the death of Robert Wilhelm Bunsen (1811-1899). He is famed chiefly for the burner named after him, though others had already invented rather similar apparatus for using coal-gas as a laboratory heating agent [*see* SHiPS 7/1]. However, Bunsen had the services of a technician suffciently enterprising to make such burners in large quantities and associate with them the name of the famous professor at Heidelberg: an early case of chemical sponsor-ship? As with much named apparatus (Leibig condenser, Dewar flask, Crookes tube, etc.), this device did not represent the main contribution of its presumed inventor.

Bunsen obtained his doctorate in 1830 from the University of Göttingen. Thereafter his chief work was done as professor at Marburg (1839-1851) and Heidelberg (1852-1889). His first sustained research programme concerned the substance cacodyl (now named tetra-methyldiarsine), which seemed to persist in a number of its compounds (oxide, chloride, cyanide) and thus offered the beleaguered followers of Berzelius new "evidence" for the existence of the radicals he had proposed as part of his dualistic system. It stimulated Bunsen's students Kolbe and Frankland to further important work with the same quest. After this, Bunsen had little to do with organic chemistry, partly because he had little patience with detailed theoretical schemes which were inevitably a part of this growing new subject.

His next research, still at Marburg, was on gas analysis. This seems to have begun with early (1838) work on the gases present in the blast furnaces used for making iron. Accompanied by Lyon Playfair, he visited England and their results were taken up by iron-masters with huge savings of fuel that would otherwise have been needlessly wasted. From this work he went on to show how to determine the specific gravity of gases, to measure their absorption by liquids, and their rates of diffusion. Above all, he perfected the technique of eudiometry, where known volumes of gas are exploded with oxygen and the amounts of the products measured. His pioneering studies of gas analysis laid the foundation of techniques still in use 100 years later.

At Heidelberg, Bunsen pioneered studies in photochemsitry (with H. E. Roscoe), working with hydrogen/chlorine mixtures exposed to sunlight. Shortly afterwards he launched into spectroscopy with his colleague in physics, G.R. Kirchoff. Using simple prisms they devised the first chemical spectrometer, determining the position of the spectral lines emitted from highly purified samples of alkali and alkaline earth compounds. In this way they discovered two new alkali elements: cesium and rubidium. Investigations of solar spectra convinced them that here was a method of chemical anlaysis applicable to luminescent material millions of miles away. In electricity, Bunsen invented the "Bunsen battery," where the expensive platinum of the Grove cell was replaced by carbon, with zinc as the other electrode. This device assisted Kolbe in his early research on electrolysis, and led its inventor to many important experiments in electrochemistry.

For teachers it seems that the life and work of Bunsen have three obvious lessons. First, was the importance of technique. No great theoretician, Bunsen nevertheless made possible the development of future chemcal theory by providing a sound empirical basis for the subject. "His" burner, and still more, his analytical and spectroscopic methods proved indispensable to future generations of chemistry students. Do we, perhaps, underplay the importance of experimental technique in reducing chemistry to a science of "black boxes," or abstruse results from higher mathematics?

Second, Bunsen deplored the demarca-tion lines between related sciences and would today be a hero for those who worship at the shrine of interdisciplinarity (assuming they had ever heard of him). He held strongly to the view that "a chemist who is not also a physicist is a mere nobody." One of his earliest researches was on the volcanic phenomena of Iceland, and through this work he became one of the founders of petrology. An integrated approach to science does not need complex ideological justification. As Bunsen found, it simply works!

Third, Bunsen illustrates the supreme importance of dedicated teaching. At Göttingen he attended the first teaching chemistry laboratory in Germany, and that may have inspired his later efforts. A lecture from 8 to 9 every day of the week (or 9 to 10 in the winter) was followed by a full day in the laboratory alongside the students, teaching by example and advice throughout the day. His superb technique could never have been passed on by mere exhortation.

So it was that the students or co-workers of Bunsen represent a roll call of chemical distinction in the 19th century and beyond, persons who passed on to their successors the valued aspects of the Bunsen tradition: Playfair, Frankland, Crum Brown, Ludwig, Mond, Roscoe, Kolbe, Lothar Meyer, Victor Meyer, Baeyer, Ladenburg and many more. All had an immense respect for the grand old man living out in bachelor loneliness his last decade in Heidelberg. He would be remembered by them for much more than a mere burner.

Reprinted from the BSHS Education Forum*, with our appreciation.*

Further Resources on Bunsen:

- www.woodrow.org/teachers/chemistry/institutes/1992/Bunsen.html
  ---written by teachers at the Woodrow Wilson Institute on Hist. of Chem. (1992)
- images of Bunsen & early spectroscope at: ships.umn.edu/8-2/index.htm#bunsen

---

RESOURCES

- **Topical Essays** for Teachers
  Kenneth Manning on **race, gender and science**; Frederick Gregory on **religion and science** in western history; Stanley Goldberg on **atomic bomb** research and high energy physics; and Edmund P. Russell III on science and **the environment**. Available ($8) from the History of Science Society, Univ. of Washington, Box 351330, Seattle WA 98195-1330, or hssexec@u.washington.edu.
- The Poynter Center for the Study of Ethics and American Institutions has just released a new **monograph addressing death and dying**, *The Social Face of Death: Confronting Mortality in Paoli, Indiana*. "Americans die badly," they conclude—suggesting that we need better efforts by the helath care system in informing and empowering families in advance of need, training programs for patient advocates, expanded options for end-of-life care and more discussion within families.
  Contact: Poynter Center, 410 N. Park Ave., Bloomington IN 47405, or poynter@indiana.edu.
- **Physics** teachers in search of **historically oriented texts**, be on the lookout for:
  Harris Benson, *University Physics* (Wiley, 1996) (integrated historical approach)
  H.C. Ohanian, *Principles of Physics* (Norton, 1994) (historial notes and illustrations)
  As yet, we have no formal reviews.
- A special issue of the journal *Ethics and Behavior* (Vol. 7, No.2) focuses on "**Ethical Issues in the Use of Animals in Research**." Contributions address the concept of animal rights (pro and con), religion, the role of institutional review boards, the design of experiments using animals, and the work of Harry Harlow, who examined the effect of depriving monkeys of maternal care in the 1950s-60s.

Women who packed explosives during World War II had unusually low blood pressure. Nitroglycerine releases nitric oxide, which relaxes smooth muscle and hence dilates blood vessels. Alfred Nobel, the discoverer of nitroglycerine, apparently treated his own heart problems this way.

--Chem New Zealand 66(1997): 13

Membrane Models *(cont. from p. 1)*

Likely the first to study this phenomenon scientifically was one not normally associated with the biology of membranes—Benjamin Franklin. Self-trained scientist, author, inven-tor, philosopher, and statesman, Franklin's interests were far ranging. During a stay in England in 1774 Franklin conducted an experiment on the effects of oil on the surface of water. He added a small amount of oil to the water in a small pond in Clapham Common. Immediately he noticed that the oil spread in a thin film over the surface of the water until a large portion of the pond was "smooth as a looking glass" (Tanford 1989). Although later published in *Philosophical Transactions of the Royal Society*, Franklin's experiment passed largely unnoticed. A little more than a century later, Franklin's experiment was repeated by Lord Raleigh. Raliegh, originally John William Strutt, had attended Cambridge University, majoring in mathematics and physics. After graduation he held various scientific appoint-ments, including the prestigious Professor of Natural Philosophy at the Royal Institution in London.

In 1890 Lord Raleigh conducted a series of quantitative experiments with oil and water. He was able to carefully measure the area to which a known volume of oil would expand and also calculated the thickness of the oil film (Tanford 1989).

His results were published, but noticed by only a few experts in the field. The following year, however, he received a letter from a German woman named Agnes Pockels, describing some experiments that she had conducted in her kitchen. Agnes Pockels, it seems, had developed on her own with little training and support from others in the scientific establishment, a device for carefully measuring the exact area of an oil film. Lord Raleigh assisted Agnes Pockels in publishing her results, the first of fourteen scientific articles she published. Her greatest contribution to science, however, was likely the device that she invented, which is still used today by chemists and physicists studying surface phenomena (Tanford 1989).

At about the same time that Lord Raleigh was experimenting with oil films, Charles Ernest Overton was working on a doctoral degree in botany at the University of Zurich. As it happened, Overton discovered quite acciden-tally, some important properties of membranes. His research was related to heredity in plants and in order to complete his studies he needed to find substances that would be readily absorbed into plant cells. He found that the ability of a substance to pass through the membrane was related to its chemical nature. Nonpolar substances, Overton discovered, would pass quickly through the membrane into the cell. This discovery was quite contrary to the prevalent view at the time that the membrane was impermeable to almost anything but water.

Based on his studies of how various molecules pass through the membrane, Overton published a preliminary hypothesis in which he proposed: (1) that there are some similarities between cell membranes and lipids such as olive oil, and (2) that certain molecules (i.e., lipids) pass through the membrane by "dissolving" in the lipid interior of the membrane. Today, we realize the significance of Overton's hypothesis. At the time, however, there was considerable opposition to Overton, and his ideas (Tanford 1989).

Further research on the nature of oil films was conducted by Irving Langmuir. Trained in physical chemistry, Langmuir worked in the laboratories of General Electric doing research on molecular monolayers. His research eventually turned to lipids and the interaction of oil films with water. Using an improved version of the apparatus originally developed by Agnes Pockels (generally referred to today as a Langmuir trough), he was able to make careful measurements of surface areas occupied by known quantities of oil.

Langmuir published only one paper on molecular monolayers (Langmuir 1917). He proposed that the fatty acid molecules form a monolayer by orienting themselves vertically with the hydrocarbon chains away from the water and the carboxyl groups in contact with the surface of the water. As it turns out, this was a key piece in the puzzle of understanding lipid bilayers and membranes as well. 6

Fig. 1. Representative phospholipid

Fig. 2. Lipid monolayer

In Figures 1 and 2 above, this is illustrated with phospholipids, a component of cell membranes.

Likely the first to actually study the lipids found in cell membranes was Evert Gorter and his research assistant, Grendel. Gorter was a pediatrician and professor at the University of Leiden. Although afflicted with rheumatoid arthritis, he was able to carry on a dual career in pediatrics and basic research.

In their classic experiment, Gorter and Grendel extracted the lipids from red blood cells with acetone and other solvents. Using a modified trough, similar to Langmuir, they were able to demonstrate that lipid molecules could form a double layer, or bilayer (Figure 3), as

Fig. 3. Lipid bilayer

well as a monolayer. Further, they were able to show that the surface area of the lipids extracted from the red blood cells was about twice the surface area of the cells themselves.

Based on these two observations (i.e., that lipid molecules can form bilayers, and that the surface area of the monolayer extracted from the cells is approximately equal to twice the surface area of the cells) and repeated studies with red blood cells from several animals (human, rabbit, dog, guinea pig, sheep, and goat) Gorter and Grendel concluded that "chromocytes [red blood cells] are covered by a layer of fatty substances that is two molecules thick" (Gorter and Grendel 1925). Although not generally thought of as a "model" of cell membranes, Gorter and Grendel did describe a plausible structure for the membrane.

It is perhaps interesting to note in passing that later researchers discovered that the work of Gorter and Grendel was hampered by the poor techniques of the time. They actually did not completely extract the lipids and also underestimated the surface area of the red blood cells. As it turned out, the two errors essentially canceled each other out and their conclusions were basically correct (Sadava 1993).

The first membrane model to be accepted by the majority of scientists was proposed by Danielli and Davson in 1935. James F. Danielli was trained as a physical chemist, although much of his work was related to biology. His doctoral research was in the area of surface properties of lipids and following graduation he worked at Princeton University from 1933-35 with E. Newton Harvey, an expert in the area of cell surface studies. Working in Harvey's lab, Danielli had found that proteins could be adsorbed to oil droplets obtained from mackerel eggs (Stein 1986). This finding would later become a major component of the membrane model proposed by Danielli and Davson.

In 1935 Danielli returned to University College in London where Hugh Davson, a physiologist, was working. It was through the association of these two that the first membrane model originated.

The model proposed by Danielli and Davson (Figure 4) was basically a "sandwich" of lipids (arranged in a bilayer although no mention of Gorter and Grendel was made in the

protein

lipid
bilayer

protein

Fig. 4. Danielli-Davson model

initial paper) covered on both sides with proteins (Danielli and Davson 1935). Later versions of the model included "active patches" and protein lined pores (Danielli 1975).

This was the basic model for membrane structure accepted by biologists for many years. It was, however, inadequate in explaining many of the findings of later research (Hendler 1971). In 1957 J. D. Robertson proposed a modified version of the membrane model, based primarily on electron microscope studies, which he called the "unit membrane" (Robertson 1957).

Under the high magnification of the transmission electron microscope, membranes have a characteristic "trilaminar" appearance consisting of two darker outer lines and a lighter inner region. According to the unit membrane model, the two outer, darker lines are the protein layers and the inner region the lipid bilayer.

During the 1960s and early 1970s, textbooks generally included an electron micrograph illustrating the "unit membrane," and biologists described the membrane as a "lipo-protein sandwich." It was not to last however, because a major change in the understanding of membrane structure was underway (Hendler 1971).

The unit membrane model was eventually replaced in the early 1970s by the current model of the membrane. This model, known as the fluid mosaic model, was proposed by biochemists S. J. Singer and Garth L. Nicolson (Singer and Nicolson 1972). The model (Fig. 5) retains the basic lipid bilayer structure first

Fig. 5. Fluid mosaic model

proposed by Gorter and Grendel and modified by Danielli and Davson and Robertson. The proteins, however, are thought to be globular and to float within the lipid bilayer rather than form the layers of the sandwich-type model.

The hydrophobic tails of the phospho-lipids, the major lipid component of the membrane, face inward, away from the water. The hydrophilic heads of the phospholipids are on the outside where they interact with water molecules in the fluid environment of the cell. Floating within this bilayer are the proteins, some of which span the entire bilayer and may contain channels, or pores, to allow passage of molecules through the membrane. The entire membrane is fluid—the lipid molecules move within the layers of the bilayer while the "floating" proteins also freely move within the bilayer.

The nature of these membrane proteins was studied by Unwin and Henderson (1984). They found that the portion of the protein that spans the lipid bilayer is hydrophobic in nature (i.e., similar to the lipids forming the bilayer) and arranged in a three-dimensional shape, often in the form of an alpha helix (Figure 6).

Fig. 6. Fluid mosaic model with alpha helical protein

Since 1972, the fluid mosaic model has been modified because of more recent discoveries, such as those of Unwin and Henderson, but it still remains the model preferred by biologists today. It explains the current knowledge of membrane structure and also serves as the basis for our understanding of how membranes function. It has a long history—back at least to the time of Pliny. Like most of modern science, the fluid mosaic model resulted from the cumulative work of numerous individuals. Current biology textbooks, however, generally ignore the historical development and present the model almost as if it were a recent discovery. There are a few textbooks that do contain historical details and teachers wanting more information can consult these (Avilia 1995; Becker, et al. 1996; Mader 1996). Although it may not be covered in your particular textbook, with a little extra effort and imagination, however, you can enliven your class and bring your students a little closer to these pioneer scientists of the past by including some of this history.

References

Avilia, V. L. 1995. *Biology: Investigating Life on Earth*. Boston: Jones and Bartlett.

Becker, W. M., Reece, J. B., and Poenie, M. F. 1996. *The World of the Cell*. Menlo Park, CA: Benjamin/Cummings.

Danielli, J. F. and Davson, H. 1935. A contribution to the theory of permeability of thin films. *J. Cell Comp. Physiol.* 5:495-508.

Danielli, J. F. 1975. The bilayer hypothesis of membrane structure. In G. Weissmann and R. Clairborne (eds.), *Cell Membranes: Biochemistry, Cell Biology, and Pathology* (pp. 3-11). New York: Hospital Practice.

Gorter, E. and Grendel, F. 1925. On bimolecular layers of lipoids on the chromocytes of the blood. *J. Exp. Med.* 41:439-443.

Hendler, R. W. 1971. Biological membrane ultrastructure. *Physiol. Rev.* 51(1):66-97.

Langmuir, I. 1917. The constitution and fundamental properties of solids and iquids. II. *Liquids. J. Am. Chem. Soc.* 39:1848-1906.

Mader, S. S. 1996. *Biology*. Dubuque, IA: Wm. C. Brown.

Robertson, J. D. 1957. New observations on the ultrastructure of the membranes of frog peripheral nerve fibers. *J. Biophys. Biochem. Cytol.* 3:1043-1047.

Sadava, D. E. 1993. *Cell Biology: Organelle Structure and Function*. Boston: Jones and Bartlett.

Singer, S. J. and Nicolson, G. L. 1972. The fluid mosaic model of the structure of cell membranes. *Science* 175:720-731.

Stein, W. D. 1986. James Frederic Danielli, 13 November 1911-22 April 1984. *Biographical Memoirs of Fellows of the Royal Society* 32:117-135.

Tanford, C. 1989. *Ben Franklin Stilled the Waves: An Informal History of Pouring Oil on Water with Reflections on the Ups and Downs of Scientific Life in General*. Durham, NC: Duke University Press.

Unwin, N. and Henderson, R. 1984. The structure of proteins in biological membranes. *Scientific American* 250(2): 78-94.

SCIENCE DRAMAS

Bertold Brecht has his *Galileo*. Now British playwright Michael Frayn has set two famous chemists together on stage:

Copenhagen. Michael Frayn. Methuen (1998). ISBN 0-413-72490-5.

This well publicized new play is worthy of all the critical acclaim it has received. It deals, in fictional form, with a historical event—the visit of Werner Heisenberg from Nazi Germany to Neils Bohr in German-occupied Denmark in 1941—and the reasons for the visit.

The three characters, Heisenberg, Bohr and his wife Margarethe, are drawn into a verbal attempt to reconstruct the visit, what happened and why it happened. In the process they bring vividly to life the nature of Heisen-berg and Bohr's earlier collaboration, the foundations of Heisenberg's Uncertainty Principle, and the elements of their own life stories, characters and approaches to science. Central concerns are the relationship between science, scientists and society in wartime, and the extent of a scientist's responsibility for weapon's development.

The play is firmly based on later, published recollections by Heisenberg and Bohr, on recent biographies and on the Farm Hill Transcripts (transcripts of secret recordings of discussions among Nazi scientists interned at Farm Hill, Cambridgeshire, at the end of World War II). In a detailed Postscript, Michael Frayn outlines where fact ends and fiction begins, discusses his sources, and provides a bibliography which would be useful for anyone interested in Bohr or Heisenberg.

The script provides a thought-provoking insight into issues of science and society, and a powerful humanizing of two scientific heroes. It deserves to be a must for all high school students focusing on science, twentieth-century history, English or general studies.

—Isobel Falconer

reprinted from *BSHS Education Forum*

BOOK BRIEFS

Remarkable Discoveries! Frank Ashall. Cambridge Univ. Pr. (1996). ISBN 0-521-58953-3.

In 1966 Charles Huggins was awarded the Nobel Prize for physiology and medicine. He had discovered a way of controlling cancer of the prostate. In the same year, President Lyndon Johnson claimed that "too much emphasis is being placed on basic research at the expense of immediate medical problems." Alistair Cooke regarded this as "senseless, mis-leading and wildly impractical." He then traced a series of events which led to this discovery. He started with Fohn Hunter, who was interested in the physilogy of bulls, introduced one J. Griffith, who hoted the change in the size of the prostate in moles and hedgehogs with seasons, to the effect of the female hormone on the size of the prostate, to two types of phosphatase to Huggin's work. This is the theme which pervades Ashall's book. In the preface Ashall states that "obody can predcit what benefits will come from pure research." "Who can put a price on Faraday's curiosity?"

The first chapter is devoted to Faraday. A short introduction reminds the reader of the range of domestic devices which are derived from Faraday's discoveries. This is followed by a "Hisotrical Context," the state of scientific understanding before Faraday. The work of Thales, Gilbert, Von Guericke, Franklin, Volta, Galvani and Oersted is discussed. A short biography of Faraday is included. (Unfortunately, other sicentists do not receive the same coverage.) Finally, we have an account of Faraday's discoveries: electromagnetic rotation, electric motors, dynamos and electromagentic induction. Students of physics of age 14+ will have met many of the experiments described.

In contrast to Chapter 1, devoted to one scientists, Chapter 4 is a wide sweep of the work of sveral scientists in the field of radioactivity. The 14+ student should be able to follow the methods used to establish the "Becquerel Ray." The work of the Curie family is discussed. I hope the 14+ student will reflect on the difficulties faced by Marie Curie in the isolation f radium. Here, Ashall introduces a moreal imperative to science: the Curies did not patent or profit from their discovery!

There are 18 chapters in the book. The works of Maxwell, Röntgen, Planck, Einstein and de Broglie appear. There are chapters on the Big Bang and Relativity. Lavoisier, Priestley and phlogiston are included; so are Buckyballs. The biological entries include Pasteur and his germ theory of disease and fermentation, Robert Koch, Edward Jenner, milkmaids and cowpox, malaria and Ronald Ross, Fleming and penicillin. There are three chapters on DNA, a recent entry in the history of science.

Ashall leads the reader through the developments of many remarkable discoveries. It is a book I will use with my 14+ students.

—Campbell Boag

reprinted from *BSHS Education Forum*

The Trouble with Science. Robin Dunbar. Harvard Univ. Pr. (1995). ISBN 0-674-91019-2.

Dunbar claims that the trouble with trying to inform the public about science— epitomized in Snow's characterization (accurate, it seems) of the two cultures—is that our brains just aren't evolved to deal with extremely rigorous quantifi-cation, abstract theories and logic. (I know students who would like that as a defense.) If true, the outlook for science teachers is pretty dismal indeed. Oddly, Dunbar doesn't seem to explain why some individuals seem to have a knack for science: maybe they got the "rigor" genes—or maybe it has nothing to do with evolution at all. The speculation is provocative, but the evidence wanting. —Ed.

ETHICS CASE

• ***Should we restrict recreational causes of soot pollution?***

"*The issue*: Many communities are trying to do their part to reduce the level of black carbon pollution in the air. It is difficult for a small city or town to restrict driving or to impose pollution regulations on trucks and automobiles. However, another source of soot is from the burning of wood in fireplaces and charcoal briquets in barbeques.

"Some communities have imposed a ban or sharp restriction on the recreational use of wood-burning fireplaces and barbeques. It is unclear whether these new regulations will be enforceable, nor how effective the new ordinances will be in reducing emissions. However, one could easily argue that these recreational activities are non-essential, and that anything which will help reduce soot production is worth trying."

— ˜ —

Some basic principles might emerge from discussion: What is the balance between individual freedom and social responsibility? How does scientific information about the scale of the problem or possible harm affect an assessment of the balance (consider also second-hand smoke)? Does it matter that these sources are recreational, not commercial —and why? What is the relationship between the *meaning* of the pollution (its source) and its *magnitude* (sheer measured quantity)? How does this case relate to automobiles as individual point sources? What does this case add to understanding larger scale pollution?

The issue was downloaded from a more extensive case study on indoor and outdoor pollution from the Lawrence Berkeley National Laboratory's Ethical, Legal and Social Issues Project (www.lbl.gov/Education/ELSI/pollution-main.html). Other cases (grades 7-12) address:

- Basic and applied research
- Breast cancer screening
- Genetic patents and intellectual property
- Personal privacy and medical databases
- Sustainable development

WEBSIGHTS

(Ratings are on 4 **i** scale.)

Note: We will incorporate all these links into the SHiPS website (distributed to the appropriate pages). The quarterly *News* will continue to profile new sites as links are added.

• **Original Papers** — From the *Origin of Species* (complete and online!) to papers in chemistry, psychology, etc., see our own index:
ships.umn.edu/papers.htm

• Classroom project on "**black boxes**" to convey the nature of models (**i i i**):
depts.washington.edu/hssexec/ committee /hss_nature.html

• The Univ. of Cambridge HPS Department provides excellent links for basic **HPS resources** on the web (not necessarily about teaching):
www.hps.cam.ac.uk/IRHPS.html

• Search for your favorite **NOVA** programs:
www.pbs.org/wgbh/nova/search.html

• **A Science Odyssey** (WGBH). Based on the 1997 TV series. Includes several activities.
www.pbs.org/wgbh/aso/

• Special essays by noted historians profile specific fields (under the egis of the History of Science Society):

Life Sciences in the 20th Century
depts.washington.edu/hssexec/newsletter/1997/allen.html

Russian and Soviet Science & Technology
depts.washington.edu/hssexec/newsletter/1997/graham.html

• **Museum** of the History of Science, Oxford
www.mhs.ox.ac.uk

This site includes several online exhibits: on the technology of photographic imaging; Tycho Brahe; mathematics in war battles (1500-1750) and practical mathematics in Renaissance Europe.

• partial list of **African American inventors**:
www.ai.mit.edu/~isbell/HFh/black/events_and_people/009.aa_inventions

• 4,000 Years of **Women in Science** (which here means mostly before 1900!?) — includes biographies, photos and references. Quality and depth are inconsistent, but the site has promise for future growth (**i i**).

crux.astr.ua.edu/4000WS/4000WS.html

• **Women in Science**: High-quality photos from an exhibit of Cambridge University graduates, including a handful of scientists (but not labeled as a group): Carol Vorderman, Penelope Leach, Alice Stewart, Wendy Savage, Julia Shelton, Sarah Springman, Olga Kennard, Jane Goodall, Anne Campbell, Alison Brown, Margaret Bray and Jocelyn Bell Burnell (no biographies).

www.admin.cam.ac.uk/offices/press/eve/

• Advise on "Nine Steps to Achieve **Gender Equity** in the Science Classroom" (**i i i i**):

www.brown.edu/Administration/Dean_of_the_College/homepginfo/equity/Equity_handbook.html

• The Biography Project of the Society for the Advancement of **Chicanos and Native Americans** in Science (NACNAS) -- mostly interviews of current scientists. The general theme is role models and recruitment:

www.sacnas.org/bio/index.html

• "**Medicine Through Time**" — sorted by era, and by topic (diseases, hospitals, alternatives), with biographies:

www.bbc.co.uk/education/medicine/ nonint/home.shtml

• **History of Phrenology** — well organized, if you want to venture into the fascinating realm of this now disreputable science which is, oddly, a logical expression of the structure-function relationship (**i i i**).

www.jmvanwyhe.freeserve.co.uk

• Online **magazine for biology and medicine**, frequently with historical features.

www.biomednet.com/hmsbeagle

• **Ben Franklin** (Franklin Institute)

sln.fi.edu/franklin/rotten.html

• **Alchemy** Central! — This site is so extensive that it's easy to get lost. A nice introductory page awaits someone wanting to venture into the territory *seriously*.

www.levity.com/alchemy/home.html

Especially good for images:

www.levity.com/alchemy/images_s.html

• For the **origins of chemistry** (especially metallurgy and glass through medieval times, as well as alchemy):

www-shist.sci.kun.nl/shist/

• **Nobel Prizes in Chemistry**

userpage.chemie.fu-berlin.de/diverse/ bib/nobel_chemie_e.html

• More links for **history of chemistry** for teachers — from *The Catalyst*

www.TheCatalyst.org/m04histr.html

• "This Week in **Chemical History**" — charting history **by the calendar**:

www.chemcenter.org/history.html

• **Physics timeline**

www.weburbia.demon.co.uk/pg/historia.htm

• **Einstein** Online -- a virtual shrine of information for afficianadoes

www.westegg.com/einstein/

• **Volta** is best known for inventing the voltaic pile,or battery. But we are also indebted to him for discovering methane, the electrophorus, plate condenser, straw electrometer, condenser electrometer, eudiometer, and, finally, the electric pistol—an adult toy that James Burke connects to the spark plug in modern automobile engines. Historians will also note his debates with Galvani on "animal electricity." For information on Volta, primary and secondary sources, manuscripts, and Volta's instruments and physical cabinet (**i i i i**), see:

File-server.cilea.it/Museo/Pages/ePage0.html

A gallery of Volta portraits is at:

www.tin.it/alessandrovolta/inglese/alevol/volti/volti1.html

What Side of the Fence for Linus Pauling?

Linus Pauling earns renown for his two (unshared) Nobel Prizes. He was invited to the White House in 1962 to celebrate his award in Chemistry along with other laureates, but by then he had also been awarded the Peace Prize for his efforts to ban nuclear testing in the atmosphere. Hours before the reception, Pauling demonstrated in front of the White House to support the ban. Pauling was among those amused by the resulting headlines.

Chemical Heritage, 13(#2): 12-13.

On the SHiPS Horizon

Special issues being planned for the future include: **Science and Art** (emphasis on the science of aesthetics and the aesthetics of science); **Science and War**; and **Error in Science**. Please forward your resources, websites, book briefs, case studies, ideas— and, of course, notify the editor if you'd like to write something!

SHiPS Science Teachers Network
Douglas Allchin, Editor
737 Heller Hall
University of Minnesota
Minneapolis MN 55455