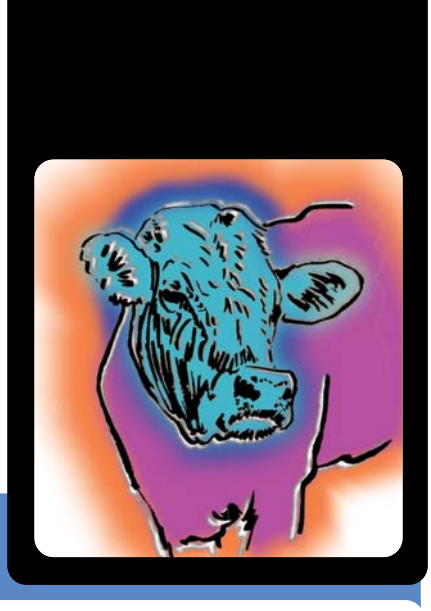

William Harvey & Capillaries

Can you "discover" circulation without connections between arteries & veins?

DOUGLAS ALLCHIN, DEPARTMENT EDITOR

Circulation of the blood is so familiar that one can hardly imagine a time when it was not fully understood. Indeed, the Ancients knew about the pulse and the flow of blood. They recognized, too, the vital importance of the heartbeat and nourishment. Yet the concept of a complete blood circuit emerged only in the early 1600s, due largely to experiments by William Harvey. Harvey has since earned renown as one of biology's great heroes. But what exactly did Harvey discover? Careful study reveals at least one major misconception of history and–far more importantly–a clue to widespread misunderstandings of science itself.

Anyone interested in Harvey's discovery will surely turn to his original 1628 publication, *De motu cordis et sanguinis*. Well, its English translation, perhaps, *On the Motion of the Heart and the Blood*. (Harvey, like most scholars of his era, wrote in Latin. Note this first subtle clue to the intellectual distance between then and now.) In the first half, Harvey describes the motion of the heart and arteries. They do not actively "breathe" and fill, like lungs, as Galen and others had described. Rather, the heart contracts as it beats. At the same time, the arteries expand from the influx of blood, in an *opposing* rhythm. Harvey shares his observations of living animals (vivisection), especially of frogs and other "lower" animals. With their slower hearts, the stages of motion were more readily seen. From observing blood flow in fishes and fetuses, and noting how heart valves work, Harvey reasoned that all blood must flow through the lungs. Harvey reflected a renewed spirit of experimentation among his contemporaries: an eagerness to tinker with and actively probe nature.

In the second half of his small book, Harvey argues for full circulation. First, an immense volume of blood passes through the heart from the veins (via the lungs) to the arteries. Where does it all go, if not returning to the heart to cycle again? Second, a series of half-tight ligatures demonstrates that blood moves away from the heart and collects in the veins of the extremities. Third, valves direct the blood flow in the veins toward the heart only. Here, Harvey included a now famous diagram showing how readers could demonstrate this for themselves. Evacuate the blood from a segment of vein in the forearm,

DOUGLAS ALLCHIN has taught both high school and college biology and now teaches History of Science at the University of Minnesota, Minneapolis, MN 55455; e-mail: allch001@umn.edu. He is a Fellow at the Minnesota Center for the Philosophy of Science and edits the SHiPS Resource Center (ships.umn.edu). He hikes, photographs lichen, and enjoys tea.

then open the segment alternately at either end. Blood fills the vein again only from the distal end. Taken together these three observations, Harvey claimed, demonstrate "motion, as it were, in a circle."

The modern reader may notice that Harvey's argument omitted one key element. That is, blood must pass from the arteries to the veins. How? Capillaries complete the circuit. Yet without a microscope, Harvey could not possibly have observed them. Surely he must have understood their role *even without seeing them.* That is, the power of his observations and logic apparently allowed him to predict something yet unknown. That leap of imagination, that bold conjecture, only seems to deepen Harvey's greatness. Indeed, the observation of capillaries in the decades after Harvey's death, by both Marcello Malpighi and Antony von Leeuwenhoek, seems triumphant, albeit ironic confirmation, bringing nice closure to the story.

Indeed one finds this story of the capillaries frequently, not the least in this very journal (Lewis, 1988; Lawson, 2000). But the actual history diverges from the popular story. Harvey did not postulate capillaries (Elkana & Goodfield, 1968). How can this be? How else could blood circulate? Harvey believed instead that blood "percolates" in the lungs. It is absorbed into the veins from the "pores and interstices" of the tissues. He offered as analogy "the way water percolating the earth produces springs and rivulets" (1628, Ch. 7, p. 283). For Harvey, the tissues were like porous sponges that would yield their blood when in motion or when adjacent muscles contracted (1649a, pp. 308-309). The rate of blood flow even varied through the organs, depending on their "denseness or sponginess" (1649b, p. 322). For Harvey, the blood passed freely from arteries to veins—as we find in mollusks, arthropods, and other organisms with open circulatory systems.

Even more puzzling, perhaps, Harvey argued *against* anastomoses, or direct meetings of the arteries and veins. In responding to critics, he reported on his search for any such connections:

> *I myself have pursued this subject of the anastomosis with all the diligence I could command, and have given not a little both of time and labour to the inquiry; but I have never succeeded in tracing any connexion between the arteries and veins by a direct anastomosis of the orifices.*
>
> *... by boiling, I have rendered the whole parenchyma of these organs (liver, lungs, spleen and kidneys) so friable that it could be shaken like dust from the fibres, or picked away with a needle, until I could trace the fibres of every subdivision, and see every capillary filament distinctly. I can therefore boldy affirm that there is neither anastomosis of the vena portae with the cava, or the arteries with the veins, or of the capillary ramification of the biliary ducts, which can be traced through the entire liver, with the veins.* (1649a, p. 311)

Harvey did use the word capillary, but clearly to mean only a very fine vessel. For Harvey, an anastomosis would allow blood to flow (as Galen had claimed) *from* the veins *into* the arteries. Harvey wanted to deny just that. He thus readily trusted his plain observations in rejecting today's "essential" capillaries.

One might well be tempted to cast the error about Harvey and the capillaries as a minor historical footnote. Of import only to the most fastidious student or teacher of biology. But the error –like any error, perhaps– holds great significance for the reflective observer. Namely, why did the error ever occur? Consider, in particular, the vast reach of this error. One finds the story of predicting capillaries in a nationally syndicated radio series on science, a biographical reference from a university publisher, a prominent Web site for biology teachers, and even for a medical research foundation named after Harvey himself! (Leinhard, 1997; Oxford University Press; Phillips, 2004; the William Harvey Medical Research Foundation—I indicate the sources not to fault them, but to underscore the impressive scope of the error. Even many historians, as Elkana and Goodfield [1968] document, once succumbed to the same mistake.) One cannot simply brush aside the error as trivial or due to willful ignorance. If errors are opportunities for learning, what does this particular error about Harvey indicate about how we think—and thus how we might think more effectively in the future?

First, we are liable to read Harvey's 17th century work in terms of today's science. For example, one may interpret Harvey's concept of circulation as our own. One readily assumes—without even recognizing any assumption at work—that he accepted the capillary model. Any strange wording or anomalous phrase that might clue us to Harvey's different perspective—and they are frequent—may be easily dismissed as confused or irrelevant. Our minds subtly filter exceptions to expectations.

We may also anachronistically import ideas about *the nature of science*. In Harvey's case, this is the hypothetico-deductive (HD) format, often touted as "the scientific method." (See especially earlier discussions of Harvey in *ABT.*) Accordingly, one may be far too ready to imagine that Harvey *deduced* capillaries, based on an alleged theoretical gap. The case can be shaped to fit one's model of science. Again, this historical error might be inconsequential were it not for an added irony. Harvey's case has become, in turn, an exemplar to parade before students of the role of hypothetico-deductive method in science! The assumption became written into history. The history then seems to justify the very

assumption behind it. A flawed *historical* interpretation can thereby subvert effective understanding of *the nature of science.*

A second theme also emerges when reflecting on the mistaken notion that Harvey discovered capillaries. That is, Harvey's achievement is inflated. This error, too, would matter far less were it not echoed further in depictions of Harvey's work. So, for example, Harvey was not the first to notice blood flow to and from the lungs. Miguel Serveto, Realdo Columbo, and Andrea Cesalpino each elucidated the pulmonary circuit in the decades before Harvey. (Arab physician al-Qurashi, known as Ibn al-Nafis, did likewise in the 13th century, although his work did not reach Renaissance Europe.) Likewise, the valves in the veins were first observed by Harvey's teacher, Gerolamo Fabrizio (Fabricius). Harvey is portrayed as the brave critic of the ancient Galen, although others also questioned Galen's claims and authority. Like most scientists, Harvey worked in a tradition. Yet classroom stories tend to attribute the separate discoveries to only one person.

Once Harvey is cast as a singular hero, his own errors recede, his critics are vilified, and his triumph amplified. For example, consider Harvey's analogies. In describing physiology, he alludes to cisterns, gunshots, and pistons. Some immediately conclude that he thereby established a modern, mechanical view of the body, including the heart as a pump. Yet Harvey ultimately attributed all motive power to the warmth of the blood. That view, now abandoned, remains hidden in most popular accounts. So, too, is Harvey's argument that the body is a microcosm of the world and the heart its Sun. Harvey's vitalism also pervades his other great work, *On Generation.* Antagonistic characters further heighten the drama. The Greek physician Galen, in particular, is blamed for blatant errors perpetuated for centuries. Yet Harvey himself explicitly praised Galen's expertise. Finally, Harvey's critics, such as Jean Riolan, are portrayed as inept fools, impeding the progress of science. Their reasoning or evidence *in context* is eclipsed. At its worst, science is reduced to melodrama. Scientists become superhuman legends—yet also hollow characters.

The errors about Harvey, then, reflect a syndrome also found in other "textbook" histories. The actual history is not just truncated for simplicity's sake. (Note how the capillary story *adds* illusory facts.) Rather, these fables—masquerading as authentic history—convey only positive achievements, inerrant methods, and idealized role models. An implicit "moral" about science emerges: Proper method is algorithmic; solutions are guaranteed; evidence is unequivocal; scientists transcend human limitations. Such stories may seem to inspire. But they also mislead:

- They generate false promises and thus foster anti-science views when science "fails" to solve urgent social problems quickly.
- They pathologize scientific uncertainty and disagreement among scientists.
- They inhibit critical engagement with scientists and their findings.
- They suggest that a scientific career is beyond the reach of an average or "merely" good student, however motivated or keenly interested.

The story about capillaries and related versions of history are not idle. They subvert effective understanding of the nature of science. Recent new science education standards remind us just how important those lessons are in preparing citizens to assess science in personal and public decision making.

The greatest irony in the mythic stories of Harvey is that they often understate his "real" achievement. To fully appreciate his influence, however, one must understand a bit about Renaissance medicine and physiology—as unfamiliar and perhaps absurd to us now as our current beliefs would no doubt appear back then. Fundamental was the notion that the body was sustained by the equilibrium of four special fluids, or *humors*—phlegm, yellow bile, black bile, and blood. While Harvey focused just on circulation, his ideas about blood indirectly affected the entire network of concepts. First, he implied that bloodletting—a common practice aimed at restoring the body's harmonious balance—was irrelevant. Second, by unifying the arterial and venous systems, he disturbed prevalent theories of nutrition, based on the (venous) blood as a product of the liver. By reconceptualizing blood, he opened a reassessment of all the humors and thus of all physiology.

The other influence of Harvey was already noted—his advocacy of observation and experiment. Harvey was certainly not unique in such support. But the discovery of circulation certainly exemplified and dramatized its value. Harvey's perspective, ironically, was not new at all. He adopted his disposition for ocular demonstration from Aristotle. The value of experiment had been richly demonstrated in ancient times by Galen.

Note

For a related student activity, see: http://www.timelinescience.org/resource/students/blood/act1.htm

References

Elkana, Y. & Goodfield, J. (1968). Harvey and the problem of the "capillaries." *Isis, 59,* 61-73.

Harvey, W. (1628/1952). *On the Motion of the Heart and the Blood,* translated by Robert Willis. In *Great Books of the Western World,* Vol. 28. Chicago: Encyclopedia Britannica, Inc.

Harvey, W. (1649a/1952). *Anatomical Disquisition on the Circulation of the Blood, to Jean Riolan,* translated by Robert Willis. In *Great Books of the Western World,* Vol. 28. Chicago: Encyclopedia Britannica, Inc.

Harvey, W. (1649b/1952). *A Second Disquisition to Jean Riolan,* translated by Robert Willis. In *Great Books of the Western World,* Vol. 28. Chicago: Encyclopedia Britannica, Inc.

Lawson, A. (2000). The generality of the hypothetico-deductive method: making scientific thinking explicit. *The American Biology Teacher 62*(7), 482-495.

Leinhard, J.H. (1997). No. 336: *William Harvey, Engines of Our Ingenuity.* URL: www.uh.edu/engines/epi336.htm (accessed April 2, 2004).

Lewis, R. W. (1988). Biology: a hypothetico-deductive science. *The American Biology Teacher, 50*(6), 362-366.

Oxford University Press. (1999). *A Dictionary of Scientists,* Market House Books Ltd. URL: www.xrefer.com/entry/494530.

Phillips, R.E., Jr. (2004). *The Heart and the Circulatory System, Access Excellence Classic Collection.* Access Excellence. URL: www.accessexcellence.org/AE/AEC/CC/ heart_background.html (accessed April 2, 2004).

William Harvey Medical Research Foundation. (1998). About William Harvey. URL: www.williamharvey.org/wm_harvey.htm (accessed April 2, 2004).