CHAPTER 1

Harvey versus Primrose, Riolan, and the Anatomists

Circulation of the Blood

In the 17th century it had been "known" for some 1,400 years that the blood was created in the liver, moved outward from the heart toward the extremities, and, in nourishing the tissues, just disappeared there. The heart was also the source of some sort of vital spirit, which in some mysterious way had to do with the blood.

In 1628, British physician and anatomist William Harvey announced his discovery of the circulation of the blood and, just as shocking, reported that the heart was merely a pump that was pushing the fluid around and around in the body.

He had laid out his theory, carefully and clearly, and of course in Latin, in a small book consisting of 72 poorly printed pages. Its title, *Exercitatio Anatomica de Motu Cordis et Sanguinis in Animalibus*,[1] is often shortened to *De Motu Cordis* (On the motion of the heart), or *DMC*. One reason for the poor print job was that it had to be published in far-off Germany, for the British censor forbad its publication, and no British publisher would touch it.[2] The publisher, Wilhelm Fitzer in Frankfurt, offered as an excuse for the many printer's errors the "unfavorable times," meaning the Thirty Years' War that was then ravaging Germany.[3]

Nevertheless, no one had any trouble figuring out Harvey's message. In the first half of the book, he presents his findings on the heart, and mentions some of his fears and hesitations. Though he published in 1628, he had started his work more than a dozen years earlier, and had been demonstrating parts of it at his own Royal College of Physicians for at least nine of those years,[4] hoping to build up support among his colleagues.

A quick look at the first chapter of *DMC* tells us what his experience had been up to the date of publication. His discovery, he writes,

"pleased some more, others less; some chid and calumniated me and laid to me as a crime that I had dared to depart from the precepts and opinions of all anatomists."[5] He also lays out his research program in this first half and, mainly, gives the first scientifically based description of the heart's functions.

Then, in chapter 8, Harvey introduces the idea that the blood circulates, which, he feared, rightfully, would be even more shocking to his readers. In the opening paragraph, he states: "What remains to be said upon the quantity and source of the blood . . . is of a character so novel and unheard-of that I not only fear injury to myself from the envy of a few, but I tremble lest I have mankind at large for my enemies. . . ."[6]

Paranoia or Realistic Fears?

Was he just being paranoid? Hardly. Not long before, in 1591, Eufame Macalyane, a Scottish lady of rank, sought relief for the pain of childbirth. For this transgression—does not Holy Writ refer to "the primeval curse on woman"?—she was burned at the stake in Edinburgh.[7]

And in 1600, only a quarter century before Harvey's book appeared, Giordano Bruno, a pugnacious Italian philosopher, had been burned alive for his stubborn espousal of the idea that the universe was infinite and not bounded, as maintained by the Greek astronomer Ptolemy (second century A.D.). The Ptolemaic system had been strongly supported by the Church, which took Bruno's ideas to be sacrilegious and therefore dangerous.

A few years after Harvey's book was published, the great Galileo Galilei did recant when faced with the fearsome might of the Inquisition. As a result, he was merely sentenced to house arrest for the balance of his life—because he had published a book that argued against the same Ptolemaic system. But Bruno and Galileo were only the better-known examples of theological intolerance. Many others suffered and perished for even lesser crimes.

Granted, Harvey was an Englishman and an Anglican in a non-Catholic country. But England had been a Catholic country not long before and could be one again if the monarch chose to convert.

And Catholicism was not the only source of danger. In the middle of the previous century, Spanish-born Michael Servetus, a sort of itinerant physician with a strong interest in theology, had come up with a correct description of the pulmonary circulation (the movement of the blood from heart to lungs and back again). Unfortunately, his insight

was connected with and contained within one of his many theological writings. This tract particularly *(On the Restitution of Christianity)* managed to aggravate both Protestants and Catholics, and, in 1553, it was burned by Calvin in Geneva—along with Servetus himself.

Witch-hunting and a widespread belief in the occult was another possible source of danger. In 1618, Harvey became one of King James I's personal physicians. But James was a strong supporter of witch-hunts, and had written a book on it. Harvey was fearful of the awful credulity of the time.

Harvey's era was also one of extreme political unrest. The Royalists, those supporting the king, and the Parliamentarians, looking to overthrow the monarchy, were constantly at odds. One never knew from which direction trouble might come. Harvey, as one of James's physicians, was blamed for bringing on the king's death (1625) when he defended the use of a remedy suggested by the king's favorite, Lord Buckingham. Fortunately, there were no serious consequences for Harvey, but the suspicions lingered.

All of this makes it a bit easier to understand why Harvey might be nervous, and perhaps explains why he walked around with a dagger strapped to his waist. The 17th-century biographer John Aubrey described him thus: "He was very Cholerique; and in his young days wore a dagger (as the fashion then was) but this Dr. would be apt to draw-out his dagger upon every slight occasion."[8] A more recent biographer, Geoffrey Keynes, adds that the dagger, which Harvey continued to wear in his middle years, reflected his earlier experience as a medical student at the University of Padua, where gangs of young students, representing factions from different countries, often battled each other.[9] There were also scuffles and even more serious disorders between students and townspeople.[10]

Harvey has been described as "rather on the small side, with raven hair, dark piercing eyes, somewhat sallow complexion, and a keen restless demeanour and rapid speech."[11] Science historian Jerome J. Bylebyl writes that Harvey "seems to have been well liked by those who knew him, although he was an outspoken man and perhaps somewhat short-tempered."[12]

A small, outspoken, somewhat short-tempered scientific genius in a superstitious and dangerous age. Is it any wonder that Harvey was nervous?

Initial Response

Harvey himself initially stood apart from the controversy that erupted after publication; but although he was not subject to physical violence, he took plenty of flak nonetheless. He was given the nickname Circulator, a conflation of the idea of circular reasoning with his theory of the blood's circulation.

The term's derivation also contains the implication of quack or mountebank. Aubrey wrote: "I have heard him say, that after his Booke of the *Circulation of the Blood* came out, that he fell mightily in his Practize, and that 'twas believed by the vulgar that he was crackbrained, and all the Physitians were against his Opinion. . . ."[13]

Viscount Conway advised his daughter-in-law not to use Harvey as her physician: "he is a most excelent Anatomist, and I conceive *[De Motu Cordis]* to be his Masterpiece . . . but in the practicke of Physicke I conceive him to be to[o] mutch, many times, governed by his Phantasy. . . . [And] to have a Physitian abound in phantasie is a very perilous thing. . . ."[14]

What Conway meant by "phantasie" was, clearly, Harvey's ideas about the circulation. Conway was writing in 1651, 23 years after *DMC* was published, by which time acceptance was relatively widespread. Yet the basic problem, that Harvey was attacking and overturning the ancient anatomists, still bothered many of his contemporaries.

The Galenic Corpus

Among those Harvey was overturning was Galen, a second-century Greek physician and anatomist. A genius and well ahead of his time, he produced enormous quantities of medical writings. Though Galen did not himself become a Christian, his search for design and purpose in all things, including the human body, made his works well-liked by the Church, and this in turn ensured the survival of his theories into Harvey's day.

Galen argued, for example, that nature always acts with perfect wisdom; and that the body is nothing but a vehicle for the soul. Christian theologists found that these ideas fitted nicely with some of their own: disease is punishment for sin, and the body is sacred. As a result, dissection of humans is a sin, and anything that detracts from the Great Physician is anathema.

Now, Galen had a high opinion of both himself and his work, but he recognized the likelihood of advances beyond his claims and explanations. He would probably have laughed had he returned in Harvey's day and seen what the academics had made of his doctrines—edifices to be admired, even revered, rather than foundations on which to build new ones.

One of these edifices was the *Anatomy* that Galen had put together, a comprehensive work that described much of the body and "explained" many of its functions as well. As attending surgeon at the gladiatorial games under the Romans, he had considerable experience with human bones, muscles, and blood. Not afraid to get his hands dirty, he had also done dissections and even experiments—which was more than could be said for most of Harvey's contemporaries.

There are hints that he did some of these on human bodies, but virtually all of his physiological research was on animals. He performed vast numbers of dissections and experiments on a variety of animals, from which he certainly learned a great deal about anatomy.

Unfortunately, he extrapolated what he learned from his experimental creatures to the human body. Some of it he got right, and much of it he got wrong. His descriptions of the muscles in humans were excellent, for example, and he did some good experimental work involving the spinal cord.[15]

But Galen's physiology—that is, his explanations of the functioning of the body's organs—comprised an amazing concoction of moonshine and faint glimmerings of nature's ways. An example of the moonshine was his use of "spirit." This vague concept was somehow connected with the blood. It also lent itself nicely to later religious and philosophical teachings involving the soul, the breath of life, and so on. Now, the air we breathe in and out does indeed have some sort of connection with the blood. But the spirit idea added nothing of value to anyone's understanding.

It could, however, be used in a vast variety of creative ways. As a Galenic follower explained in 1556: "During waking the face and other external parts are red, and well colored, each according to its nature; but they become pale and livid during sleep, which could only happen because at this time all the blood, or at least its lighter and more spiritous portion, betakes itself to the inner parts, while in waking it rushes out to the external parts."[16]

Fear was another example of the movement of heat, spirit, and blood to the inner regions of the body, while anger exemplified outward flow. Sadness was a less extreme inward movement, and joy an

equally moderate outward dispersal. According to Galen, anger never caused any deaths, but some weak-spirited individuals may have died of overabundant joy. Sudden fear may also cause death, because the blood comes together and has a suffocating effect.[17]

By Harvey's day, medicine had solidified into a Galenic corpus. Teachers of medicine had relied for centuries on Galen's illustrations of the human body and saw no need to do any dissections themselves.

So religion, superstition, and medicine remained tied up in a huge Gordian knot. The Galenic corpus may be old; it may be wrong in many respects; but that doesn't mean it's simple. An edition of Galen's extant works, comprising 2.5 million words in 22 thick volumes, is estimated to be only two-thirds of his complete output.[18] Seventeenth-century anatomists and physicians didn't know a lot of medicine as we know it today, but that doesn't mean there wasn't plenty to teach.

Here I can only give the vaguest idea of the complex system of physiology they taught. The blood, said the Galenists, began in the liver, then moved outward from the heart and toward the extremities; it normally moved only in the veins and, in nourishing the tissues, just disappeared there, so there was no need for it to return anywhere.

The movement of blood was a volatile activity, not a regular thing, a response of some sort to a wide range of bodily requirements. It might be local in character, or it could be a massive movement both inward or outward. All of these were associated with a wide range of phenomena.

The arteries and the veins comprised two independent systems, each of which dealt with its own type of blood: venous blood had to do with nutrition, and the arterial with "vivification." The latter was a kind of pneumatic system that controlled the distribution of vital spirit and heat (including air) throughout the body.

Another source of trouble was Galen's belief that there are minute pores in the septum (the dividing wall between the two side-by-side ventricles of the heart), which permitted passage of substances, such as blood and spirit, between them. It was clear that there was some sort of connection between arteries and veins, so Galen invented the pores. He explained that it was not possible to see them "both because of their smallness and because when the animal is dead, all its parts are chilled and shrunken."[19]

Though hobbled by tradition and religion, however, 16th- and 17th-century surgeons, physicians, and anatomists still had eyes and brains. Experiments and observations did take place. It was their wonderful, creative explanations that kept the whole thing together.

They saw, for instance, that arteries and veins were physically dif-

ferent from each other. What then is the reason for the thicker, stronger construction of the arteries? That's easy. It is needed to hold in the strongly active and penetrating animal spirits.

The great anatomist Fabricius—Harvey's own teacher at the University of Padua—made what should have been a momentous discovery. In 1579 he described "little doors" (valves) in the veins. Fabricius, however, saw the valves as regulating the movement of blood to deal with pathological conditions. So he never understood their real purpose—permitting perfectly normal flow only toward the heart, exactly the reverse of what Galen had postulated.

Further, after a creature suffers a violent death, autopsy reveals that the veins are congested with blood, while the arteries are relatively empty. To the Galenists, this was proof that the arteries are normally filled with air and spirit, not blood. What actually happens is that the venous blood is held in place by the valves found everywhere in the veins, while the arterial blood has been free to flow out unimpeded.

Yet they also saw that if an artery is cut, it clearly spurts blood. This, however, was again taken to be a pathological condition: what is happening, they reasoned, is that as a direct result of the puncture, a sort of one-way evacuation is taking place, in which blood from the veins is drawn into the arteries and then expelled through the opening in the artery.

The worst part of it all is that these theories did not exist in a vacuum; they were drawn upon for clinical purposes. So if one is bleeding from an artery, the Galenists believed there must be too much blood in the veins, and that it has found its way to the arteries. Cure for puncture wound in an artery: bleed the veins.

In fact, all disease involved the distribution, or maldistribution, of blood and spirits, and it was relocation of these substances that they were trying to accomplish in their treatments. But Galen also supported Hippocrates' belief that disease resulted from an imbalance in the vital fluids, or humors, namely, blood, phlegm, black bile, and yellow bile. The easiest to get at, obviously, was the blood. This explains why bleeding, the deliberate letting of blood, played such an important part in Galenic medicine.

It's no wonder that Lewis Thomas could write that before the injection of science, medicine was an "unbelievably deplorable . . . story. . . . It is astounding that the profession survived so long, and got away with so much with so little outcry."[20]

Obviously, this couldn't change until a fresh look was taken at the physiology of the body, including the part actually played by the blood

and, even more fundamentally, at that prime mover, the heart. In the Galenic view, the heart was the source of the vital spirit. It was also a flaccid organ; it swelled on a regular basis as a result of, rather than being a cause of, the movement of the blood. Until its proper function was understood, little more could be accomplished.

Steps along the Way

In the first chapter of Harvey's book he tells us:

> When I first gave my mind to vivisections, as a means of discovering the motions and uses of the heart, and sought to discover these from actual inspection . . . I found the task so truly arduous, so full of difficulties, that I was almost tempted to think . . . that the motion of the heart was only to be comprehended by God. . . .
>
> At length, by using greater and daily diligence and investigation, making frequent inspection of many and various animals, and collating numerous observations, I thought that I had attained to the truth. . . .[21]

A compulsive experimenter, he worked with all manner of creatures. But whereas Galen went off the track in many of his extrapolations from animals to humans, Harvey realized that he could actually learn more about the heart from some of the lower animals, particularly from cold-blooded creatures, because the movements of their hearts are slower and therefore easier to follow.

He points out in *DMC* that these movements "also become more distinct in warm-blooded animals, such as the dog and hog, if they be attentively noted when the heart begins to flag, to move more slowly . . ."[22] (meaning, of course, when the animals are somehow weakened or brought close to death). Over the long period of his theory's development, he may have experimented with some 80 species of animals.[23]

As he learned more about the heart, a huge puzzle presented itself. The traditional idea was that blood was formed from food in the liver; that it found its way through the system and out to all parts of the body; and that it was there consumed in the body's activities, including replacement of damaged tissue, as needed.

But Harvey, now convinced that the heart was the source of regular delivery, pursued a particularly unusual course for that time. First, he measured the volume of many left ventricles (the chamber that sends blood out to the extremities), and determined that in humans they contained an average of some 2 fluid ounces. Reasoning that even if only a quarter of the blood in such a chamber is sent out on each stroke, then the amount of blood being delivered—half an ounce times an average of 4,200 strokes an hour—would require the continuous production of over 65 quarts of blood per hour. This was clearly a preposterous idea.

The only logical explanation was that the blood was not being continually created and consumed, but was, to put it simply, conserved. Note that he was actually measuring something, in this case the volume of the left ventricle, and then putting the figure to work. In so doing he was creating a new world of experimental physiology. Of all his demonstrations and proofs, this one may have been the most telling in the long run.

But there were others. One problem he faced was that the optical equipment of his time was not sharp enough to detect the microscopic passages between the arteries and the veins in the extremities. But by a clever use of ligatures (straps) around the arm, by which he could selectively cut off and permit circulation in these vessels, he showed that blood did move from arteries to veins, though he could not say how. Whether other physiologists were convinced is another question.

But even with all this solid scientific activity, the *idea* of the blood moving in a circle may have come about in quite a different way, and again taps into the world in which Harvey lived and worked. The principle of circularity has a long history, and has been seen in a variety of applications, including the perfect orbital circles of the heavenly bodies in the Ptolemaic world system.

One of Harvey's colleagues, Robert Fludd, advocated a mystical system in the early 1620s that also involved the idea of circulation. The sun, he believed, issues some sort of "catholic spirit" (i.e., universal spirit), which gives life to the earth by penetrating a variety of "temples." These may be anything from the germ of wheat to the living heart, all of which behave like "suns." The pulsation of the heart, for example, distributes the vital spirit to the rest of the body by a process of circulatory currents, in the same way as the sun's catholic spirit spreads across the earth.[24]

Fludd, in other words, felt that both the Sun and the heart were generators of some sort and were involved in a kind of circulatory activity.

Of course, his circulation was quite different from Harvey's. But scientific ideas can arise in surprising ways.

Nor did Harvey simply leap out of the 17th century. Still an Aristotelian with metaphysical leanings, he wrote:

> The heart, consequently, is the beginning of life; the sun of the microcosm, even as the sun in his turn might well be designated the heart of the world; for it is the heart by whose virtue and pulse the blood is moved, perfected, and made nutrient, and is preserved from corruption and coagulation; it is the household divinity which, discharging its function, nourishes, cherishes, quickens the whole body. . . .[25]

We have no way of knowing for sure whether these metaphysical references reflected his own beliefs, or whether he included such writings to fend off attack.

Another interesting possibility: Jean Hamburger, a distinguished French medical researcher and writer, has recently suggested that the British political philosopher Thomas Hobbes may also have played some role in Harvey's vision of circularity. In an unusual kind of fictional biography, Hamburger postulates a diary entry by Harvey in which he writes: "While he [Hobbes] was thus evoking an image of a King whose mission it is to see that order and reason circulate among his subjects . . . another image was superimposed in my mind, that of a heart whose mission it was to circulate through the body the blood that bears the necessary spirits."[26]

Was Harvey influenced by Hobbes and his ideas about the state? They did meet sometime between 1621 and 1626. Although Hobbes's major works emerged well after Harvey had already come to his early conclusions, some early idea of Hobbes's might have provided a spark.

Interestingly, in Harvey's dedication to his royal patron, Charles I, he compares Charles to the sun. "The King, in like manner, is the foundation of the kingdom, the sun of the world around him, the heart of the republic, the fountain whence all power, all grace doth flow."[27] (Twenty years later the "foundation of the kingdom" was overthrown by the Parliamentarians and decapitated.)

One more possible influence on the development of Harvey's theory. Galileo was a professor at Padua when Harvey took his medical degree there. Galileo had been working on the mechanics of fluids in motion, including the theory of pumps. It seems reasonable to conclude that Harvey, exposed to this work, was influenced by it. Descartes, too, was working on a theory of motion at about this time, which may also have had some effect on Harvey.

These were some of the possible ideas and influences that got Harvey going. However it happened, Harvey came to his conclusions, built up a body of evidence, did what he could to convince his colleagues, and, finally, bit the bullet. The military metaphor is apt.

The Galenic Brigade

In the dozen years prior to the appearance of *DMC* in 1628, during which Harvey was developing his theory, preparing his manuscript, and lecturing on his ideas, there seems to have been little argument against his work, at least not in print. Harvey's reputation remained secure. His friend Fludd even published a work shortly after *DMC* appeared that supported Harvey. It was, however, mainly a metaphysical treatise, with little scientific discussion of Harvey's ideas. In fact, his main point was that Harvey's work provided support for his own mystical ideas.

There were a few other halfhearted efforts at support. Descartes issued the first actual discussion—meaning with some scientific content—of Harvey's work in 1637, but argued against his theories on the heart.[28] The earliest real, published support among Englishmen seems not to have appeared until 1641 (George Ent) and 1644 (Kenelm Digby)—which must have seemed like forever to Harvey. Digby, in fact, was finally answering Descartes's objections to parts of the new theory.[29]

On the other hand, three book-length refutations appeared in short order. The first, in 1630, came from James Primrose, an English provincial physician and a voluminous writer.

His work, with a title even longer than Harvey's[30] (but ending in *adversus Guilielmum Harveum*), was a compilation of misreadings, misunderstandings, and misstatements, at least to a modern reader. Robert Willis, the translator of *DMC* whose work I am using, wrote in 1878 that Primrose's book consisted of "obstinate denials, sometimes of what may be called perversions of statements involving matters of fact, and in its whole course appeals not once to experiment as a means of investigation."[31]

Primrose's style, however, is interesting. Here and there he addresses Harvey directly in apparently worshipful tone:

> Thou has observed a sort of pulsatile heart in slugs, flies, bees, and even in squill-fish [a kind of shrimp]. We congratulate thee upon thy zeal. May God preserve thee in such perspicacious ways. . . . Those who mark in thy writings the names of so many

> and diverse animals will take thee for the sovereign investigator of nature and will believe thee to be an oracle seated upon the tripod. . . .

Then comes the snide attack:

> I speak of those who are not physicians and have but a smattering of the science. But if we read the works of real anatomists, such as Galen, Vesalius, the illustrious Fabricius and Casserius, we see that they have provided us with engraved plates representing the animals they have dissected. As for Aristotle, he made observations of all things and no one should dare contest his conclusions.[32]

Primrose added that he had managed to refute in 2 weeks what it had taken Harvey 20 years to develop.

Primrose was generally contentious; not only did he have difficulty accepting new ideas, but he seemed compelled to fight them in print. More than a dozen years later, with the circulation idea gaining adherents, he was still in action. In 1644 he engaged in a pamphlet war with a defender of blood circulation.[33]

Primrose's contentiousness could be part of the reason for his attack on Harvey. He had also, however, made application to the College of Physicians in December 1629–January 1630, and was not accepted; he may have put at least part of the blame on Harvey for his rejection and was probably angry about Harvey's continued high position at the college in spite of his crazy anti-Galenic ideas.

But the plot may be even thicker than that. There is evidence that the president of the college, Dr. John Argent, exhorted Primrose to mount his attack.[34] Yet Harvey considered Argent a good friend and even dedicated his book to him.

In 1632 a respected Danish professor of medicine, Ole Worm,[35] also looked into the circulation question. He apparently teetered for a bit, but when he balanced Harvey's evidence against the strength of the old masters, Harvey came out second best. Worm let loose the second major critique of the new idea.

Then, in 1635, Emilio Parigiano, an elderly and respected Venetian physician, gave the world yet another extensive critique in the form of lengthy abstracts from *DMC* with, on the opposite page, acerbic criticism of each section. Regarding specific heart sounds, for example, which Harvey considered important, he suggested that Harvey was a

victim of his own imagination. "Our poor deaf ears, nor those of any physician in Venice, cannot hear them; thrice fortunate those in London who can."[36] He also, says historian Roger French, "saw Harvey as attempting to overturn the rationality and providence not only of nature, but of God."[37] Parigiano, interestingly, had studied with the eminent Fabricius, the same anatomy teacher Harvey had studied with in Padua.

In 1636, Harvey was in Nuremberg and paid a visit to the University of Altdorf, where he gave a public demonstration of his new theory. The main objective was to win over a distinguished anatomist and professor of medicine, Caspar Hofmann, another implacable foe of the new idea. Hofmann attended and promised to give Harvey his answer the next day. He did, in the form of a letter.

It began: "Your unbelievable kindness, my Harvey, makes me not only like you but love you . . ." After more of the same, he changes course: "You appear to accuse Nature of folly in that she went astray in a work of almost prime importance, namely, the making and distribution of food. Once that is admitted, what degree of confusion will not follow in other works which depend on the blood?"[38] He promises, however, that "if, after the clouds have been dispelled, you will show me the truth which is more beautiful than the evening and the morning stars, I will . . . publicly recant and retire from the field."[39]

Harvey, perhaps believing Hofmann's promise, replied immediately with a long, carefully crafted letter. His manner, as demanded by the times, is as courteous as Hofmann's, but he used some fairly direct words: "First you thought fit to indict me . . . because I seemed to you to charge and convict Nature of folly and of error, and to characterize her as a very stupid and idle worker . . . But . . . as I have always been full of admiration for Nature's skill, wisdom, and industry, I was not a little upset to have been given such a reputation by a man so very fair-minded as yourself."[40] He then goes on to answer Hofmann's objections. They corresponded further and Harvey even visited again. All to no avail.

Later years brought a truly strange twist of the knife. Harvey began to hear of lecturers on anatomy in England—where acceptance grew much faster than elsewhere—who were giving credit for the discovery of the circulation of the blood to Hofmann! In one case Harvey actually had to compare letters and dates in order to defend and clear himself.[41]

Among the many attacks on Harvey was one that could have been dreamed up by a spymaster like John Le Carré. In 1639 there had

appeared a pamphlet titled *A Most Certaine and True Relation of a Strange Monster or Serpent Found in the Left Ventricle of the Heart of John Pennant, Gentleman, of the Age of 21 years,* by Dr. Edward May, physician to Queen Henrietta Maria (wife of Charles). In it May details the results of an autopsy that showed clearly a "worme or serpent" coiled up in the cavity of the young man's left ventricle.

This was, ipso facto, a kind of proof that Harvey was wrong; a monster living in the ventricle showed that the blood does not circulate (if it did, the serpent would have been flushed out). Bad enough; but then, in 1643, Marco Aurelio Severino, a distinguished professor of anatomy at Naples, published the second edition of his important textbook *De Recondita Abscessuum Natura* (Of the hidden nature of abscesses), and included an account of May's finding.

But Severino, located in Naples, had actually written to an English colleague, Dr. John Houghton, asking for some details of the monster. Houghton had shown the letter to Harvey, who had quickly understood what was going on. May had actually found a plain old blood clot, but one in the form of a "serpent," which had slipped into the heart from a nearby blood vessel.

This is a very puzzling story, however. In an exchange of letters, Houghton must have told Severino about Harvey's conclusion. Yet although Severino is effusive about how much he admires "the great Harvey, that pillar of England as well as medicine and anatomy,"[42] he nevertheless included May's description of the "cardiac worm" in his textbook.

The "finding" was again recounted in a 1678 book called *Wonders of the Little World,* and apparently remained in the literature for another century.

It was also put to use by one of Harvey's most vicious enemies, though perhaps unwittingly. In 1648, a full two decades after publication of *DMC,* Jean Riolan, dean of the Paris Faculty of Medicine and personal physician to both the French king and the queen mother (and one of Primrose's teachers in Paris), unleashed the first of two major attacks on Harvey's work. The first (1649) was relatively gentle and attacked him only indirectly.

The second, *Opuscula Anatomica Nova,* came a year later; it is much more vituperative and even goes after a Leyden physician, Jan de Wale, who had supported Harvey's ideas. This, in spite of the fact that de Wale claimed the idea had its origin in antiquity and that other workers had brought it along to the point where Harvey could, and did, merely confirm the theory.[43] Harvey faced this problem over and over.

Riolan's attack reiterated the old arguments; for example, "Harvey is very learned, but when he says that the blood passes through the lungs, he is going against Nature."[44]

Now, Riolan was neither a fool nor a mountebank. He recognized that there were some discrepancies between Harvey's (and others') new findings and those of Galen. He felt, however, that when experimental findings contradicted Galen there must be something wrong with the new findings. Experiments might also create experimental injury that would destroy the physiological conditions and prevent accurate observation.[45] Other possibilities included a deterioration of the Galenic texts; minor errors of Galen owing to his lack of human cadavers; and changes in human physiology since Galen's time due to the influence of climate, soil, and diet.[46]

He felt that there was some circulation of the blood going on, but not as Harvey saw it. "I assert," he wrote, "that the use of the circulation lies in the uninterrupted generation of vital blood and the maintenance of a continual heart beat."[47] One of his major objections was that if Harvey was right, the liver lost its central position as the source of the blood.

What made Riolan's objections so worrisome was his high standing in the world of medicine; his skill as an anatomist was celebrated throughout Europe. In fact, anatomy students still read today of Riolan's arch (in the colon), Riolan's bone (a small bone at the back of the head), Riolan's nosegay (a small group of muscles in the same region of the head), and Riolan's muscle (in the eyelids).

Riolan hoped by the strength of both his reputation and his "arguments" to finally put Harvey's nasty theory out to pasture. What must have been particularly galling to Harvey was that he had actually cited "the learned Riolanus" in the introduction to *DMC*.[48]

Through all of the preceding two decades Harvey had shown enormous self-restraint, hoping that his colleagues would step in to counter the continuing tirades. Unfortunately, there was precious little of such support.

Some of Harvey's reticence had to do with his own reluctance to engage in controversy, and some to the continuing problems that plagued the England of his era. Part of the time he spent in exile with the king; in the early 1640s the Parliamentarians ransacked his apartment and made off with some of his notes and manuscripts. As a member of the College of Physicians, he also had to deal with opposition from two other groups looking to assert their independence and authority: the apothecaries and the surgeons.

Although Harvey was reluctant to engage his opponents in print, he

had no compunctions about complaining to others, and particularly about Riolan. When a German colleague, Johann Daniel Horst, wrote to Harvey asking about Riolan's claims, Harvey answered:

> [Riolan] has very obviously achieved mighty trifles with great effort and I cannot see that his fictions have brought pleasure to anyone. Schlegel[49] wrote more carefully and modestly and, had the fates permitted, would doubtless have taken the force out of Riolan's arguments and even out of his taunts. But I learn, and that with sorrow, that he shuffled off this mortal coil of ours a few months since.[50]

Harvey Responds to the Attacks

Finally, Harvey could stand no more and, in 1649, he issued the only published response he ever made to criticisms of *DMC*. More than two decades had passed, an astonishing example of self-control. He penned two essays in the form of letters to Riolan, a fairly common form of scientific communication.

In published form, his essays/letters are generally known as *De Circulatione*.[51] The first letter, probably written in 1648 or 1649, presents a set of detailed answers to Riolan's objections. The first three paragraphs and the closing paragraph of the second letter also direct answers to Riolan. But the rest answers many of the objections made by one and all in the years leading up to this point, and includes a description of four new experiments he had performed since publication of *DMC*.[52]

Like the interchanges mentioned earlier, the second letter starts off with some courteous, even courtly, language. But it also includes some honest venting of feelings long pent up against "those who cry out that I have striven after the empty glory of vivisections, and [who] disparage and ridicule with childish levity the frogs, snakes, flies, and other lower animals which I have brought on to my stage. Nor do they abstain from scurrilous language."

Harvey writes that he refuses to "return scurrility with scurrility." Nevertheless, he adds, "It is unavoidable that dogs bark and vomit their surfeit . . . but one must take care that they do not bite, or kill with their savage madness, or gnaw with a canine tooth the very bones and foundations of truth." Finally, "Let them enjoy their evil nature. . . . Let them continue with their scurrility until it irks if it does not shame them, and finally tires them out."[53]

He kept to his word. His only other major publication, *De generatione* (1651), summarized later work he had been doing on embryology. True, his intent in these efforts was, at least partly, to buttress his work on circulation, but he steered clear of the controversy itself.

Because of Harvey's early experience, this publication had to be pulled from him by the same Dr. Ent who had been one of his early supporters. Ent later reported that Harvey argued at first. "Do you really wish once again to send me out into the treacherous sea away from the peace of this haven [his brother's house] in which I pass my life? You know well how much trouble my earlier studies evoked. . . ."[54]

Nevertheless, Harvey was by this time enjoying a rather different atmosphere than he had faced a quarter century earlier. Though there were still objections being voiced, and complaints about the overturning of ancient wisdom, he had managed to live long enough to see his theories widely accepted and even admired. Science historian I. B. Cohen maintains that Thomas Hobbes's seminal masterpiece, *Leviathan* (1651), was heavily influenced by Harvey's work.[55] Harvey seems also to have found a kind of peace in his researches, both earlier and later in his career.

We don't hear much of his wife, but she was apparently a source of strength and quiet pleasure over the 40 years of their marriage. She died in 1646, after which he spent his later years living with his brother, Eliab.

In that same period he was offered the presidency of the college he loved for so long and so well. Pleading ill health and the weariness of old age, he turned it down. He appears also to have turned down the offer of certain titles, referring to them as "wooden leggs," which was his way of showing his valuation of learning over rank.[56]

Abraham Cowley, in his "Ode, Upon Dr. Harvey" (1663),[57] refers to:

> Coy Nature, (which remain'd, though Aged grown,
> A Beauteous virgin still, injoyed by none,
> Nor seen unveiled by any one)
> When Harvey's violent passion she did see,
> Began to tremble and to flee . . .

But, says Cowley, eventually she would strike back:

> For though his Wit the force of Age withstand,
> His Body alas! and Time it must command,
> And Nature now, so long by him surpass't,
> Will sure have her revenge on him at last.

But not until 1657, at which time Harvey had reached the age of 79, a small miracle in those days, and with faculties intact and active till the last. He had become a man of wealth, but had simple tastes and was generous both publicly and to his friends and family.

Bishop Brian Duppa, a friend and neighbor of Harvey in his later days, considered Harvey a good example of long life, and felt that "being of a dry sear body, he praeserved it so long by the rules of art and diet . . . Then," Duppa adds, "his life went out like a spark, without any violence or noise at all."[58]

Though Harvey continued to express some bitterness and cynicism in his later years, the consensus seems to be that he managed to transcend the difficult years and to show an essential humanity and to exhibit, as one of his colleagues put it, a kind of "facetious [witty] courteousness."[59]

One of Harvey's problems was that he could never explain how the interchange occurred between venous and arterial blood. In the same year that *DMC* appeared, there was born the infant who—33 years later, and 4 years after Harvey's death—provided the proof Harvey had lacked. Using an improved microscope, Marcello Malpighi, an Italian physiologist, was able to show that arterial blood does not simply leak out into the tissues, to be collected somehow by the veins, as was commonly believed. Rather, his microscopical studies showed clearly the exquisitely tiny capillaries; these, distributed throughout the body, connect the two sets of vessels. The circuit was, finally, complete, and Harvey could rest in peace.