Wellcome Film Project

William Harvey and the Circulation of the Blood, 1978

Presented by The Royal College of Physicians of London

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<**Opening titles**>

<Tony Adams narrates>
William Harvey was born at Folkestone on the 1st of April, 1578. He was educated at the King's School, Canterbury, and in 1593 went to Gonville and Caius College, where 4 years later at the age of 19 he took his degree as Bachelor of Arts.

After this he turned to medicine and in 1599 went to the University of Padua. There on the 25th of April 1602, he received his degree as Doctor of Medicine and Philosophy having passed the appropriate examinations in both of these subjects as is attested by the signatures of his examiners on his diploma.

Having returned to London, Harvey was given a licence to practise medicine by The College of Physicians and in 1607 he was admitted as a Fellow.

Two years later he became physician to St Bartholomew's Hospital; from then on the whole of his professional life was spent as a practicing physician. In 1618 he was appointed one of the physicians to King James I, and his ties with the royal family became closer particularly after the accession of Charles I in 1625.

His investigations into the problems of the movement of the heart and blood and of the generation of animals, were throughout his life the pursuit of his leisure hours.

When Harvey began to study medicine the opinion generally held on the movement of the blood came from the teaching of Galen, the Greek physician of the 2nd century AD; his writings covered all aspects of medical knowledge from anatomy to therapeutics and over the centuries had acquired such authority that none dared to question the truth of his findings or opinions.

According to Galen's opinion, the food passed into the stomach and intestines and underwent a process known as concoction as a result of which the refined portion, chyle, was separated off and conveyed through the portal vein to the liver. There it underwent a further concoction and became venous blood. It was endowed with 'natural spirit' and so acquired the power of imparting life and nourishment to all parts of the body to which it was conveyed through the veins.

The different parts of the body sucked up the nourishment brought to them, the venous blood ebbed back to the liver for fresh supplies and a continuous movement of ebb and flow was believed to go on in the veins. From the liver, the vena cava brought the venous blood to the right ventricle of the heart. Some of it was expelled

through the pulmonary artery into the lungs for their nourishment while the remainder passed through porosities in the interventricular septum into the left ventricle. There it met the air which had passed through the lungs and travelled through the pulmonary vein into the left ventricle. This ‘inspired air’ was thought to contain the basic principle of life. In the left ventricle of the heart a further concoction took place and the venous blood and the inspired air were refined together to become arterial blood endowed with vital spirit. Arterial blood went from the left ventricle, through the aorta into the whole body.

At the same time, the fuliginous vapours, given off by the concoction of blood and air in the left ventricle, were driven back through the pulmonary vein into the lungs and so breathed out of the body.

The timing of these movements was held to coincide with the action of the heart. When the heart was in diastole it was thought to suck venous blood into the right ventricle and air into the left, and when in systole to drive out the venous blood through the pulmonary artery, arterial blood through the aorta, and fuliginous vapours through the pulmonary veins. But diastole was thought of as an active movement and the heart was believed to be in diastole when it struck the chest wall and the apex beat occurred.

When Harvey went to Padua, the university had one of the best medical schools in Europe. One reason for its fame was the excellence of its teaching of anatomy and this was due to the work of Andreas Vesalius and his successors. In 1540, when only 25, Vesalius was appointed Lecturer in Surgery and Reader in Anatomy and in 1543 he published the first great treatise on the anatomy of the human body, *De Humani Corporis Fabrica*. Vesalius did not challenge Galen’s opinion on the movement of the heart and blood though he made it clear that he could find no pores penetrating the septum of the heart.

Vesalius was succeeded by Realdus Columbus whose one book, *De Re Anatomica*, was published after his death in 1559. He pointed out that the current opinion on the timing of the apex beat with the diastole was wrong and that the active movement of

the heart was in systole. He utterly denied the existence of pores in the interventricular septum and of the formation of fuliginous vapours in the left ventricle. Instead, he maintained that the blood left the right ventricle of the heart through the pulmonary artery, passed through the lungs and entered the pulmonary vein and so went into the left ventricle. He based his hypothesis on his understanding of the competence of the valves of the heart and he proved it by the simple experiment of opening the pulmonary vein to see whether it contained air or blood.

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Hieronymus Fabricius of Aquapendente became Lecturer in Surgery and Anatomy in Padua in 1565, and was still teaching when Harvey arrived. The building in which he taught is now the administrative centre of the university. It stands on the site of the ancient hostelry of Il Bue, The Ox, and contains the permanent anatomy theatre constructed in 1584. There Harvey certainly stood to watch demonstrations by Fabricius who was an excellent teacher and popular with the students. Fabricius did not challenge the orthodox Galenic opinion on the movement of the heart and blood; he did not believe in the truth of Columbus' findings, but he did demonstrate the existence of valves in the veins. His treatise concerning them, *De Venarum Ostiolis*, was published in 1603, after Harvey had left Padua.

Fabricius believed that venous blood left the heart through the veins and that the valves were placed in the veins to delay the blood and prevent the whole mass of it from slipping headlong down into the hands and feet. It may well be, as Harvey himself said many years later to Robert Boyle that it was thinking about the manner of action of the valves of the veins that first gave him the idea that the blood might circulate.

But no such idea had occurred to him in 1616 when for the first time he gave a full-scale public anatomy at the College of Physicians – his notes for these lectures show that by then he had not advanced very far in his study of the action of the valves of the heart or of the veins. It is probable, therefore, that between 1619 and 1625 Harvey first formulated the hypothesis that the blood circulated; and in 1628 he

published from Frankfurt his great work, *De Mortu Cordis*, an anatomical disputation concerning the movement of the heart and blood in living creatures, in which he set forth the experimental proofs of his hypothesis and the logical arguments which supported it.

Harvey worked not from books but from dissections and the fabric of nature herself. Let us hear his own words:

<**Leonard Goodwin reads from Harvey's *De Motu Cordis***>

> When I first applied my mind to observation that I might find out the use of the motion of the heart, I straight away found it a thing hard to be obtained and full of difficulty so that I almost believed that it was known to God alone and that by reason of the quickness of the motion which in many creatures appeared and disappeared in the twinkling of an eye, like the passing of lightening. At last, using daily more search and diligence, I did believe I had hit the nail on the head, unwinded and freed myself from this labyrinth and gained the knowledge I so much desired.
>
> First then, after you have opened the chest and cut up the capsule which immediately surrounds the heart, you may observe that the heart moves sometimes, sometimes rests. This is more evident in the hearts of colder creatures and of warmer animals also if you observe attentively until the heart begins to die and to beat more faintly and in its moment of stillness lies drooping.

<**Adams narrates**>

From these and other observations Harvey concludes that at the moment of systole, the heart feels harder, contracts and is lifted up and strikes the chest wall at which moment the apex beat can be felt.

Next, Harvey analysed the action of the heart and demonstrated that blood was thrown by the contraction of the auricles into the ventricles, and by the contraction of the ventricles into the arteries:

<**Goodwin reads from Harvey's *De Motu Cordis***>

There are, as it were, at one time, two motions – one of the auricles and the other of the ventricles and they are not altogether simultaneous, but the motion of the auricles goes before and the motion of the ventricles follows.

When all things are already in a languishing condition, the heart dying away, the ventricle ceases to answer by its motion, and only by gently nodding its head seems, as it were, to give consent. And whilst by little and little the heart is dying, you may see after two or three beatings of the auricles, the ventricle will, being as it were roused, answer, and very slowly and with difficulty beat once. After the ventricle has left beating and the auricles are beating still, if you cut away the point of the heart with a pair of scissors you will see the blood flow from vents at every pulsation of the auricle so that from thence it appears which way the blood comes into the ventricles; not by attraction or distension of the ventricles, but sent in by the impulsion of the auricles.

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There is here with us a sort of very little fish called a shrimp, whose body is transparent. I have often shown it in water to some of my friends so that we could most clearly discern the motion of its heart.

In a hen's egg, I showed the first beginning of the chick, like a little cloud, by putting an egg, of which the shell was taken, into water, warm and clear. In the midst of the cloud there was a point of blood which did beat, so little that when it was contracted it disappeared and vanished out of our sight; and in its dilatation showed itself again red and small as the point of a needle, so that between being seen and not being seen, as it were between being and not being, it did represent a beating and the beginning of life.

<**Adams narrates**>

To prove that the systole of the heart coincided with the diastole of the arteries, Harvey devised the following experiment:

<**Goodwin reads from Harvey's *De Motu Cordis***>

> In fish, if you cut the vessel which leads from the heart to the gills you will see the blood forcibly thrust out through the cut at the very moment the heart is tensed and contracted. From this it is clear that the arteries are filled and distended like water skins or bladders by reason of the inflowing and thrusting of blood made by the constriction of the ventricles, or after the same fashion as when one blows into a glove and all the fingers are distended at the same time and mimic the impulsion of the air.

<**Adams narrates**>

Harvey sums up the series of the movements of the heart by comparing them to the firing of a shot where all the events follow each other so swiftly that they appear to be simultaneous. He then goes on to demonstrate how the blood passes from the right ventricle by the pulmonary artery into the lungs, and from thence by the pulmonary veins into the left auricle and left ventricle of the heart.

He denies the existence of pores in the interventricular septum and agrees with Columbus on the function of the valves:

<**Goodwin reads from Harvey's *De Motu Cordis***>

> That opinion is not to be tolerated which does assert that the blood seeps through hidden pores in the septum of the heart out of the right ventricle into the left. By my troth there are no such pores, nor can they be demonstrated! Why, I ask you, do they have recourse to hidden, invisible, uncertain and obscure pores for the passage of the blood into the left ventricle, when there is such an open way through the pulmonary vein? Truly it is a wonder to me that they should make, or indeed invent, a way through the septum of the heart which is gross, thick, hard and most compact, rather than through the patent pulmonary vein or else through the substance of the lungs; thin, loose, most soft and spongious.

> There are in the orifice of the pulmonary artery, three doors, made like a sigma or half moon, which altogether prevent the blood sent into the pulmonary artery from returning again to the heart. So, likewise, in the aorta. When they are raised up they meet together in a three-cornered line such as is left by the bite of a leech, so that they may prevent the reflux of blood.

<**Adams narrates**>

The experiment to prove that the septum is indeed a solid wall Harvey did not devise until 1651. Then in a letter written to the German physician Paul Marquart Schlegel he described the perfusion experiment he had recently performed, by which he showed that water passed through the vena cava into the right ventricle, all the other vessels of the heart being ligatured, merely distends the right ventricle and does not flow through a cut made in the left ventricle. Whereas if water be injected through the pulmonary artery it immediately gushes out from the hole in the left ventricle.

Harvey now sets down in *De Motu Cordis*, the evidence on which is based his hypothesis that the blood circulates throughout the whole body:

<**Goodwin reads from Harvey's *De Motu Cordis***>

> Now truly, when I had often and seriously considered with myself the many varied means of searching – how many there were – and from the dissection of living creatures for experiments sake, and from the opening of arteries as well as from the symmetry and great size of the ventricles of the heart, and of the vessels which go into it and go out from it, and from the carefully balanced and exquisite contrivance of the valves and fibres and from the rest of the fabric of the heart. And when I had for a great while turned over in my mind these questions, namely how great was the abundance of blood that was passed through and in how short a time that transmission was done and when I perceived that the juice of the food that had been eaten could not suffice to supply the amount of the blood – nay more, we would have the veins empty and altogether drained dry, the arteries on the other hand burst open with a too great inthrusting of blood, unless this blood should somehow

flow back out of the arteries once more into the veins, and return to the right ventricle of the heart; I began to bethink myself whether it might not have a kind of movement, as it were, in a circle.

<**Adams narrates**>
Harvey's first proof of the circulation is a quantitative one and is important for it is the first argument from quantity to be used in the history of physiology. Though his estimates are low, his conclusions are irrefutable:

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<**Goodwin reads from Harvey's *De Motu Cordis***>

Let us suppose how much blood the left ventricle may contain in its dilatation, say 2 ounces. I have found in a dead man over 2 ounces. Let us suppose likewise how much less the heart may contain in its contraction, and from thence how much blood is thrust out into the aorta. Therefore let us suppose that in a man there is sent forth at every beat of the heart at least 1 drachm of blood which cannot possibly return to the heart by reason of the hindrance of the valves. The heart in one half hour makes above 1000 pulses. Now, multiply the drachms passed through the heart into the arteries and you will always find a greater quantity than can be found in the whole of the body. So likewise in a sheep in whose body is generally not contained more than 4 pounds of blood, for I have tried it.

<**Adams narrates**>
Harvey's next experiments were designed to prove that the arteries received blood from the veins in no other way than by transmission through the heart:

<**Goodwin reads from Harvey's *De Motu Cordis***>

If anyone cut up a live snake, he will see the heart beat calmly and distinctly, for more than a whole hour, and contracting itself in length like a worm in its constriction. The vena cava enters the lower part of the heart, the artery comes out at the upper part. Now, taking hold of the vena cava with a pair of

forceps, and the course of the blood being stopped a little way below the heart, you will see almost immediately after the heart beat that the space between your forceps and the heart is emptied, the blood having been drained out by the pulse of the heart, and the heart will be of a far lighter colour, and smaller too in its dilatation for want of blood, and at last will beat more faintly. But as soon as you let go the vein, both its wonted colour and size return to the heart. Unless you will deny your own eyesight you must needs affirm the recourse of blood to the heart.

Afterwards, if you relinquish the vein and ligate or repress the artery at a little distance from the heart, you will see the parts where they are compressed, swell vehemently and that the heart is swelled beyond measure and acquires a purple colour to the point of being bluish black and that it is at last so oppressed with blood so that you would think that it would be suffocated. But letting go the artery the heart returns to its normal constitution, in colour, size and beat.

<**Adams narrates**>

It now remained for Harvey to prove that the blood returned to the heart through the veins. The actual connections between arteries and veins he never saw, for no lens of sufficient power of magnification was then available. It was not until 1661, four years after Harvey's death, that the capillary connections were seen and described by Marcello Malphigi. But Harvey could, and did, give experimental proof of the existence of these connections.

<**Goodwin reads from Harvey's *De Motu Cordis***>

Some experiments are to be taken note of which show plainly that the blood enters every member of the body through the arteries and returns through the veins. Let there be an experiment made on a man's arm, and it is more conveniently done in a lean man, the body having been heated by exercise and the pulse full. If you then make a hard ligature, drawing it as straight as can be endured, you may observe first that beyond the ligature the artery does not beat. After this ligature has continued a while let it be suddenly

loosened into a ligature of middling tightness, such as they use in the letting of blood, and you will observe that the whole hand is immediately imbued with colour and distended, and that its veins become swollen and lumpy and in the space of 10 or 12 pulses, you will see the hand is exceedingly full with the much blood that is driven and forced into it.

<**Adams narrates**>
Another simple experiment to determine the direction of flow in the veins and arteries, Harvey described in his second letter to Jean Riolan, written in 1648.

<**Goodwin reads from Harvey's letter to Riolan**>

Cutting of a vein, anybody may see the nearer part of it towards the heart let out no blood, but the further part pours it abundantly. Cutting an artery, but a little blood flows from the further part, but the nearer part shoots blood with a violent force as if it were out of a spout.

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<**Adams narrates**>
The analogy of the heart with that of a pump is not found in *De Motu Cordis* and there is good reason to believe that it occurred to Harvey only after 1637 when he had seen a new kind of fire engine in use in London. In his letter to Riolan, he describes how blood spurts from a cut artery at every contraction of the heart, saying:

<**Goodwin reads from Harvey's letter to Riolan**>

Just as water by the force and impulsion of a fire engine is driven aloft through pipes of lead, and we may observe and distinguish all the forcings of the engine in the flux of the water when it passes out, the order, beginning, increase, end and vehemence of every stroke, even so it is with the blood from the orifice of a cut artery.

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<**Adams narrates**>

To explain how the blood returns from the extremities, to the heart, through the veins, Harvey demonstrates the valves of the veins and their action:

<**Goodwin reads from Harvey's letter to Riolan**>

> The most famous Hieronymus Fabricius of Aquapendente first described these membranous valves in the veins as exceedingly thin raised portions of the inner coat of the veins and shaped in the figure of a sigma or half moon. But he did not understand their use. They are situated at diverse distances from one another, looking towards the roots of the veins, for the most part in pairs, facing each other, their tips touching to prevent anything from slipping through from the root into the branches.
>
> I have often found that in dissecting, if beginning from the root of the vein I put a probe towards the small branches, it could not be further driven by reason of the hindrance of the valves. On the contrary, if I put the probe from the outer branches towards the root, it passed very easily and the valves like floodgates in rivers were most easily pushed aside. These valves were solely made lest the blood should move from the greater veins into the lesser, that it should not go from the centre of the body to the extremities, but from the extremities to the centre.
>
> But that this truth may the more clearly shine forth, let the arm of a man be tied as if it were to let blood; there will appear at intervals certain little nodes or swellings. These nodes are made by the valves. If you draw down blood with your thumb or finger from beyond a valve and hold it thus, you will see that no blood can follow, the valve is quite hindering it. If you retain the blood so drove down and the vein emptied and with the other hand press downwards, the upper part of the vein being full, you shall find that by no means can it be forced or driven beyond the valve. But taking away the finger you first applied, you shall immediately see the vein filled again from below. Again, put your finger below any valve and press the vein that no blood can go from the hand upwards, then squeeze with your finger the blood upwards to the next valve. Then taking away your finger suffer the vein to be filled

again from below. And then pressing again with your finger in the same place, squeeze out the blood again upwards and do this 1000 times in a little space. Now if you reckon the business, supposing how much blood has been moved upwards beyond the valve, you shall find so much blood passed by this means through a little part of a vein, that you will find yourself perfectly convinced concerning the circulation of the blood and of its swift motion.

And now let me put forward my opinion concerning the circulation of the blood. Seeing that it has been proved by logical arguments and ocular demonstrations that the blood passes through the lungs and heart by the pulse of the ventricles, and is driven and sent into the whole body and there creeps into the veins and porosities of the flesh, and through the veins returns from the circumference to the centre, out of the tiny veins into the greater and from thence into the vena cava and into the auricle of the heart in so great abundance with so great an outflowing and inflowing. From hence through the arteries thither, from thence through the veins hither back again that it cannot be furnished by those things that we eat and in far greater abundance than is necessary for nourishment, it must of necessity be concluded that the blood is driven into a round by a circular motion in living creatures and that it moves perpetually and that this is the action and function of the heart which by pulsation it performs. And lastly that the motion and pulsation of the heart is the only cause. All these phenomena, which can be observed during dissection, if they be rightly weighed, are seen to shed light abundantly on the truth that I have stated and to prove it completely, for it were very hard for anyone to explain by any other way than I have done for what cause all these things were so made and appointed.

<**Adams narrates**>

When Harvey died in 1657, his new theory of the circulation of the blood had won general acceptance. He was well aware that its consequences would be far-reaching, and so it has proved.

<**End credits, in addition to those listed at the beginning of the transcription**>

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