William Harvey and the Circulation of the Blood, 1957

Presented by The Royal College of Physicians of London

Harvey's experiments reconstructed by: Michael de Burgh Daly and Dr Leonard Goodwin.

Narrator: Sir Henry H Dale.
William Harvey's words spoken by Leonard Goodwin.

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Colour
Duration: 00:34:02:24

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<Sir Henry H Dale introduces film to camera>
The film which you are to see is essentially a new addition, one in the making of which I was privileged to take part nearly 30 years ago by my friend and colleague of those days, the late Sir Thomas Lewis, who was largely responsible for its design. Lewis and I made that film for an international meeting in 1928, organised by the Royal College of Physicians of London to celebrate the 300th anniversary of one of the great events in the whole history of medicine: the publication by William Harvey in 1628 of his anatomical treatise on the movement of the heart and the blood. It,

however, is not a new film, we have just remade the old one following the lines on which Thomas Lewis planned it so well, altering and extending the layout only in detail, but using for its presentation the much better methods which have become available in the intervening years. We have thus been able to photograph the experiments in colour and have the diagrams animated, while the narrative and Harvey's own descriptions and arguments have now been recorded by sound track. We hope that those who saw the original film will find that these technical advances have enabled us to effect some real improvements in its form.

<**Opening titles**>

<Sir Henry H. Dale narrates>
William Harvey was born in 1578 at Folkestone. He was one of the great figures in that age of scientific reawakening. He was educated at Gonville and Caius College, Cambridge. This is a print of the college as it was in Harvey's time. The Gate of Honour, seen in the foreground, is still an architectural gem of the older part of the college. Then he went to Italy, to study in Padua where the university was, at that time, a leading world centre of progress in the new experimental science and in medicine. Here is Harvey's diploma, signed by all the masters and officials of the university, including his own teacher, Fabricius.

Soon after returning to London he became in 1607 a Fellow of the Royal College of Physicians of London. Two years later he was appointed physician to St Bartholomew's Hospital, also in London. This is a plan of the hospital, as it was in Harvey's time. This document, also from the hospital archives is the charge given to Harvey on his appointment; it is headed The Charge of the Physician of St. Bartholomew's Hospital, and it is dated October 14th 1609.

Later in his career he became physician to King James I and to his Lord Chancellor, Francis Bacon, and then to King Charles I. This is a warrant, signed by Harvey, for the payment of money to an apothecary of the King's household.

In 1615, he was appointed Lumleian Lecturer in Anatomy to The Royal College of Physicians, and his notes for these Lumleian lectures make it clear that he had arrived at his ideas about the circulation of the blood many years before he published them. His great work, now familiarly known as *De Motu Cordis*, set forth this new conception systematically, with an array of cumulative evidence and argument. It was published in 1628. Within the compass of this short treatise, Harvey not only presented his revolutionary description of the two-fold circulation of the blood, he gave also the first example of the application to medicine and physiology of what was then the new method of advancing scientific knowledge, namely by the use of direct observation and experiment instead of by the further study of what others had written. “Not from books!” as Harvey exclaims in *De Motu Cordis*, “but from dissections.”

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Harvey refers in his book to the work of his predecessors and teachers. Vesalius had taught in Padua many years before Harvey was born and had published, in 1543, the first great treatise on the anatomy of the human body, based upon actual dissections. But he gave no challenge to the then current orthodoxy based upon Galen’s teaching concerning the functions of the heart and the blood vessels. Vesalius could not find the pores in the septum between the ventricles which Galen’s scheme required; but he did not venture to doubt their existence.

Michael Servetus, physician and theologian, though Harvey did not mention him, had already put forward in 1553 the suggestion that the blood passes from the right to the left side of the heart by way of the lungs. The suggestion was embodied in a religious treatise and Calvin had caused the unfortunate Servetus to be burned at the stake for his heresy, and the whole edition of his book with him. Three copies of it escaped the fire, but none of these became known until 1694, long after the death of Harvey who could not therefore have referred to it. He did know however, and duly made mention, of the similar suggestion that was put forward by Realdus Columbus in his *De Re Anatomica*, published in 1559, nearly 20 years before Harvey was born.

Andreas Caesalpinus in his *Quaestionum Peripateticarum*, published in 1593, seems to have come even nearer to the idea of a circulatory movement of the blood. But for him, as for Columbus, it was no more than a philosophical speculation, without any experimental basis.

More directly influential on the development of Harvey's ideas was his own teacher, Fabricius, to whom he refers as "the celebrated Hieronymus Fabricius of Aquapendente, who first gave representations of the valves in the veins." Fabricius had indeed given figures of these valves in a book which he had written while Harvey was still a student at Padua, but he clearly had not fully recognised their functional significance. None, indeed, of these predecessors of Harvey had claimed to do more than modify, in detail, the orthodox theory then current, which after some 1400 years was still based upon the teachings of Galen, the Greek physician, who attended the emperor Marcus Aurelius in the 2nd century AD, and whose writings had maintained a dogmatic authority to which Harvey's book gave the first clear challenge.

Let us look at the main features of Galen's conception. Galen supposed that the blood originated from the food as it was absorbed. From the intestines chyle passed into the blood vessels and mixed with the blood and was carried by the portal vein to the liver. Here it was believed that the blood was changed by acquiring a property termed the 'natural spirits' before it was carried by the vena cava to the right side of the heart. The action of the heart was supposed to make some of this blood ebb and flow in the veins so as to carry nourishment to the lower parts of the body by the inferior vena cava, and to the head and upper parts by the superior vena cava. Some of the blood, on entering the right side of the heart, was supposed to leave it by the pulmonary artery, to ebb and flow in the arteries of the lungs and there to give off fuliginous vapours. It still had to be explained, however, how the remainder of the blood managed to get from the right into the left side of the heart and it was just assumed that it did this by passing through minute, invisible pores, through the fleshy septum between the ventricles and thus from the right into the left ventricle. By the diastole of the heart, air was supposed to be drawn from the lungs into the left ventricle, to mix there with the blood and endow it with the so-called 'vital spirits' and it was supposed that, with the beat of the heart, this vitalised blood from its left side

was caused to flow to and fro in the arteries, carrying vital spirits to stimulate the functions of the various organs and to and fro also in the pulmonary veins between the heart and the lungs. Blood reaching the brain was supposed to be charged there with animal spirits and to be carried along the nerves to bring about movements and sensations. Such then were the ideas concerning the movements and functions of the heart and the blood which for more than 1000 years had been redolently accepted on Galen's authority as the basis of medical knowledge and practice.

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Harvey gives a review of these beliefs in the opening chapters of *De Mortu Cordis*, adds his own ironical or directly challenging comments, and comes to his conclusion. Let us hear it in his own words:

<**Leonard Goodwin narrates from Harvey's *De Mortu Cordis***>

> It is plain that what has heretofore been said concerning the motion and function of the heart and arteries must appear obscure or inconsistent or even impossible. It will be proper to look more narrowly into the matter to contemplate the motion of the heart and arteries not only in man but in all animals that have hearts; and further, by frequent appeals to dissections and constant ocular inspection, to investigate and endeavour to find the truth.
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> When I first gave my mind to discovering the motions and uses of the heart, I found the task so truly arduous, so full of difficulties, I was almost tempted to think that the motion of the heart was only to be comprehended by God by reason of rapidity of the motion which in many animals is accomplished in the twinkling of an eye, coming and going like a flash of lightening.
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> Employing a variety of animals, I thought had attained to the truth. When the chest of a living animal is laid open and the capsule which immediately surrounds the heart is slit up or removed, the organ is seen now to move, now to be at rest. These things are more obvious in the hearts of colder

animals – toads, frogs and serpents. They also become more distinct in warmer animals, such as the dog when the heart begins to flag.

<**Dale narrates**>

Harvey first demonstrated that blood was thrown with the contraction of the auricles into the ventricles, and by that of the ventricles into the arteries.

<**Goodwin narrates from Harvey's *De Mortu Cordis***>

There are two motions going on together – one of the auricles the other of the ventricles, these by no means taking place simultaneously. First of all the auricle contracts and in the course of its contractions throws the blood into the ventricle, which being filled, the heart raises itself straightaway, makes all its fibres tense and performs a beat, by which it sends the blood into the arteries.

Whilst the heart is gradually dying, it is sometimes seen to reply after two or three contractions of the auricles, roused as it were to action, and making a single pulsation slowly, unwillingly, and with an effort. But this especially is to be noted if, with the auricles along pulsating, the point of the heart be cut off with a pair of scissors, you will perceive the blood flow out upon each contraction of the auricles whence it is manifest how the blood enters the ventricles; not by any attraction or dilatation of the heart, but thrown into them by the pulses of the auricles. The heart, by squeezing out the blood it contains, becomes paler. Then, when it sinks into repose, the ventricle is filled anew with blood and a deeper crimson colour returns.

In fishes, if the vessel which leads from the heart to the gills be divided at the moment when the heart becomes tense and contracted, at the same moment does the blood flow forth from the divided vessel. From these facts it is manifest that the diastole of the arteries corresponds to the heart's systole.

A certain person was affected with a large pulsating tumour called an aneurysm. This tumour was visibly distended and it received the charge of blood brought to it by the artery with each stroke of the heart. The arteries are

filled by the blood forced into them by the ventricles and are distended because they are filled like sacks or bladders, not because they expand like bellows.

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I go on to demonstrate that the blood passes from the right ventricle by the pulmonary artery into the lungs, and thence by the pulmonary veins into the left auricle and thence into the left ventricle of the heart.

That opinion which supposes the blood to ooze through the septum of the heart from the right to the left ventricle by certain secret pores is not to be tolerated. Why I ask is recourse had to secret and invisible porosities, to uncertain and obscure channels, when there is such an open way through the pulmonary veins? It has always appeared extraordinary to me that they should have chosen to make, or rather to imagine, a way through the thick, hard and extremely compact substance of the septum cordis rather than to take that by the open pulmonary veins, through the lax, soft and spongy substance of the lungs. In faith, no such pores can be demonstrated, neither in fact do any such exist.

At the root of the pulmonary artery are 3 sigmoid or semilunar valves which open from within outwards. When the valves are raised and brought together they form a three-cornered line such as is left by the bite of a leech. They oppose no blood flowing from the right ventricle into the pulmonary artery, but closing with perfect accuracy they prevent all regurgitation from the pulmonic vessels back upon the right ventricle.

<**Dale narrates**>

This can be demonstrated by a simple experiment. Tubes are inserted into the pulmonary artery and through the superior vena cava and right auricle into the right ventricle. The pulmonary valve is therefore situated between the two tubes. A fluid

poured into the tube in the pulmonary artery will not pass beyond the pulmonary valve. On the other hand, fluid entering the right ventricle will pass through the pulmonary valve into the artery and overflow from the tube.

<**Goodwin narrates from Harvey's *De Mortu Cordis***>

> It may be well to relate an experiment which I lately tried. Having tied the pulmonary artery, the pulmonary veins and the aorta, and opened the left ventricle of the heart, we passed a tube through the vena cava into the right ventricle; and having filled an ox's bladder with warm water, we attached it to the tube and forcibly injected the fluid into the heart. The result was that the right ventricle and auricle were enormously distended but not a drop of water or of blood made its escape through the orifice in the left ventricle. The ligatures, having been undone, the tube was passed into the pulmonary artery and a tight ligature having been put around it to prevent any reflux into the right ventricle, the water in the bladder was now pushed towards the lungs upon which a torrent of the fluid mixed with a quantity of blood immediately gushed forth from the perforation in the left ventricle. The blood is continually passing from the right to left ventricle, from the vena cava into the aorta through the porous structure of the lungs.
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> I frequently and seriously bethought me and long revolved in my mind, what might be the quantity of blood which was transmitted, in how short a time its passage might be effected, and the like. And not finding it possible that it could be supplied by the juices of the ingested aliment without the veins on the one hand becoming drained, and the arteries on the other getting ruptured through the excessive charge of blood, unless the blood should somehow find its way from the arteries to the veins and so return to the right side of the heart; I began to think whether there might not be a motion, as it were, in a circle.
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> Let us assume the quantity of blood which the left ventricle will contain is 2 ounces. In the dead body I have found it to hold upwards of 2 ounces. Let us suppose that a fourth of this charge is thrown into the artery at each

contraction, which quantity by reason of the valves at the root of the vessel can by no means return into the ventricle. Now in the course of half an hour the heart will have made more than 1000 beats. Multiplying the number of drachms propelled by the number of pulses, we shall have a proportional quantity of blood sent from this organ into the artery – a larger quantity in every case than is contained in the whole body.

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I go on to show that the arteries receive blood from the veins in no other way than by transmission through the heart.

If a live snake be laid open, the heart will be seen pulsating quietly, this point in particular may be observed more clearly than the noonday sun. The vena cava enters the heart at its lower part and the artery quits it at the superior part. The vein, being now seized with forceps, and the course of the blood for some space below the heart interrupted, you will perceive the path that intervenes between the forceps and the heart to become empty, the blood being exhausted by the action of the heart. At the same time, the heart will become of a paler colour but, the impediment being removed, instantly the colour and size of the heart are restored. Unless you would deny the evidence of your senses you must needs admit the return of blood to the heart.

If, on the contrary, the artery instead of the vein is compressed or tied, you will observe the heart to become inordinately distended, to assume a deep purple or even livid colour and at length to be so much oppressed with blood that you will believe it about to be choked. But the obstacle being removed, all things return to their pristine state.

<**Dale narrates**>

The connecting channels between the arteries and veins of the systemic circulation were never seen by Harvey. From a series of brilliant experiments and deductions he

inferred the passage of blood through channels which Malpighi, was later to demonstrate as the capillary blood vessels.

<**Goodwin narrates from Harvey's *De Mortu Cordis***>

> I have here to cite certain experiments from which it seems obvious the blood enters a limb by the arteries and returns from it by the veins. Let anyone make an experiment upon the arm of a man, the best subject being one who is lean and the best time after exercise when the pulse is full. Let a ligature be thrown about the extremity and drawn as tightly as it can be born. It will be perceived that beyond the ligature the artery does not pulsate. After a bandage has been kept on an arm for some time in this way, let it be slackened a little, brought to a state or term of middling tightness, which is used in bleeding, and it will be seen that the whole hand and arm instantly become deeply suffused – the veins show themselves tumid and knotted and gorged with blood. It plainly appears that the ligature prevents the return of the blood through the veins to the parts above it and maintains those beneath it in a state of permanent distension. But the arteries, in spite of its pressure, send on the blood to the parts beyond the bandage.
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> When an artery and a vein are divided, from the part of the vein towards the heart, no blood pours out, whilst that beyond the wound gives a torrent. From the further orifice of the divided artery on the contrary little or no blood escapes, whilst the orifice next to the heart pours out a flood of pure blood in jets as if it were forced from a syringe. This experiment plainly proves in which direction the current sets in either order of vessels: towards the heart in the veins, from the heart in the arteries. And there is either an anastomosis of the two orders of vessels or pores in the flesh and solid parts generally that are permeable to the blood. We have yet to explain in what manner the blood finds its way back to the heart from the extremities by the veins.

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The celebrated Hieronymus Fabricius of Aquapendente, a most skilful anatomist and venerable old man, gave representations of valves in the veins, which consist of raised or loose portions of the inner membranes of these vessels, of extreme delicacy and of a sigmoid or semilunar shape. They are situated at different distances from one another, they are directed upwards or towards the trunks of the veins.

If I attempted to pass a probe from the trunk of the vein into one of the smaller branches, I found it impossible to introduce it far anyway by reason of the valves. But if the probe be now introduced from the extreme towards the more central parts, the valves, like the floodgates of a river, give way and are most readily pushed aside. The valves are solely made and instituted lest the blood should pass from the greater to the lesser vein.

But that this truth may be made the more apparent let an arm be tied up above an elbow as if for phlebotomy, at intervals in the course of the veins certain knots or elevations will be perceived. These knots or risings are all formed by valves. And now, if you press the blood from the space above one of the valves and keep the point of a finger upon the vein inferiorly, you will see no influx of blood from above. If you now apply a finger of the other hand upon the distended part of the vein above the valve and press downwards, you will find that you cannot force the blood through or beyond the valve. But, the finger first applied being removed, immediately the vein is filled from below. Apply the finger again and having in the same manner streaked the blood upwards again remove the finger below and again the vessel becomes distended as before. And this repeat, say 1000 times, and now compute the quantity of blood which you have thus passed up beyond the valve and I do now believe that you will find yourself convinced of the circulation of the blood and of its rapid motion.

And now I may be allowed to give in brief my view of the circulation of the blood. Since both argument and ocular demonstration show that the blood passes through the lungs and heart by the actions of the auricles and

ventricles and is sent for distribution to all parts of the body where it makes its way to the pores of the flesh and then flows by the veins from the circumference on every side to the centre, from the lesser to the greater veins, and is by then finally discharged into the vena cava and right auricle of the heart, and this in such a quantity as cannot possibly be supplied by the ingestor. It is absolutely necessary to conclude that the blood in the animal body is impelled in a circle and is in a state of ceaseless motion, that this is the act or function which the heart performs by means of its pulse and that it is the sole and only end of the motion and contraction of the heart.

<**Dale narrates**>

And so William Harvey finished his experiments and his calculations and recorded them, with the conclusions to which they had led him, in this wonderful little book. Its ideas were too new and too revolutionary to win a ready acceptance from the men of his own time. But in the end it was to change the whole aspect of medical knowledge and the manner of its progress and to provide a new starting point for physiology as the experimental science which we know today.

<**End credits – in addition to those given at the beginning of the transcription**>

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