Life Without Heart and Lungs

The Scientific Basis of Medicine

Presented by Denis Melrose, Professor of Surgical Science, Royal Postgraduate Medical School.

University of London Audio-Visual Centre, 1974.
Made for British Postgraduate Medical Federation.

Produced by John Metcalfe.

Black-and-white
Duration: 00:15:41:21

00:00:00:00

<Opening titles>

<Opening film shows close-up of heart surgery. Narration over film by Professor Melrose>

You're looking into the inside of a human heart and you're watching a surgeon preparing to repair a defect between the two pumping chambers of the heart. The fact he can do it is entirely dependent on the fact that the patient's life is being supported by a machine. All the work that the heart normally does is being carried out by a pump and the breathing that the lungs are normally involved in is also being taken over by an artificial lung. You can see him putting a stitch in the heart at the moment and this operation might, in fact, last an hour, an hour and a half, something of this order.

<Cut to Melrose, in studio, to camera>

Now, this sort of operation is probably going on at this minute in many hundreds of hospitals all over the world, and in them, these patients being operated upon are entirely dependent on such machines. I've got some film to show you now of a typical one […]

<Melrose narrates over film showing a member of the theatre staff demonstrating an artificial lung machine>

[…] and it's the sort that we use every day. At the moment blood taken from donors, blood donors, is being poured into that container and it'll work its way down those tubes and into the artificial lung. This particular machine oxygenates the blood by spreading it thinly over discs that are rotating inside that cylinder and as the blood goes along it so it picks up oxygen and gives up carbon dioxide. From that cylinder, it's pumped back into the body by that pump you see rotating there.

<End of film clip. Melrose to camera>

It's a very simple device; it's simply two rollers rotating and pumping blood forward. Now, all machines we use at this moment of time suffer from one particular disadvantage. It's a disadvantage which limits the number of hours we can use them and it's because, in them all, blood is brought into direct contact with gas – with oxygen gas. Blood doesn't like that. We've got to try and find a way of separating blood from the oxygenation gas and we've got to do it much as the human or the animal lung does it. We've got to put a thin film of tissue between the blood and the gas. Now, it's been a long and hard struggle to find such a membrane, but one does exist.

<Melrose narrates over slide showing illustration of silicone membrane, and then over illustration of other polymeric membranes, interspersed with talk to camera>

It's made of a silicone rubber and it has a very curious particular feature. You'll notice that there are rather more white dots than black dots on the right-hand of that slide, whereas, in fact, if you could count them in time, you'd find that they were in equal numbers on the left-hand side. This is because silicone rubber has this selective ability to pass oxygen gas through rather more quickly than, in this situation, nitrogen and it does the same in relation to carbon dioxide, so it has some characteristics which we're particularly interested in and characteristics which make it quite different from the other types of film membranes, the sort that you would use in wrapping food. And here's one for instance. Here you find, again, the same number of dots on the left-hand side, but now the same number also on the right-hand side but in much less numbers, of course, because these are rather difficult for gas to go through and, indeed, they tend to allow gas to go through small holes and not like the silicone material which has a particular ability to allow the gas to dissolve through it.

00:04:31:19

<Melrose to camera and then narrates over slide showing use of a silicone membrane, which enables a hamster to breathe in a cage immersed in an aquarium>

Now, to prove that this is, in fact, a possible membrane, I'm going to show you a slide in which you'll see a hamster. Now, the hamster's in a cage and that cage is covered with a very thin layer of this silicone membrane. It's about a thousandth of an inch thick and that hamster's cage is actually immersed in an aquarium. You can see a fish there. What is happening is that the silicone rubber is, of course, keeping the water out, but is allowing oxygen to come out of the water and through into the inside of that cage and also, of course, carbon dioxide to go back out. It's doing what we had hoped it would be able to do, which is to separate the gas, that the hamster's living and breathing in, from a fluid, which, of course, in our needs would be blood, but here is the water of the aquarium.

<Melrose to camera and then over illustrative slide showing mechanism of an artificial kidney>

Now, to make use of this film has also been a problem because nature has a wonderful ability to solve mechanical problems; we don't have anything like such the same ability and have to frequently use rather different solutions to nature. For instance, we could wrap that film about in a cylinder, and here's a typical example, and distribute a large amount of it so that blood would be brought to one side of it and gas to the other. This is not what nature would do; in fact, you're looking at a picture of an artificial kidney which is a relatively simple device using a membrane. Nature does not use that and for good reasons: it's not efficient enough.

<Melrose to camera and then draws diagrams to illustrate gas diffusion through tubing, whilst narrating>

Now, I'm going to try and draw for you how we are trying to solve this problem. If in nature – I'm off the picture – if in nature you have a tube, which begins rather wide, and it's a tube in which blood is flowing in that direction, by the time you want to do something to the blood, for instance, bring it into contact with air, which is here, the tube has narrowed right down to the point where only 1 single red cell is passing along it at a time. And so there's a direct contact virtually though there. Now, we can't get down to this; this is an incredibly narrow gap, or a very small tube, and we've tried various methods of laying sheets of membrane on spacers and things. None of them have worked very well, but we have found a principle that does work. If you take a straight tube and imagine that blood is flowing through it, it tends to form streamline flow, and you can imagine that while those cells at the very edge have a proper opportunity to breathe through this tube, which is made of silicone rubber, those in the middle here have almost no chance whatever to do so. They're far too far away from the tube and if this sort of smooth flow continues, they may never, throughout the passage through that tube, come into contact with the wall. But there is a way. If you imagine now that tube is curved, this has a natural effect on any flow that is running around it. It starts it spinning and if at the same time that curved tube is moved to and fro about 30 degrees, what actually happens is that instead of that nice, smooth, streamline that you saw here, you get a spin and blood takes this path around and as it does so, there's a very good chance that a cell there will touch the wall. That at some future date another one in here will be picked up by this spin and touch the wall and breathe. Now, I’m going to try and show you how that works on a model.

<Melrose to camera while demonstrating glass tube model>

It’s just a simple glass tube and there are some tea leaves in it and it’s filled with water. It’s the curve that I showed you and it’s also going to oscillate, if I can make it work for you. We’ll just wait a moment; it’s sometimes kind of difficult to get it started. It’s beginning. Can you see that, though not very clearly? There they are: just by imposing that motion, the cells are spinning round and you can imagine that if they were blood cells, they would have a very good chance of coming in contact with the wall of the tube and breathing, picking up oxygen, giving up carbon dioxide. And that’s the principle which we’re now working on to greatly increase the efficiency of such machines within the limits imposed on us by this artificial membrane.

00:09:51:13

<Melrose narrates over diagrammatic slide showing an experiment set up for oxygen uptake by blood via silicon membrane>

Now, I’m going to show you a slide of an experiment to prove to you that this really does work. You see a reservoir filled with blood and it’s flowing into that circle, which I’ve just shaken in my hands, and from there it’s being pumped round and round. And to imitate the production of carbon dioxide by the body, we’re just injecting some all the time from that syringe. So now we have a circuit running continuously and through a silicone rubber membrane, which is inside that disc on the left-hand side in what’s called the shaker.

<Melrose narrates over graph showing results of oxygen uptake by blood via silicon membrane>

Now, if I show you a graph of the results of the oxygen intake, you can see what happens. On the left-hand side, there is oxygen uptake in ccs per square minute per metre, and along the bottom is a measurement of the velocity that we've generated within the tubing by making it oscillate. On the left-hand side, there is no movement and very little oxygen is going through as you see: it's less than 30 ccs per square metre per minute. But if we increase the energy of the shake and gradually build up that spin, you can follow – each of those are at different flow rates, and that's not very important – if you take the top line, you can see that from the very small quantity of oxygen going in, as we get the energy into the system and get that spin of the cells, so the oxygen uptake increases until we get to a very respectable figure of 200 or so ccs per square metre.

<Melrose to camera>

When I tell you that the human lung is nearly a 100 square metres in size and here we have an opportunity of getting sufficient oxygen into 2 or 3 square metres to satisfy your ordinary requirements, through an operation or during the recovery from a serious illness, you see that we have found a method for producing a very efficient system. We're very hopeful too that this method, which greatly reduces the destruction of blood when going through these machines, when being brought out of the body and circulated round, will, in fact, produce for us a real possibility of life without the action of your heart and lungs. And now we're going to show you a film of an actual use of such a membrane oxygenator in this form – spiralling tubes around a rotating wheel oscillating and keeping life going in a small animal.

<Film clip featuring demonstration of a membrane oxygenator that has been used to keep a lamb alive in a cage. Melrose narrates in film, off camera>

This little lamb has lived in this cage several days and he's very unusual because he's sharing his circulation with a machine. He's breathing normally and his heart's beating but half of his breathing and half his circulation is going through this machine. It's connected to him by two tubes which come out from under this waistcoat and descend outside his cage, down here, and through one of them blood's coming out of his veins and entering this oscillating wheel. And running through these fine silicone tubes, as the blood works its way along these tubes, this motion is causing the cells inside to spin and giving them a chance of coming up and touching the walls and therefore picking up oxygen and giving up carbon dioxide. So that's the artificial lung. From there the blood, having got all the way round, is gathered up again and enters this little reservoir, and this is just a method of controlling the speed at which the pump's working, because as he stands up, more blood comes down. As he lies down, a little bit less. And it goes from there to this pump and it is simply a roller pump which rotates around and massages blood along the tube inside it. And as it does so, it drives blood back up the tubes and into the animal, so he's exchanging some part of his circulation through the machine all the while and has been for several days. And this is very encouraging to us because it does indicate that at last we've found a method for offering a life support system for those who have very severe heart failure or respiratory failure.

This machine is rather similar to the artificial kidney in a sense in that it's capable of imitating the functions of the heart and lungs for long periods at a time and we're very hopeful it will help us deal with these difficult problems of coronary cardiac infarcts of respiratory failure and so on. <*Hand stroking lamb* > As you see he doesn't mind.

<End credits>