The Art of Breathing
The mechanics of breathing

Dr Stewart Fisher:
Breathing and respiration has to continue, throughout our daily lives. It's got to deliver the gasses at the right concentrations to our muscles and other body organs, no matter what we're doing. And this happens without our thinking about it, and without our being conscious of it.

Narrator:
How do you explore the responsiveness of these intimately linked systems?
A battery of detectors monitor and record the rate and depth of breathing. Heart rate and blood oxygen levels. And the electrical activity of every heartbeat. How do the rhythms of breathing and blood flow vary throughout the day?

Heart rate varies from minute to minute, and from hour to hour. The red spots record average heart rate. And the green bars highlight the highs and lows. The overall pattern depends on the demands of the particular day. And there's a close correlation between heart rate and breathing.

Dr Stewart Fisher:
Their natural rhythms seem to be in a proportion of something like 4-1 or 3-1. Three or four heartbeats for every respiratory motion. When you're exercising, the muscles are working and requiring much more metabolism. Therefore they require more oxygen and they need to give up more carbon dioxide. And that puts requirements both on the seculatory system, and respiratory system.

Narrator:
Metabolic demands may also increase during stressful situations. Like tackling a busy roundabout in the rush hour.

Breathing and blood flow are highly responsive systems. Which are sensitive to physiological and emotional stimuli. What are the elements which make up and control these entwined processes?

Magnetic resonance imaging reveals the rhythmic movements which transfer air into and out of the lungs. In quiet breathing, the diaphragm does most of the work.

The principal influence over rate and depth of breathing, is metabolic demand. The respiratory control centre is found not in the lungs, but in the brain. Here specialised groups of cells monitor metabolic output and modify the underlying rhythms of the diaphragm and the ribs.

Magnetic resonance imaging can also be used to study movements of the heart.

Dr Philip Kilner:
We're looking here at a magnetic resonance cine image of the chest and heart. This is a cardiac gaterred image which shows the heart beat but not the breathing movement. What we see on the image is the left ventricle contracting. Which sends blood up into the aorta. This is the pulmonary trunk, which is sending blood to the lungs. Although we don't see it's branches, which are further back. And then returning back to the heart from the head and lungs, is blood flow down the superior venocaver to the right atrium. Which is on it's way to the right ventricle and on it's way to the lungs.

Narrator:
Look inside the heart, and you can see blue deoxygenated blood returning from the body and passing through the heart towards the lungs. Red oxygenated blood returns to the heart to be recirculated to the tissues of the body. How are these vital rhythms initiated and controlled?

Dr Philip Kilner:
The basic rhythm of the heart actually belongs to the heart itself. It's not initiated from outside. Viable heart muscle from almost any part of the heart will beat rhythmically. And the part that beats most rapidly and therefore control the spreading heart beat, is the senatorial node. Which is known as the 'pacemaker'. So, that's where the heartbeat is initiated. That pacemaker rhythm is controlled and modulated. Most notably by sympathetic and para-sympathetic nervous systems. In a way accelerator and decelerator on the pacemaker.

There's a whole spectrum of different influences interacting both locally and body wide through blood circulation and nervous system.

Narrator:
Invigorous exercise messages from the cardiovascular centre in the brain, shift the heart into a new rhythmic mode. Which flings blood towards the lungs and around the body, with much greater force.

Blood flow to the muscles increases dramatically. So the lungs must supply oxygen and remove carbon dioxide, at a much faster rate.

Dr Philip Kilner:
Well the main stimulus to changing the rate of breathing, is that carbon dioxide load. This carbon dioxide is generated from muscle contraction basically. Imagine if you're cycling some of the physical activity you're generating more carbon dioxide, so you're going to have to breath harder. So that you've got a lot of muscle contraction going on. And that blood draining the muscles is coming back up the veins through to the heart. And it then gets pumped into the lungs.

Narrator:
It's only when the blood reaches the brain stem that sensitive cells detect the change in blood acidity caused by the increased level of carbon dioxide.

Dr Philip Kilner:
Those cells in the carotid body get excited, and they immediately discharge up into the medulla and to the respiratory centre. That sends a discharge down through the phrenic nerves, which come our through the neck, down to the diaphragms and also down through the spinal cord into the inter-thoracic muscles. And those muscles contract harder, and so you take deep breath in. Breath harder. Breath deeper.

Narrator:
The increased flow of air through the lungs washes out excess carbon dioxide, maintaining blood acidity within it's normal range.

The deeper breathing increases the lung area available for the diffusion of gasses.

Dr Stewart Fisher:
For diffusion to occur rapidly, you require very small distances. And this can occur only if you have very large areas. In fact the lungs have an enormous surface area. Something like 70 square metres. And that has to be packed into something like five or eight litres of thoracic volume. How can this be done? Well, through a very elegant tree like structure. It's actually called 'a fractile tree'.

The fractile shape is a recurrent design theme in our bodies. It's an excellent shape for communication. You can get impulses going down the branching structures. And it's very easy to treat each end branch in the same way. Now this is terrible important in the lung. And of course superposed upon the fractile bronchial tree, there is a fractile blood tree.

Narrator:
In fact there are three inter penetrating fractal trees. In these casts, which preserve the structures of actual lungs, the airways are cast in white resin.

Blood vessels bringing blood to and from the heart, are cast in different colours.

Dr Philip Kilner:
As I sit here with the cast placed in front of me, you can begin to imagine how this would actually be in my body as I sit here. My heart beating in the middle of the chest. And here we're looking at the pulmonary veins which remember should be carrying red blood back from the alvera line to the left side of the heart. From the left side of the heart, the blood is distributed through the aorta, and it's various branches, up to the head, down to the trunk, up to the limbs. Where it meets the tissues of the body before returning through trees of the systemic veins back to the right side of the heart. The heart of course is all the time beating in the middle, carrying the two streams. Air moving in and out through the tree of airways, to meet the blood in the lungs. And all the trees of the circulation by the body flowing out and flowing back. Flowing and counter flowing. All simultaneously, but in a sequence, a circulation of blood, that connects all the parts of the body.