Artificial Hearts

The human heart includes four ”one-way” valves as shown in figures 1 and 2, the tricuspid, pulmonary, mitral and aortic valves. As the heart muscle or *myocardium* expands (relaxes) and contracts the volume

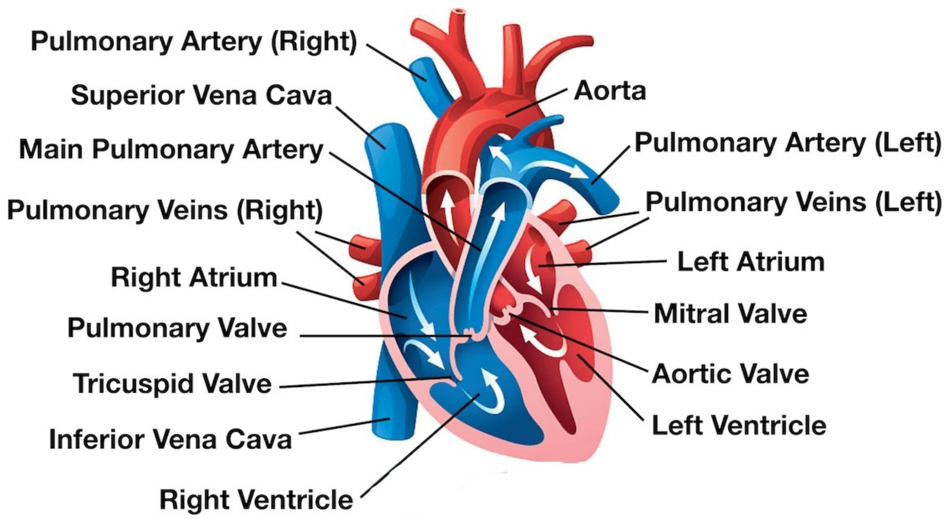

Figure 1: Diagram of the human heart.

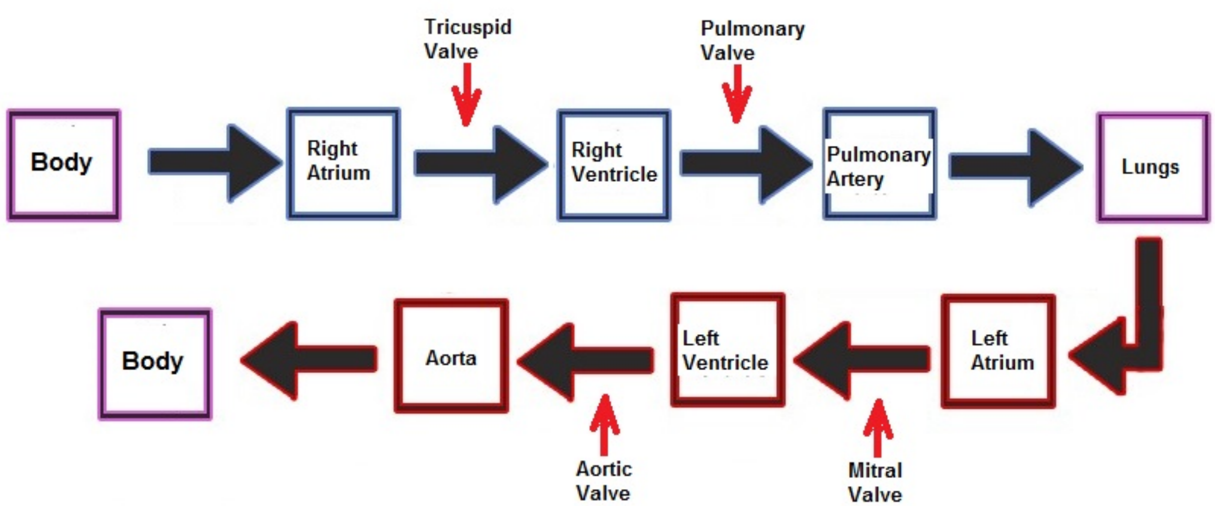

Figure 2: Schematic of the human heart.

of the heart, blood fills the chambers of the heart and then is extruded from the heart. When a chamber contracts, a valve opens to allow blood to flow through it. When the chamber relaxes, the valve closes to prevent blood from leaking back into the chamber and to allow the chamber to fill with blood again. In essence the heart comprises two positive displacement pumps that run in unison. The right side of the heart comprises the right atrium and ventricle; these take blood from the veins and pump it to the pulmonary system and lungs. The left side takes blood from the lungs through the pulmonary veins and supplies it through the aorta to the arteries of the body. As described in a preceding section, it has become a common and successful procedure to replace one (or more) valves in the heart with a artificial heart valve(s). However, in other more dire circumstances, there may be no alternative but to replace all or part of the whole heart with an artificial device.

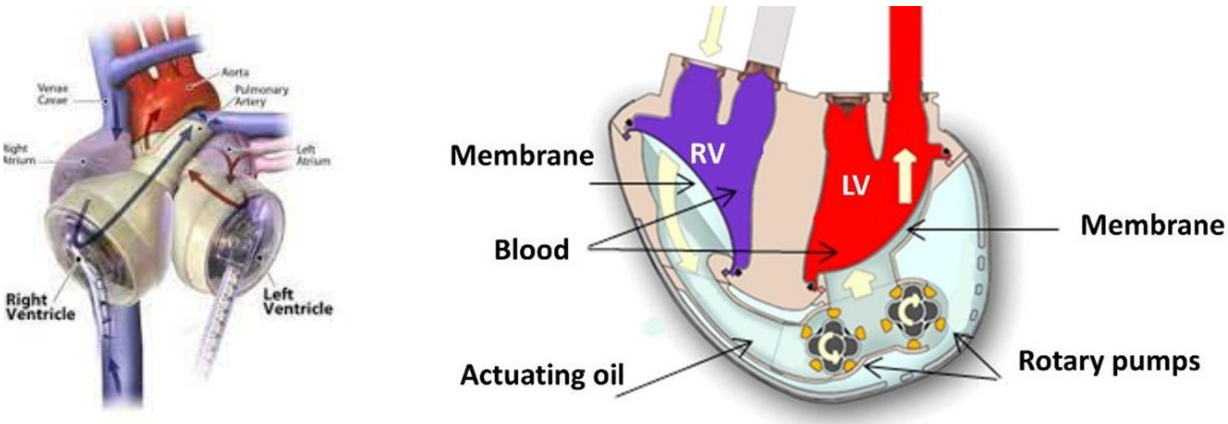

Figure 3: Left: Abicor total heart replacement. Right: Fluid inflated membrane total heart replacement device.

In the preceding sections, we described the commonest partial heart replacement devices known as *ventricular assist devices (VADs)* which are steady flow pumps and plumbing intended to supplement the pumping of either the left or right side of the heart. Total heart replacement devices necessarily involve more complex pulsatile pumps; examples are the Cleveland Clinic Foster-Miller Magscrew or the Abiocor artificial hearts (figure 3, left). Some of these total heart replacements involve installed membranes that are activated by either hydraulic fluid or air in order to fill and empty the ventricles (figure 3, right).

A review of these devices is beyond the scope of this book but some common basic issues are worth mentioning. One common concern (as with the $VADs$) is the extent to which the device causes *hemolysis* or the rupture of red blood cells. As in the case of the heart valves, more flexible structures might help but most of the current devices use conventional rigid components. As with artificial heart valves, the pulsatile flow in total heart replacement devices is more susceptible to hemolysis (and cavitation) than the continuous flow $VADs$. As a result of these complexities, much development remains to be done before artificial heart replacement designs can converge toward an optimal form.