Artificial Hearts

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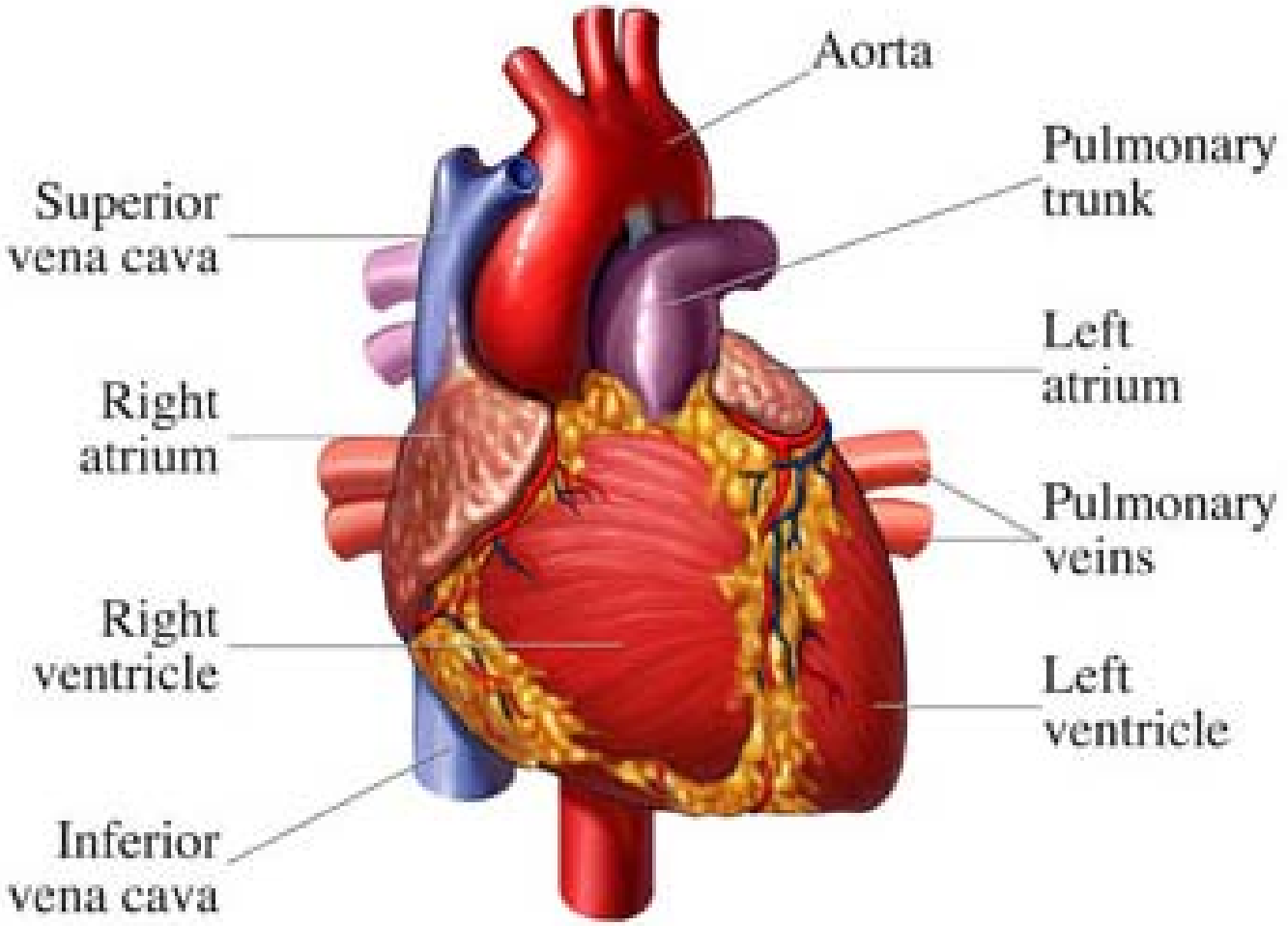
The Human Heart



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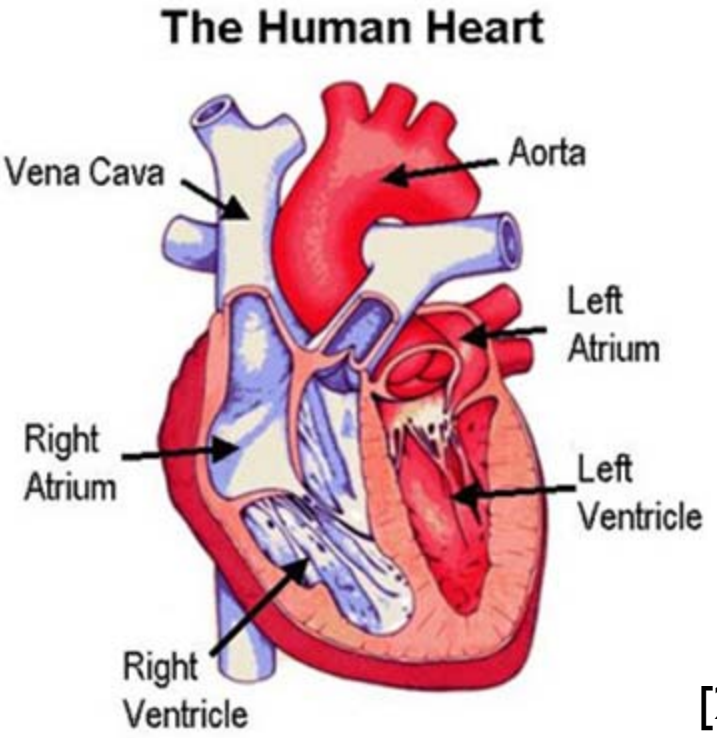
Blood Flow

- Atrioventricular
  - Mitral/Bicuspid (L)
  - Tricuspid (R)
- Semilunar
  - Aortic (L)
  - Pulmonary (R)



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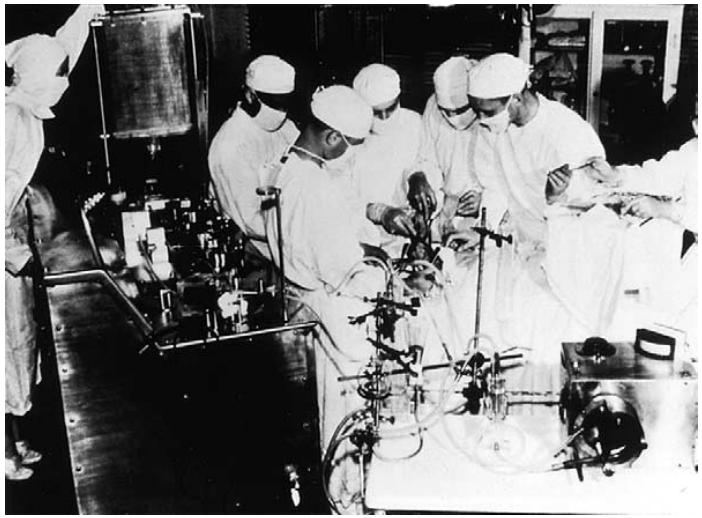
Heart Failure

- Failure to adequately pump blood to the rest of the body
- Congestive if filling pressures are normal
- Only severe cases may be eligible for heart transplant

Class	Patient Symptoms
Class I (Mild)	No limitation of physical activity. Ordinary physical activity does not cause undue fatigue, palpitation, or dyspnea (shortness of breath).
Class II (Mild)	Slight limitation of physical activity. Comfortable at rest, but ordinary physical activity results in fatigue, palpitation, or dyspnea.
Class III (Moderate)	Marked limitation of physical activity. Comfortable at rest, but less than ordinary activity causes fatigue, palpitation, or dyspnea.
Class IV (Severe)	Unable to carry out any physical activity without discomfort. Symptoms of cardiac insufficiency at rest. If any physical activity is undertaken, discomfort is increased.

History

- Cardiopulmonary bypass (CPB) machine was first used by surgeons starting in 1953
- 1957 first artificial heart designed by Akutsu and Kolff and implanted in a dog
- Early 1960s left ventricular assist devices were invented for longer-term ventricular assistance
  - First one implanted in 1963 in a patient that went into cardiogenic shock after an aortic valve replacement



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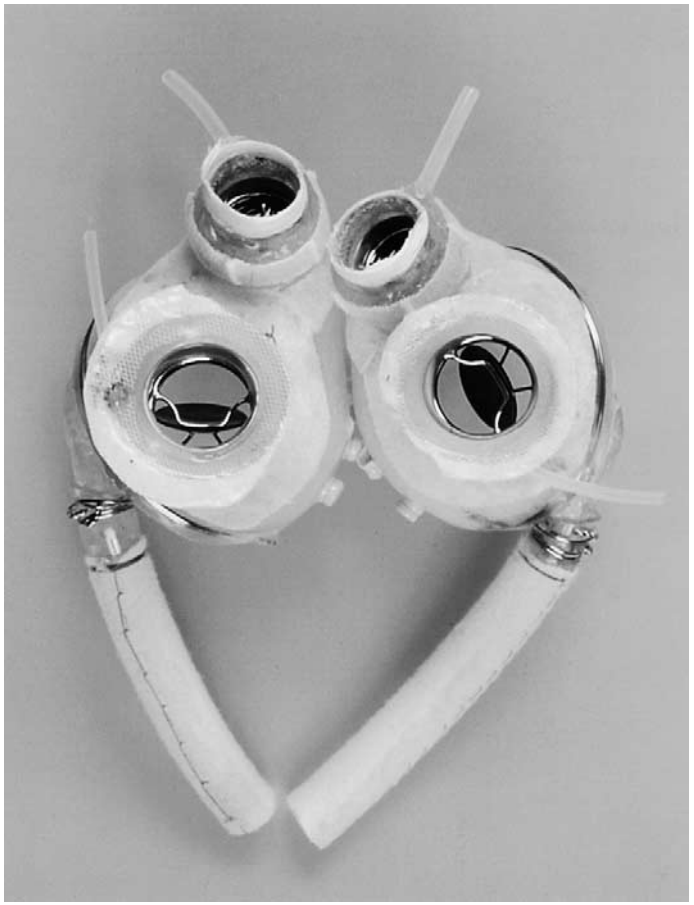
History

- 1967 first successful cardiac transplant performed by Christiaan Barnard
- 1969 first total artificial heat replacement surgery performed
  - Heart developed by Baylor Laboratories
- During the 1970s many pump devices invented to act as a bridge between heart failure and surgery (max of 30 days)
  - Norcor LVAS (developed in Ottawa)
  - HeartMate LVAS (developed in California)

[7]

History

- Second total artificial heart replacement surgery performed in 1981
  - Due to limited immunosuppressant drugs, contamination during transplant of the artificial heart made patients susceptible to bacterial infection
- Jarvik-7 was the first successful total artificial heart replacement surgery
  - Patient lived 112 days (death unrelated to TAH)
  - Patients used hearts for 2 to 620 days
- 1985 first successful bridge surgery using total artificial heart replacement performed



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History

- Early 1990s improvements made to Jarvik-7 (renamed CardioWest in 1991), AbioMed invents another total artificial heart AbioCor
- 1998 the 100th artificial heart is implanted
- 2004 FDA approves the SynCardia total artificial heart (formerly CardioWest) for bridge transplantation
- Currently 2 artificial hearts available
  - AbioCor and SynCardia

Types of Artificial Hearts

- 2 types of artificial hearts

Ventricular Assistant Devices	Total Artificial Heart
- Implanted to assist the natural heart	- Heart is removed and an artificial heart is implanted
- Patients not eligible for heart transplant	- Patients may be eligible for heart transplant
- Implant is designed to lessen the load on the heart and possibly help the healing process	- Heart has completely failed and only option remaining is an artificial heart

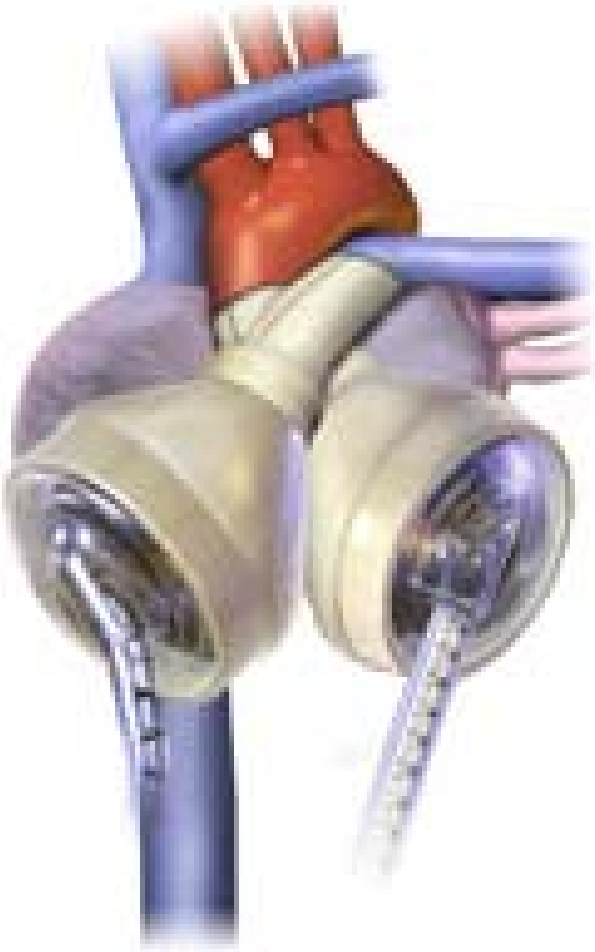
Total Artificial Hearts

- Implanted to pump blood from the heart in place of the ventricles
- Takes over functions of heart valves
- Currently 2 categories of artificial hearts

SynCardia	AbioCor
Patient eligible for heart transplant	Patient ineligible for heart transplant
External power supply; wires/tubes penetrating the body wall	Implanted power supply; no body wall penetration

SynCardia Artificial Heart

- Used as a bridge to transplant
- Restore kidney and liver function
- Prevent tissue damage



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Power Supply

- Connected by tubes through chest wall to external pneumatic driver
- Implant driver vs. Discharge driver

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AbioCor Artificial Heart

- Patients are not eligible for heart transplant
- Fully implantable
- Hydraulic pump
- Ventricles contract at different times

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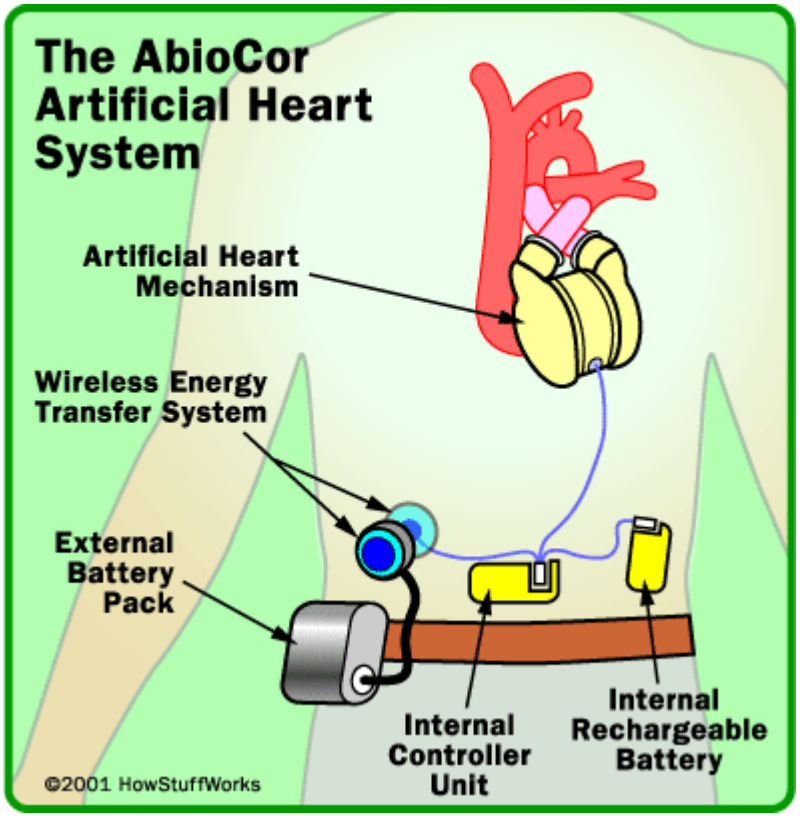
AbioCor Heart

http://www.youtube.com/watch?v=oHvIwkYRFV4&feature=related

Power Supply

- Internal and External batteries
- Uses Transcutaneous Energy Transfer (TET)



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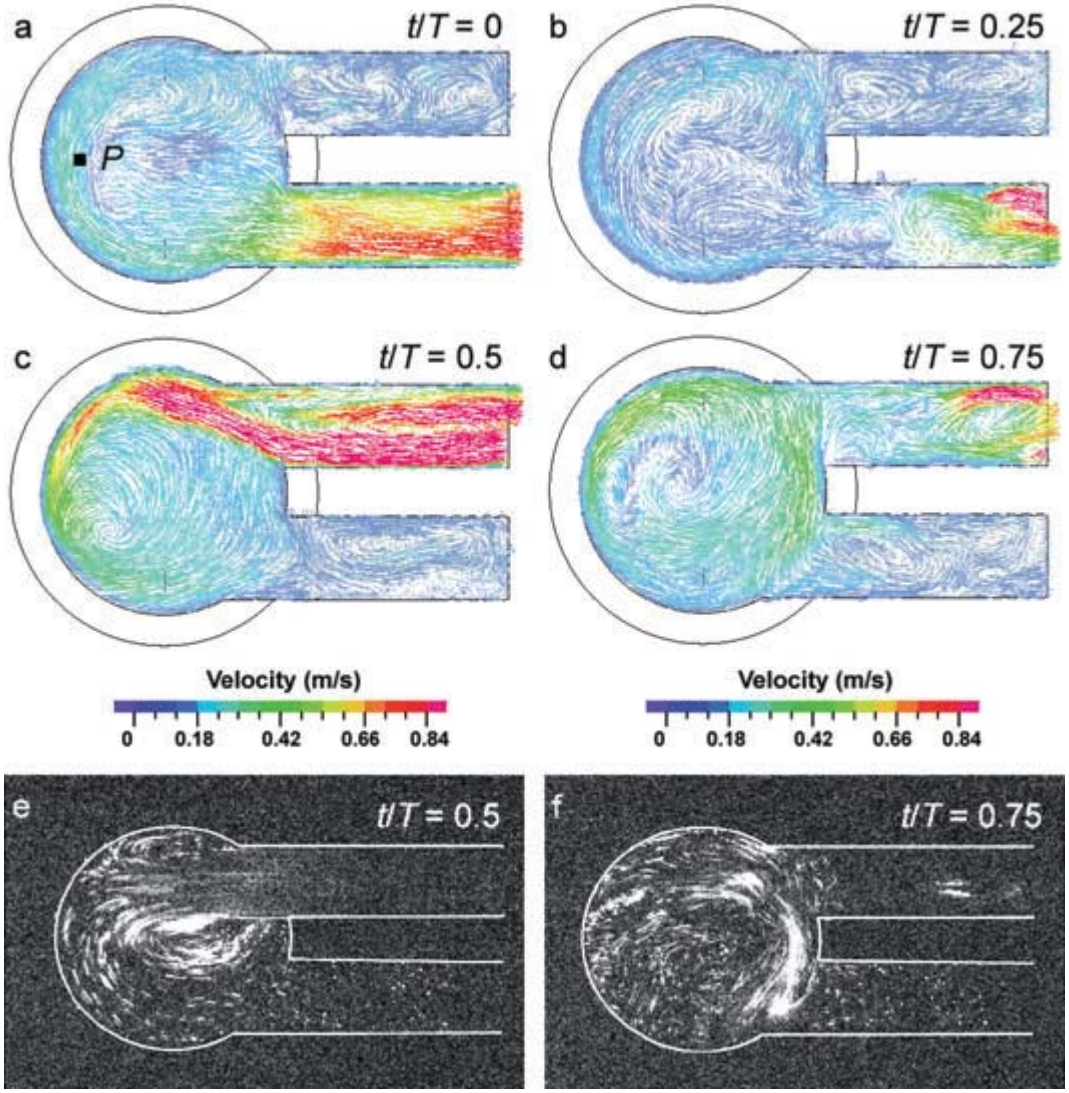
Implantation Surgery

- Outflow and atrial grafts are stretched to make connection to the body easier
- Outflow grafts are sealed using preclotting or synthetic spray
- Patient is transferred to a cardiopulmonary bypass machine
- Ventricles and valves are removed leaving the valvular rings
- Modification to the atrium is made to prevent thrombus formation

- Outflow grafts are sutured to the aorta and pulmonary arteries and the atrial grafts are sutured to the atrium
- Grafts are checked for leakage and sealed
- SynCardia heart, left and right ventricles are attached to the grafts
- AbioCor heart, the apex cannulas are inserted into the left and right atrium
- The system is started and the patient is weaned off of the cardiopulmonary bypass machine
- Average implant surgery is 7 hours

Artificial Heart Fluid Mechanics



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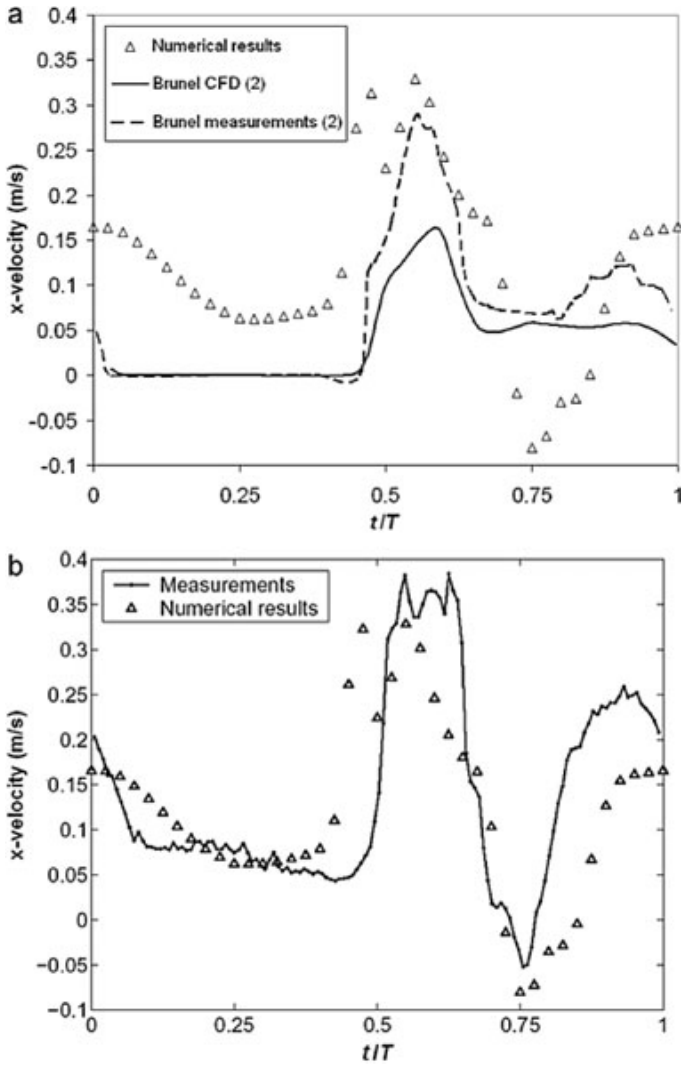
Artificial Heart Fluid Mechanics



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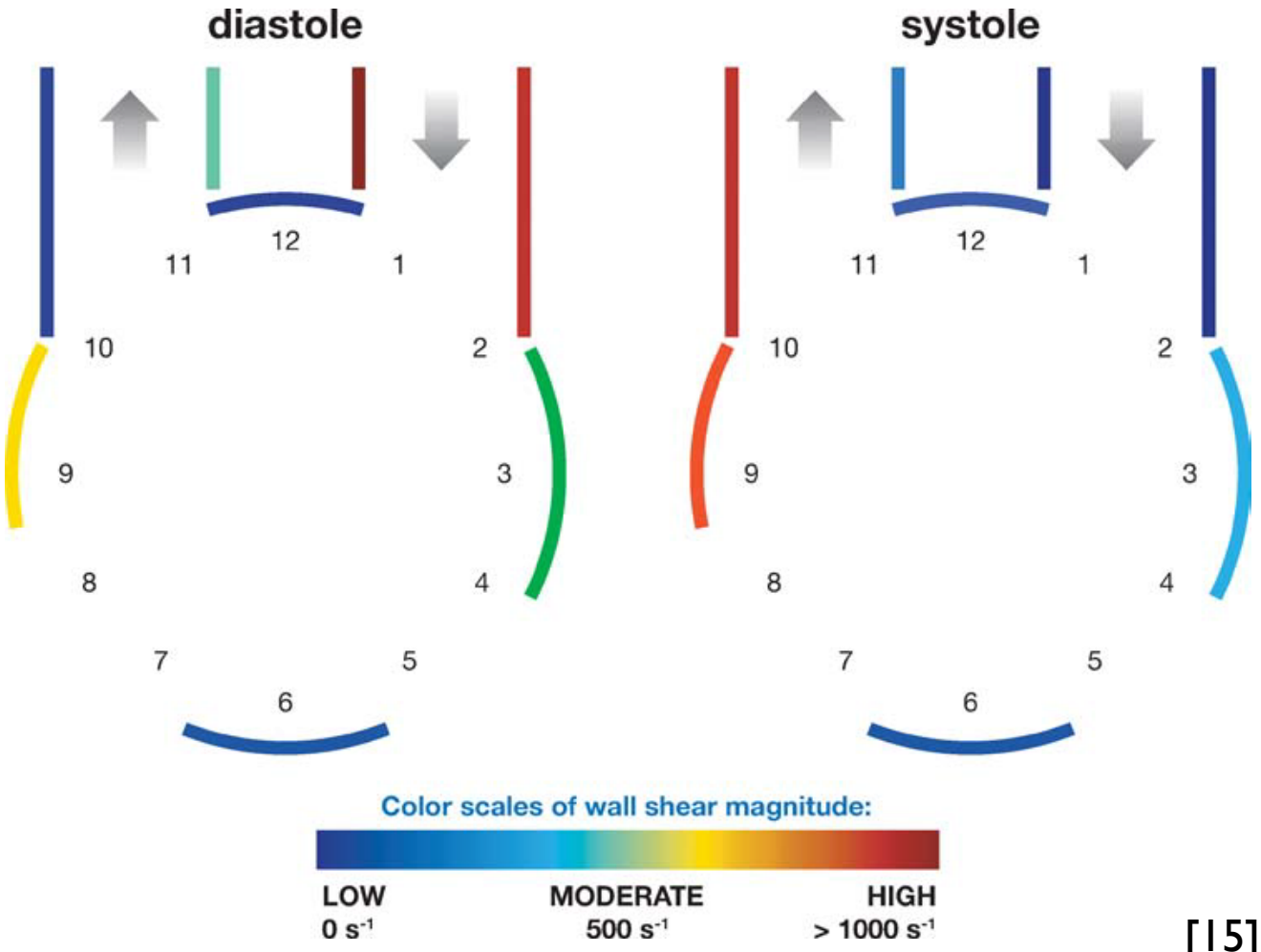
Turbulent Flow

- Turbulent flow in the artificial heart puts excessive force onto the veins and arteries that are attached to the artificial heart
- Not a problem a bridge patient experiencing an average waiting time between heart failure and cardiac transplant
- Problem for bridge patients that wait years before transplant and patients that are using artificial hearts to extend life
- Causes wear on device

Areas of Wall Shear



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AbioCor Heart

- AbioCor heart designed to minimize turbulent blood flow
- Ventricles are tube shaped
- Still turbulent blood flow around the motor as it pushes the blood out of the ventricle

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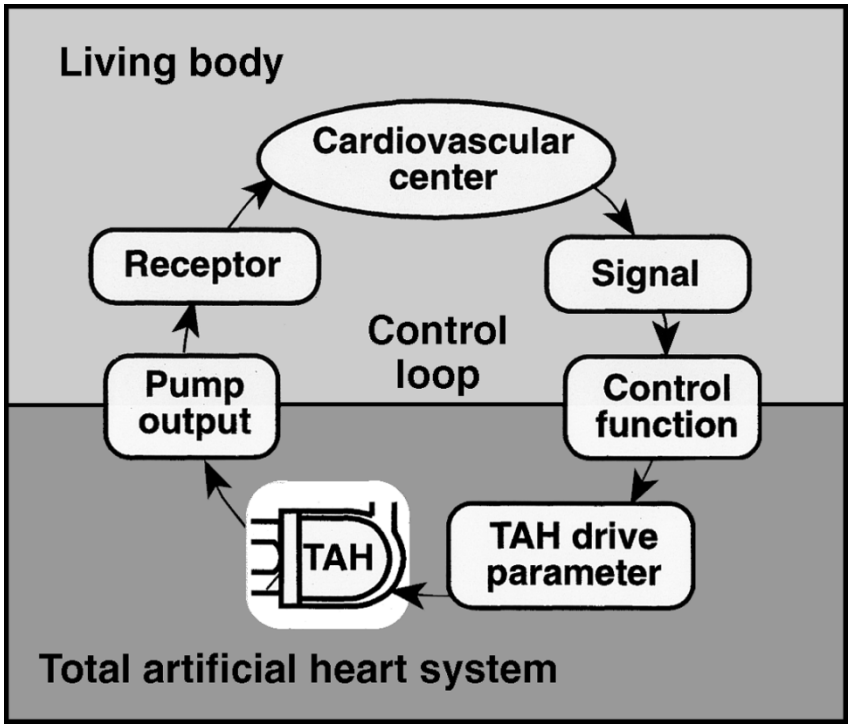
Communication with the Central Nervous System

- Central nervous system needs to communicate with the artificial heart to vary the rate at which it beats
- Artificial hearts use vascular conductance to measure the rate at which it should be beating



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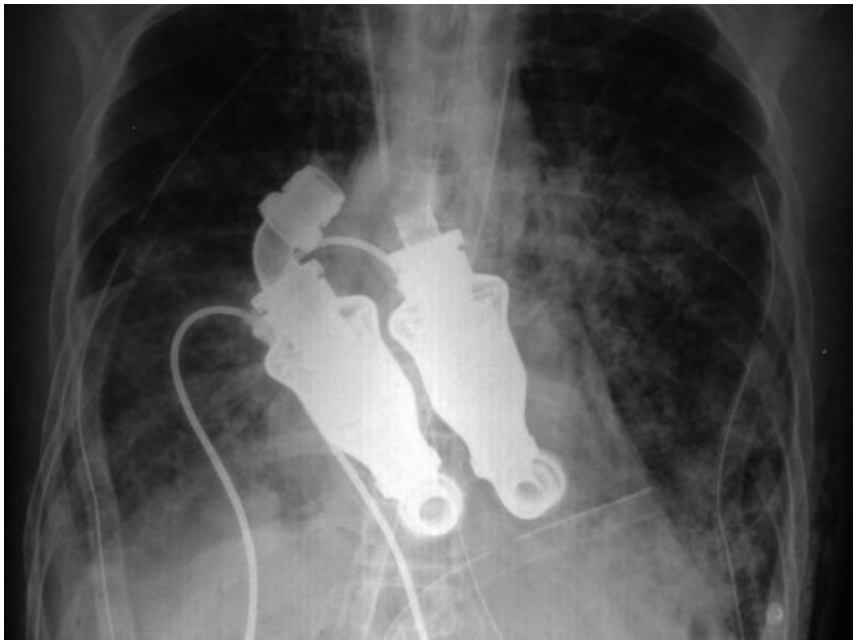
Future

- Increase life expectancy of patient
  - AbioCor patient life expectancy is 18 months
  - SynCardia patient life expectancy is to heart transplant
- Increase the durability of the artificial heart
  - Projected lifetime is to be increased to 10 years
- Decrease the size of the device

Future

- Change technology from an axial pump to a continuous flow pump
  - Continuous flow pumps are better able to adapt to the human body's changing need for blood
  - Continuous flow pumps use the pressure of the blood flowing into the heart to determine the rate at which it pumps blood
- Still under animal testing



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Hopefully advances in artificial hearts will improve the survival rate of patients living with stage 4 cardiac failure

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