Anatomy of the Heart and Circulation
A Refresher

Dr. Alexander Lyon

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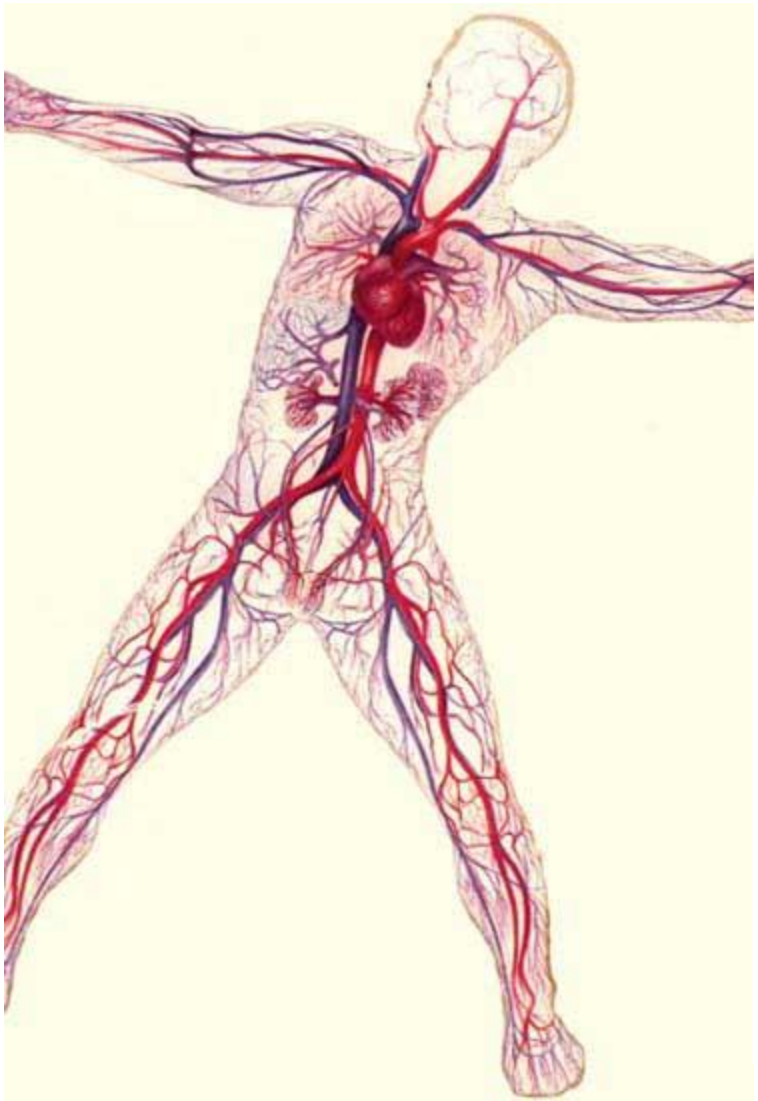
Imperial College and Royal Brompton Hospital

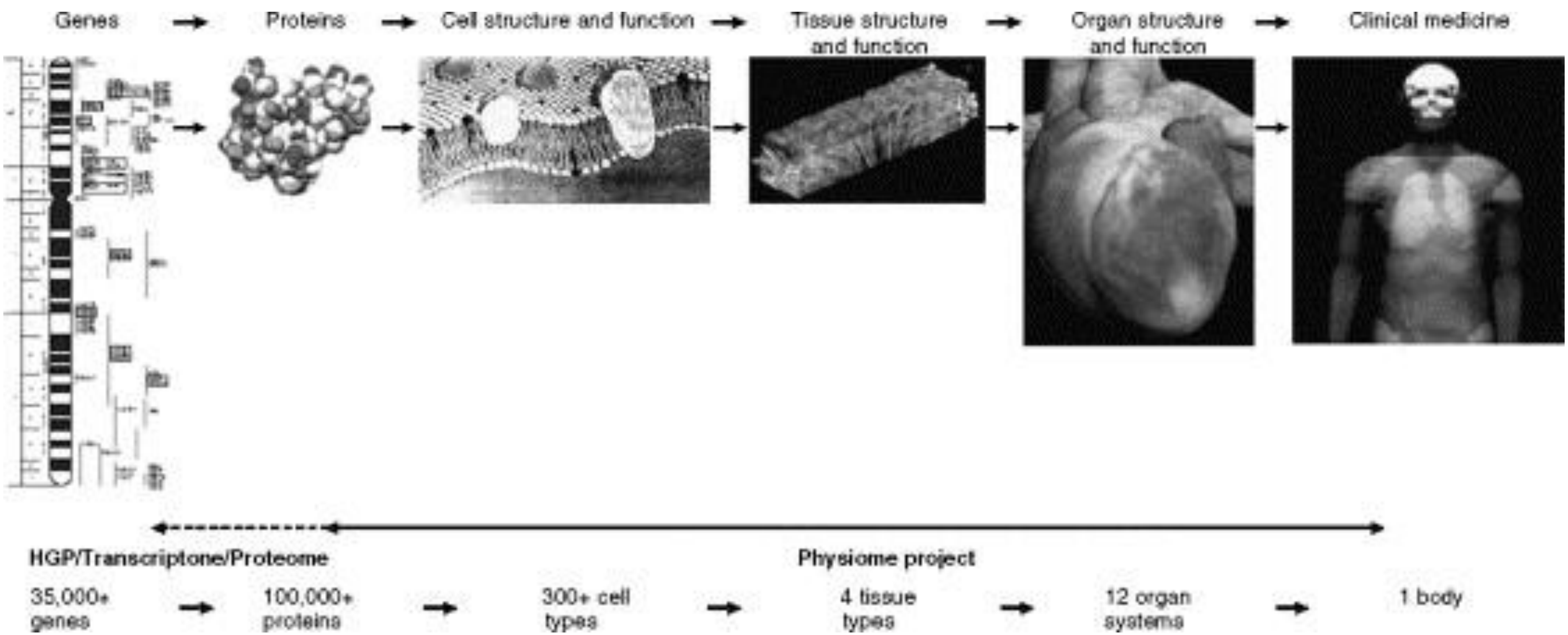
Overview

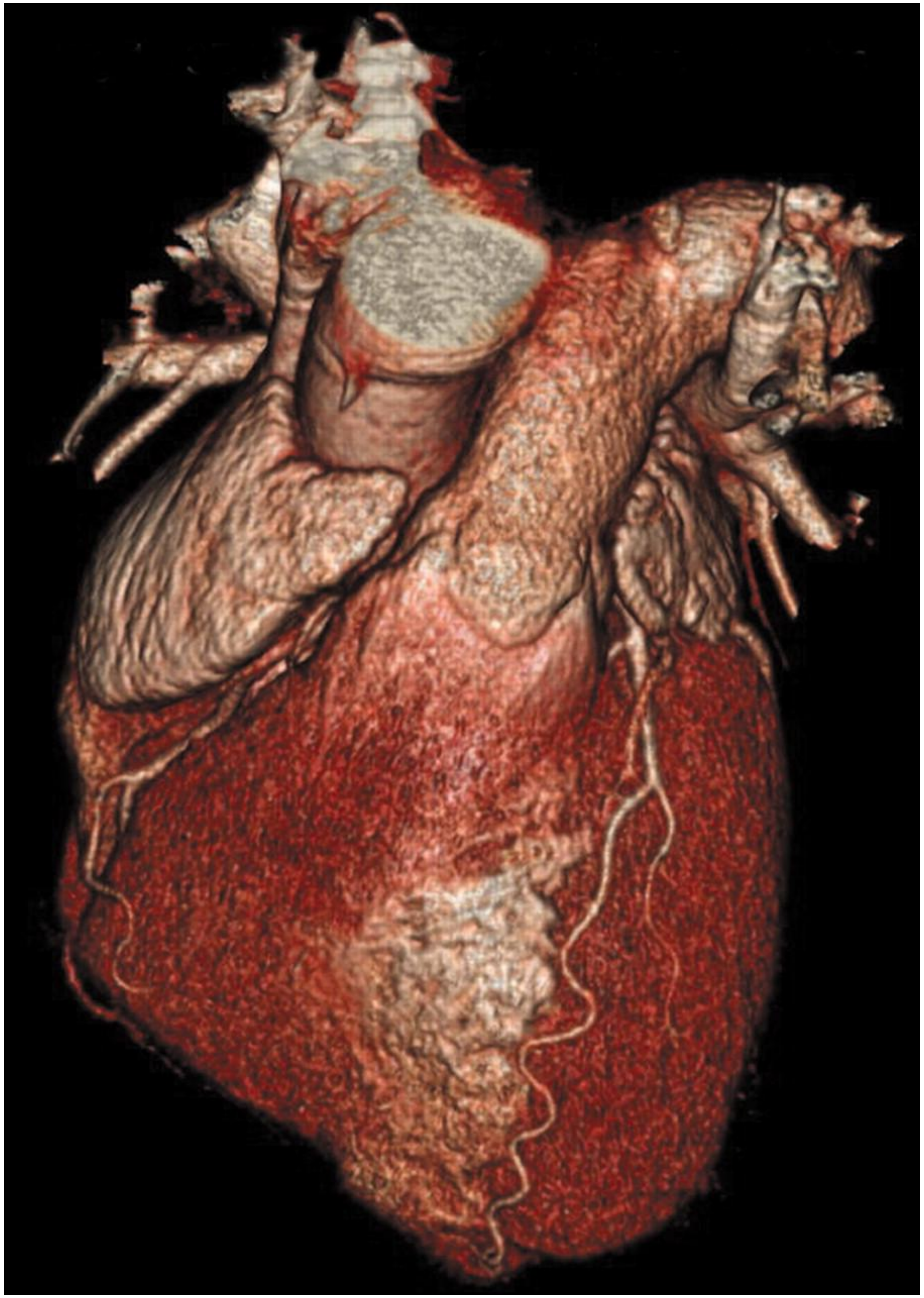
- General CVS Anatomy
- Macroscopic Cardiac Anatomy
  - Chambers
  - Valves
  - Conduction System
- Microscopic Myocardial Anatomy

Circulatory System

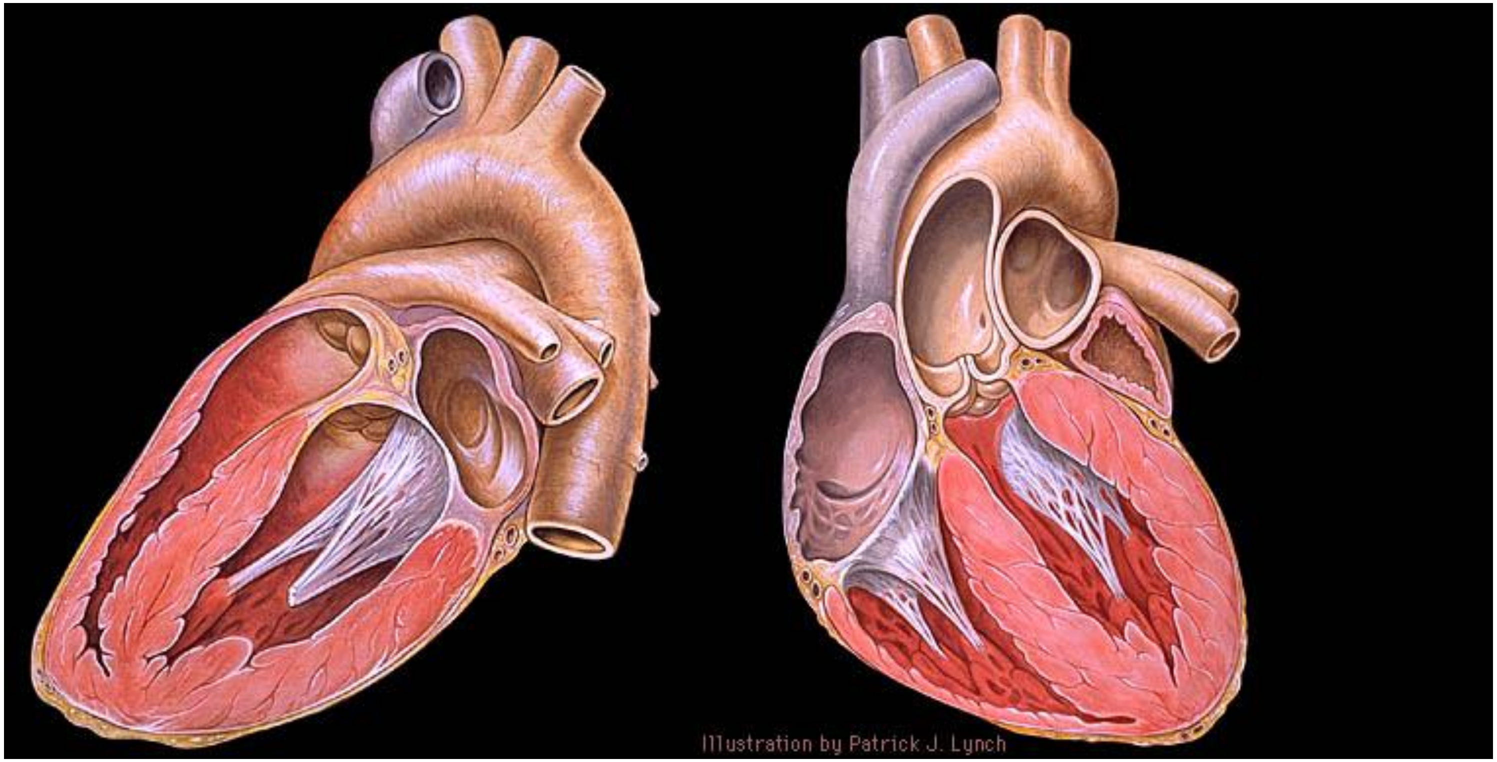


Physiome

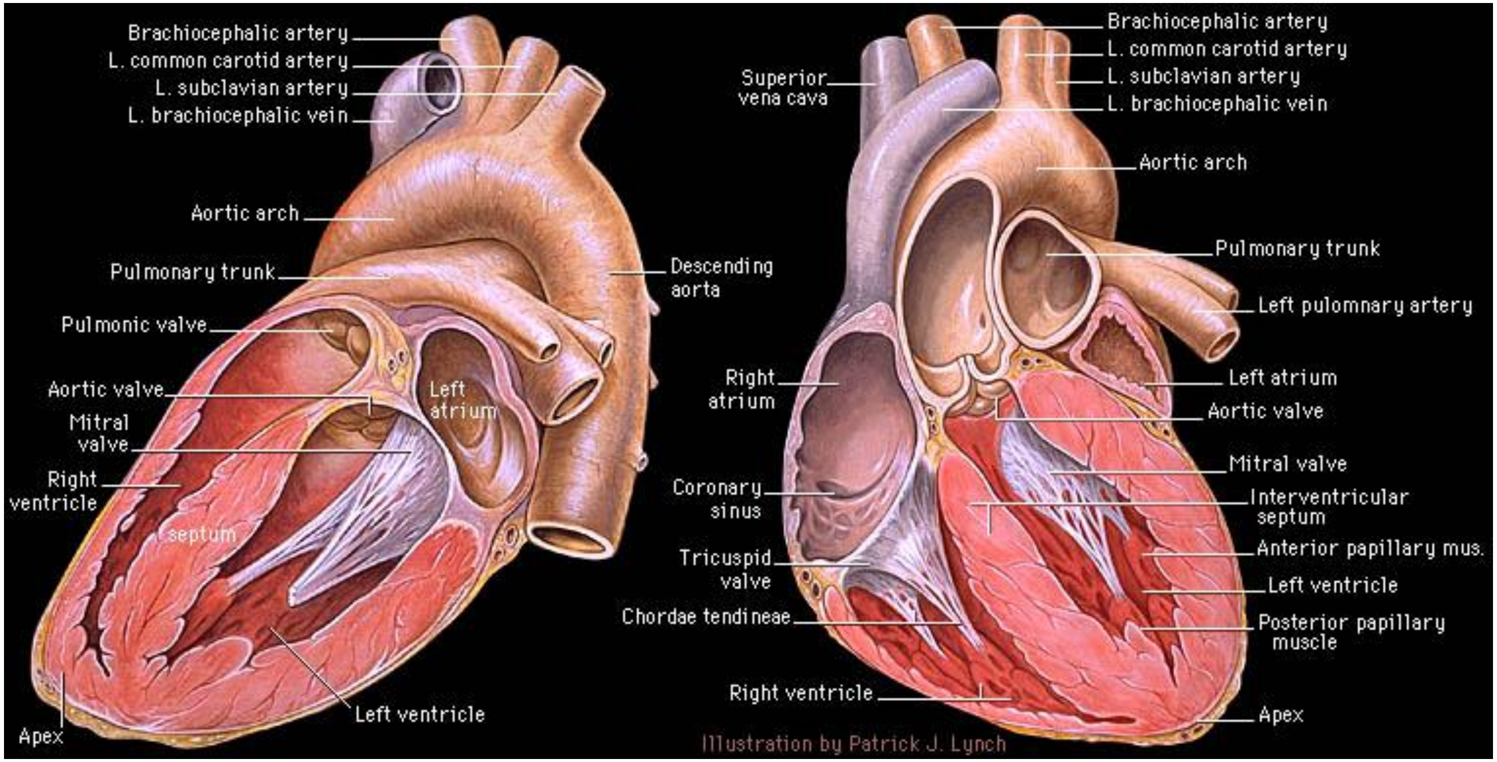

Genes
Proteins
Cell structure and function
Tissue structure and function
Organ structure and function
Clinical medicine
HGP/Transcriptone/Proteome
Physiome project
35,000+ genes
100,000+ proteins
300+ cell types
4 tissue types
12 organ systems
1 body



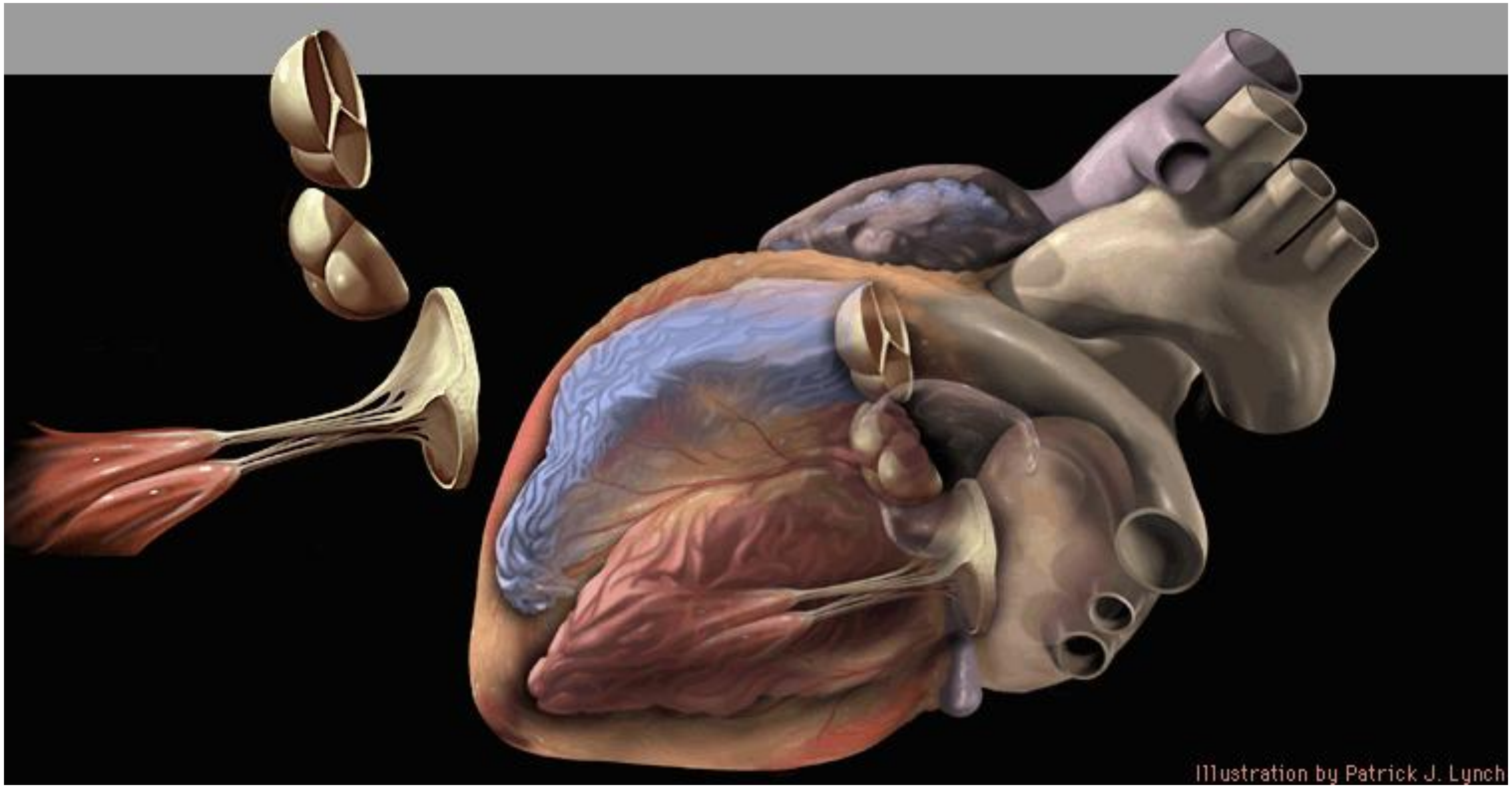
Macroscopic Cardiac Anatomy



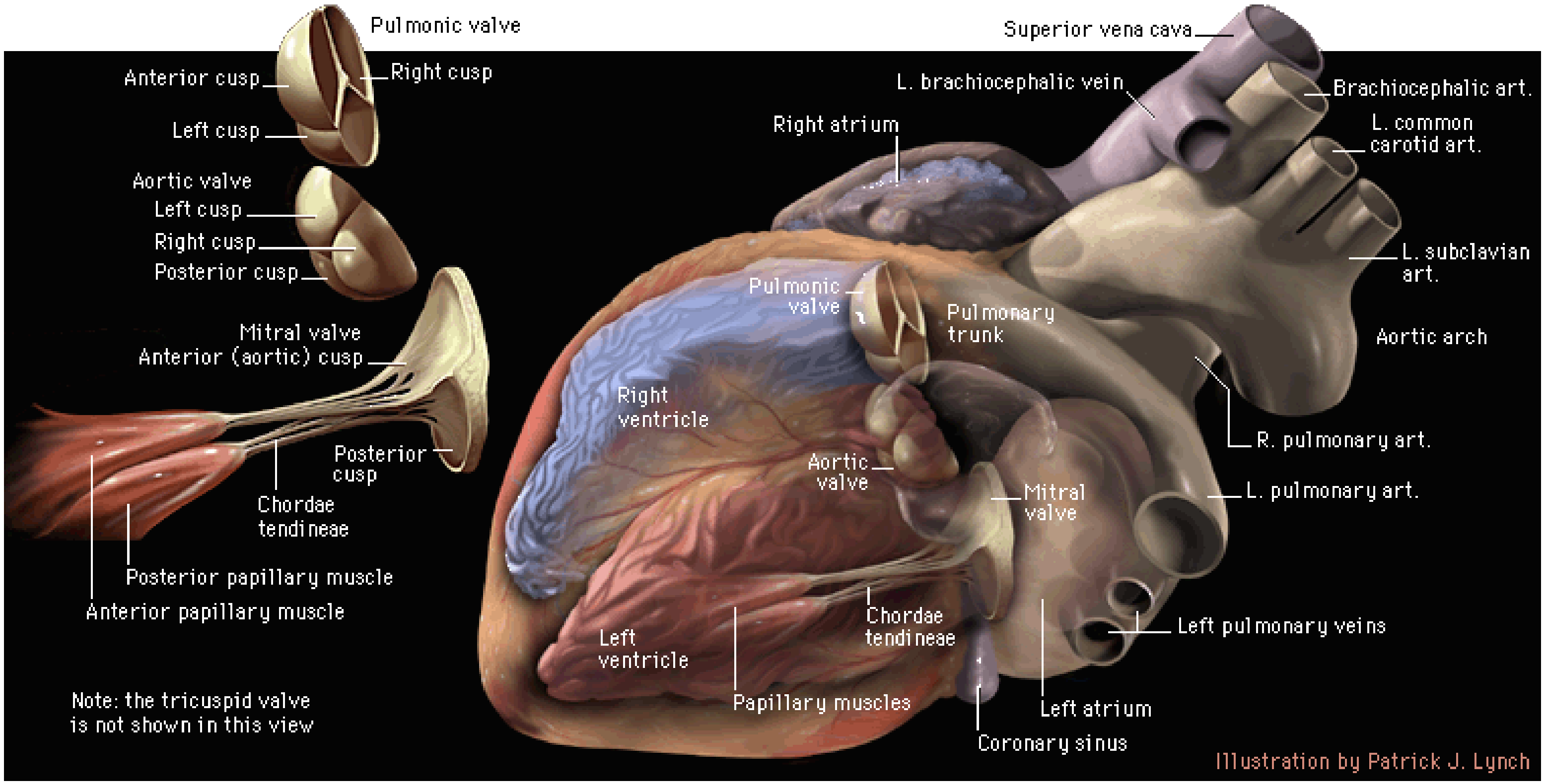
Macroscopic Cardiac Anatomy



Macroscopic Cardiac Valve Anatomy



Macroscopic Cardiac Valve Anatomy



Aortic Valve

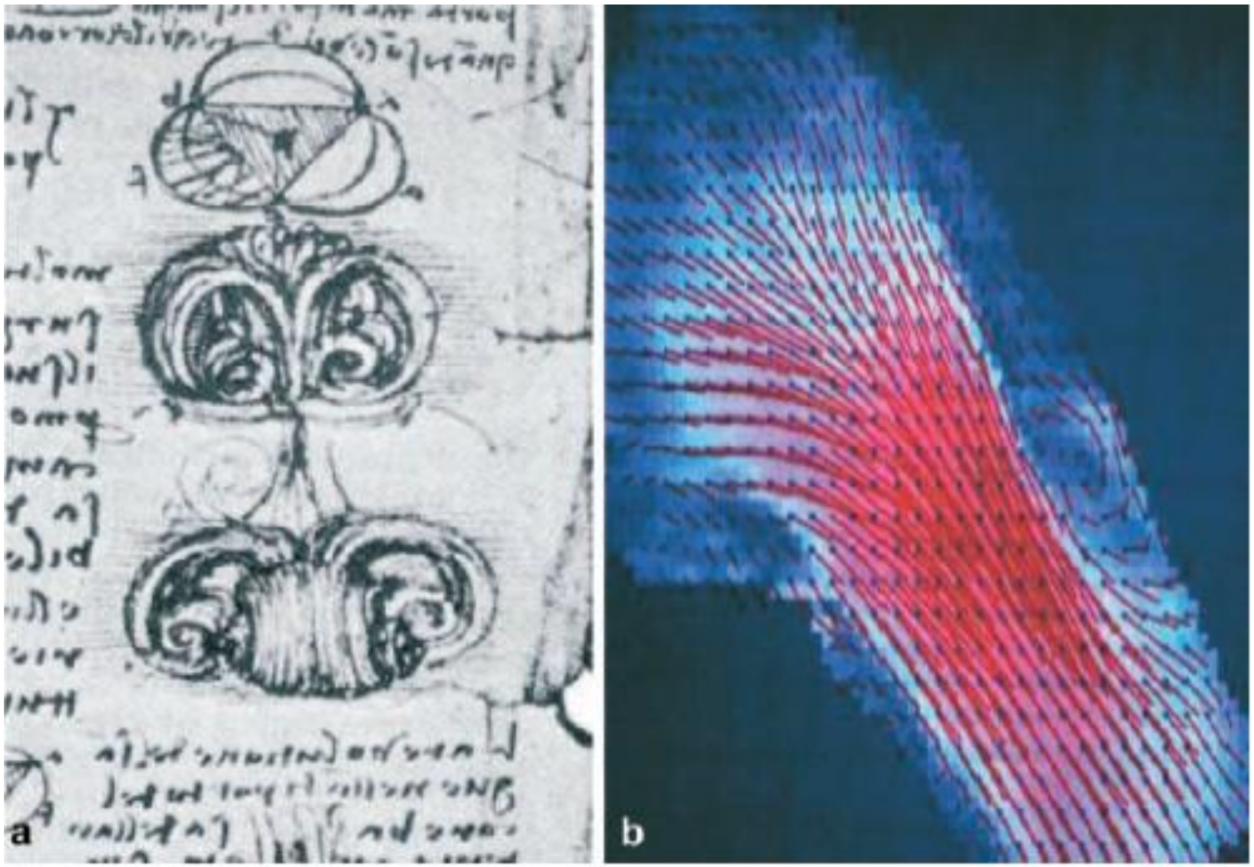
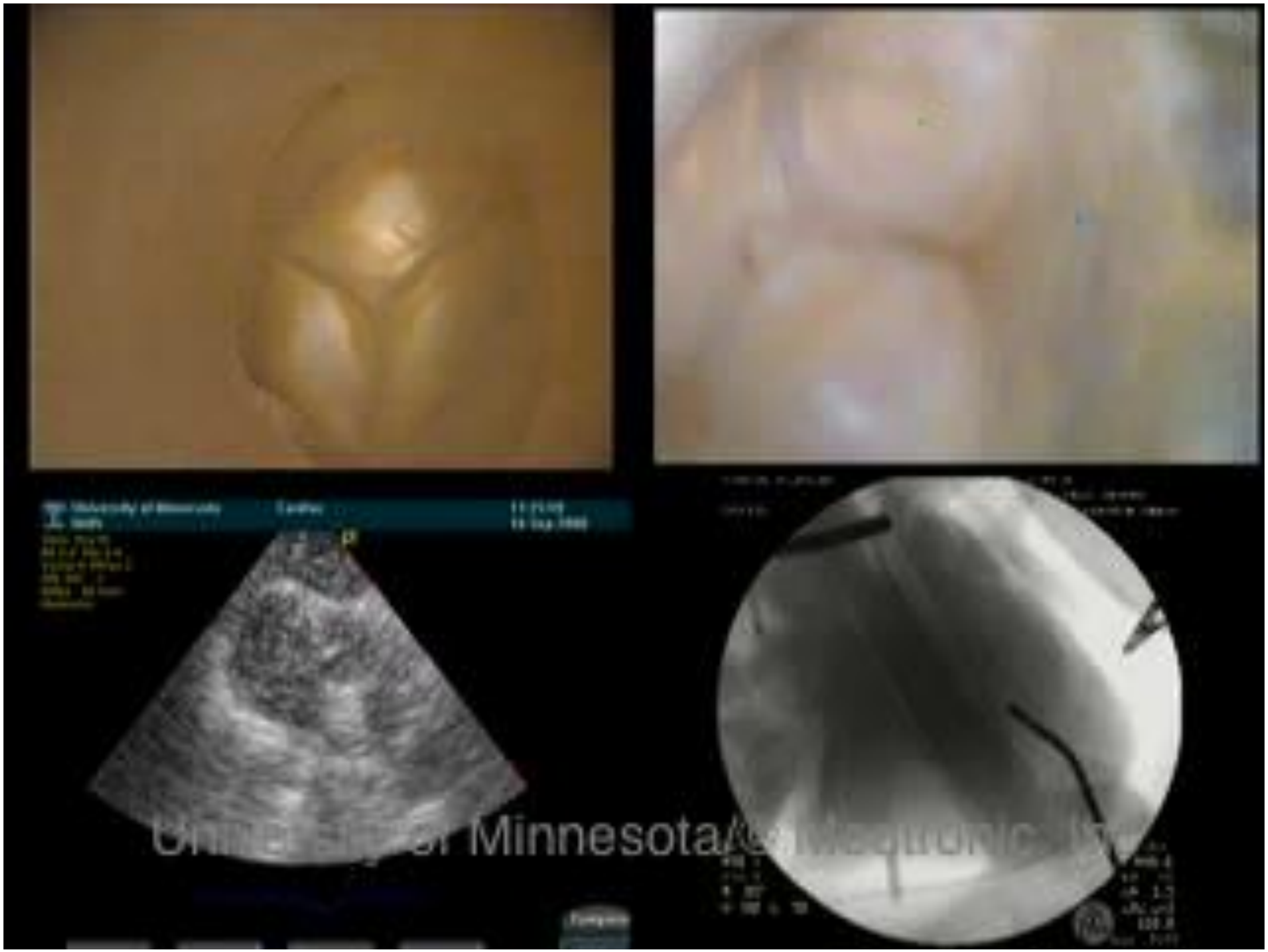
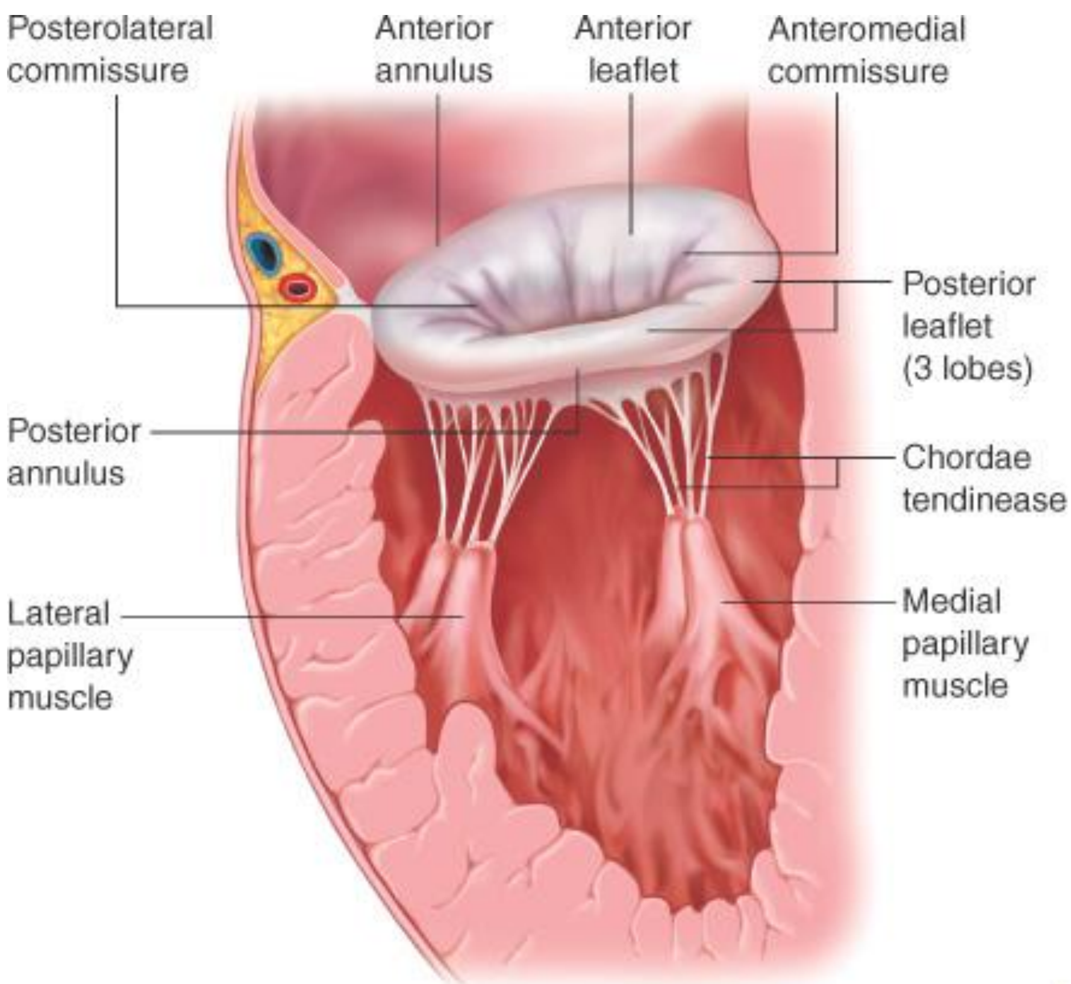


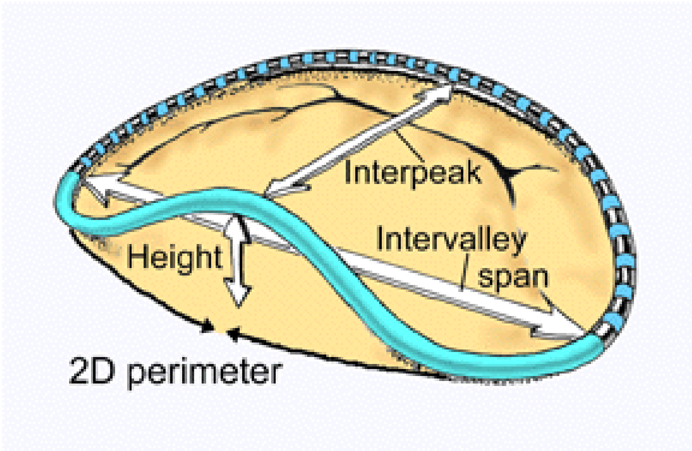
Fig. 1. **a** Leonardo da Vinci's depiction of aortic valve vortices in the left heart. (Detail of RL19116 recto – Courtesy of The Royal Collection © 2002, Her Majesty Queen Elizabeth II). **b** Velocity vectors from MRI in the left ventricular outflow tract, again showing vortices in the Sinus of Valsalva. (Courtesy of Dr. Tal Geva of Children's Hospital Boston)

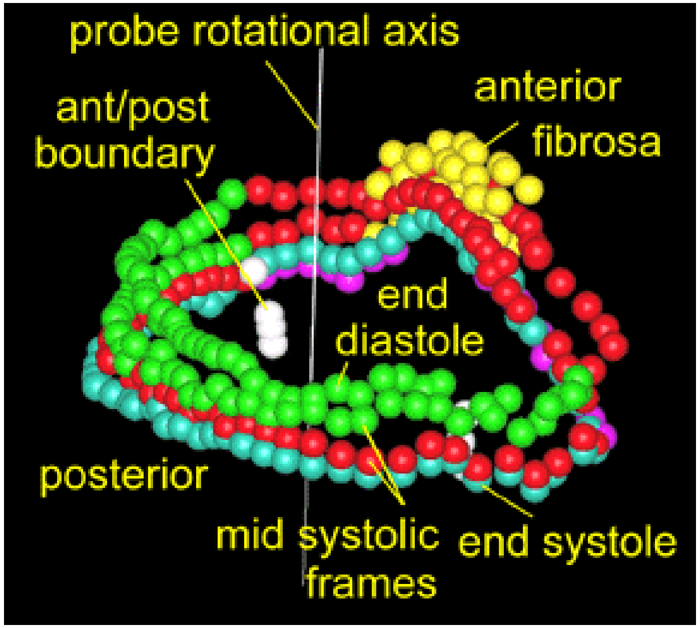
Aortic Valve



Mitral Valve



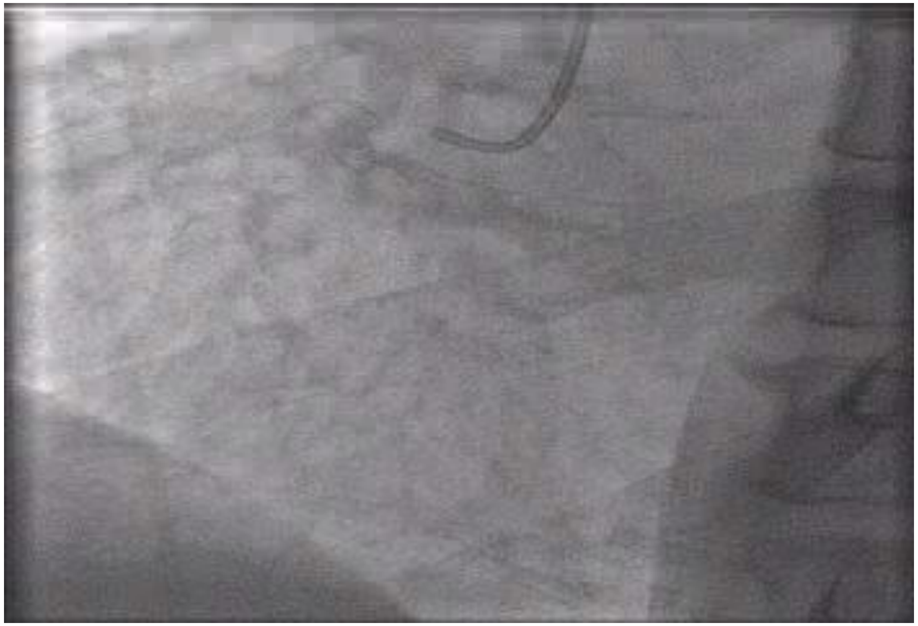




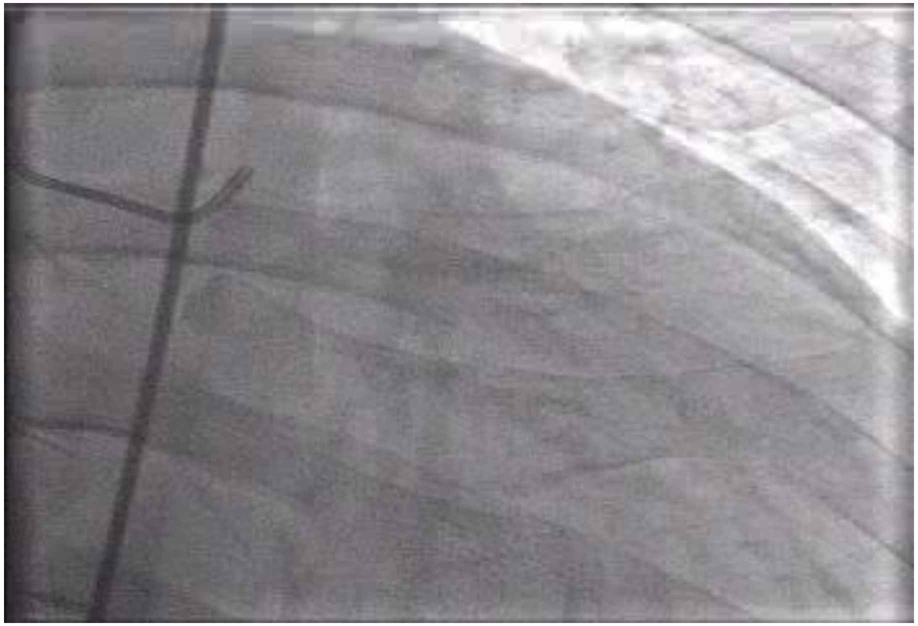
Mitral Valve

Coronary Anatomy

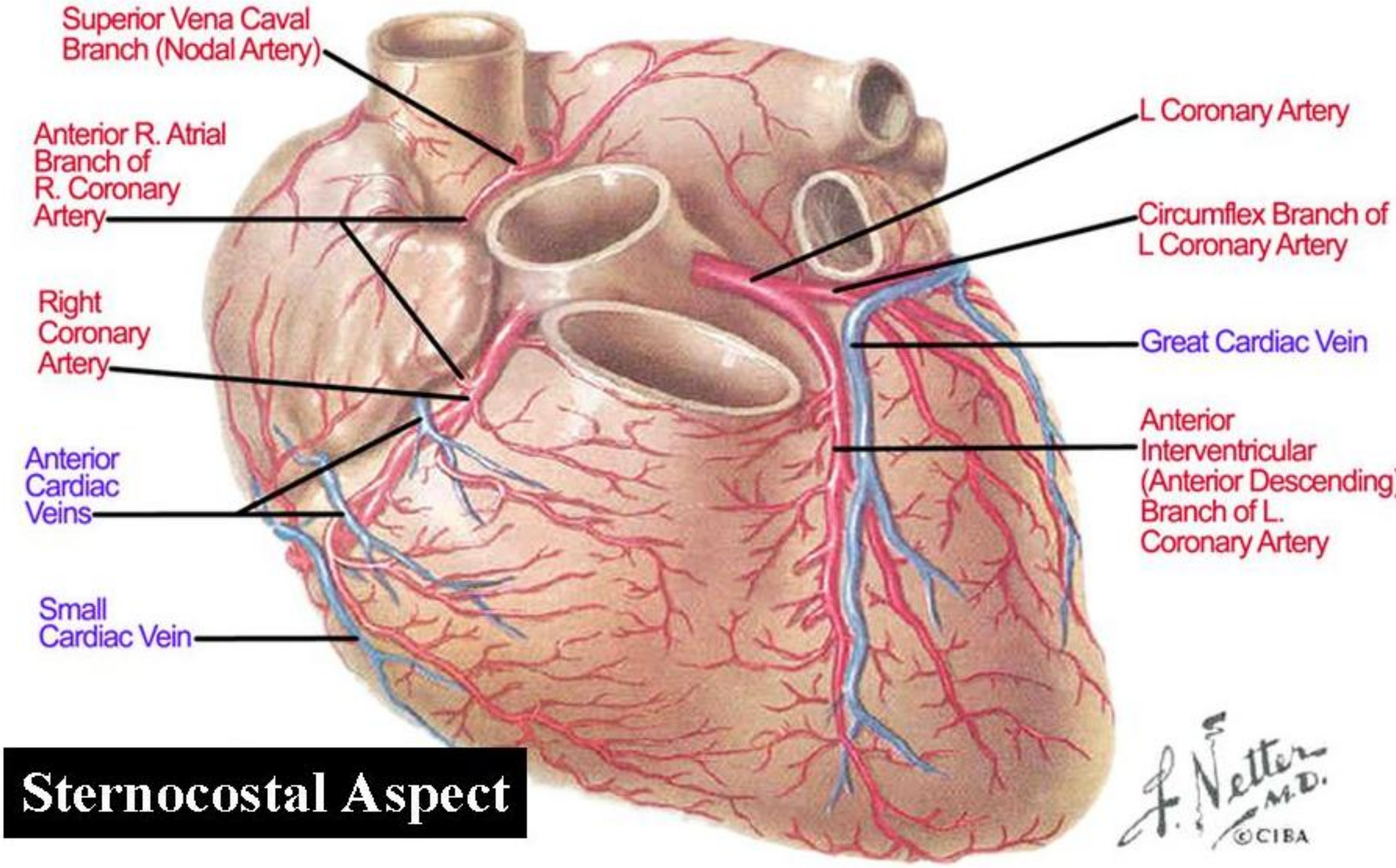
Right Coronary Angiogram



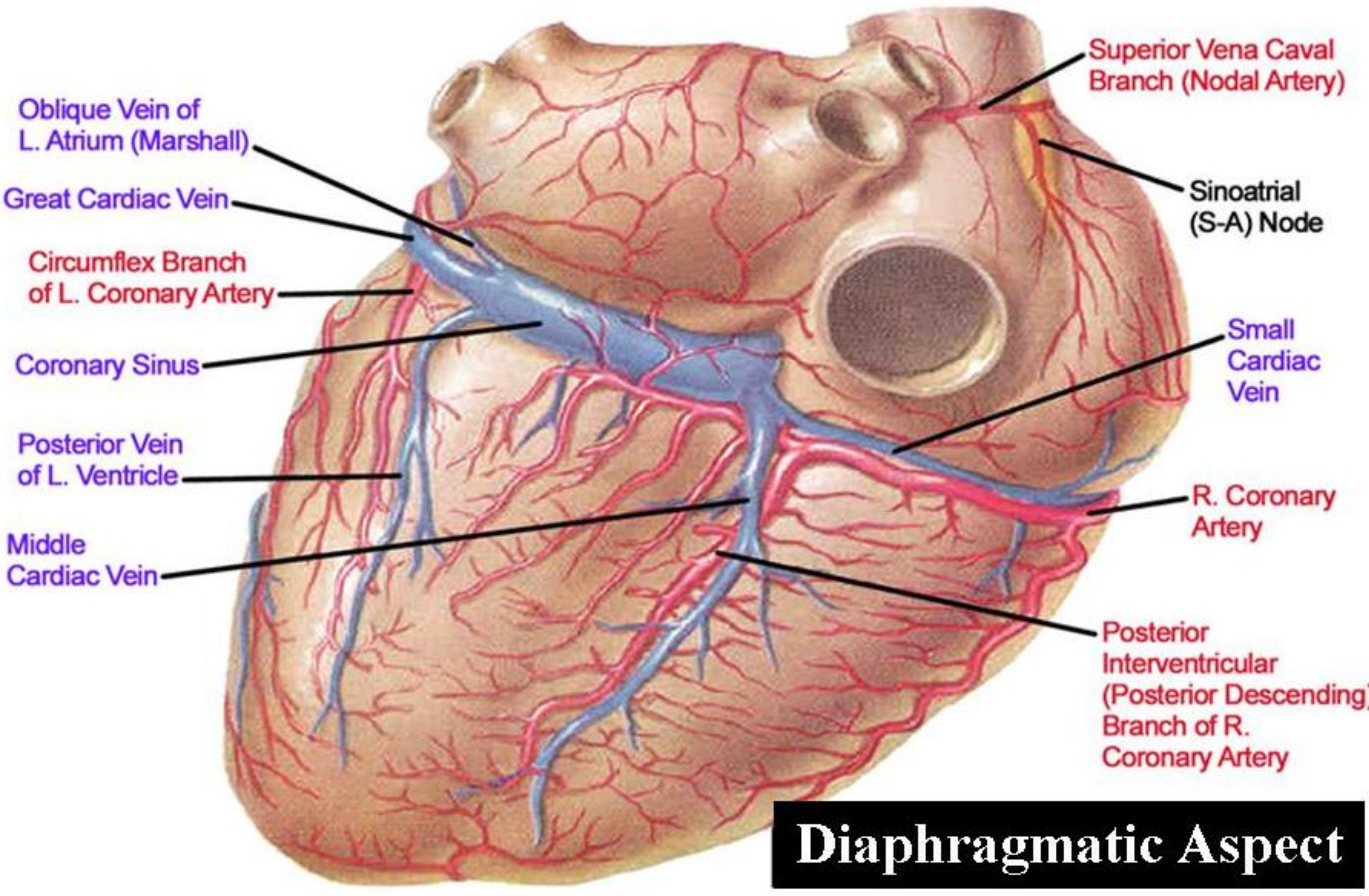
Left Coronary Angiogram



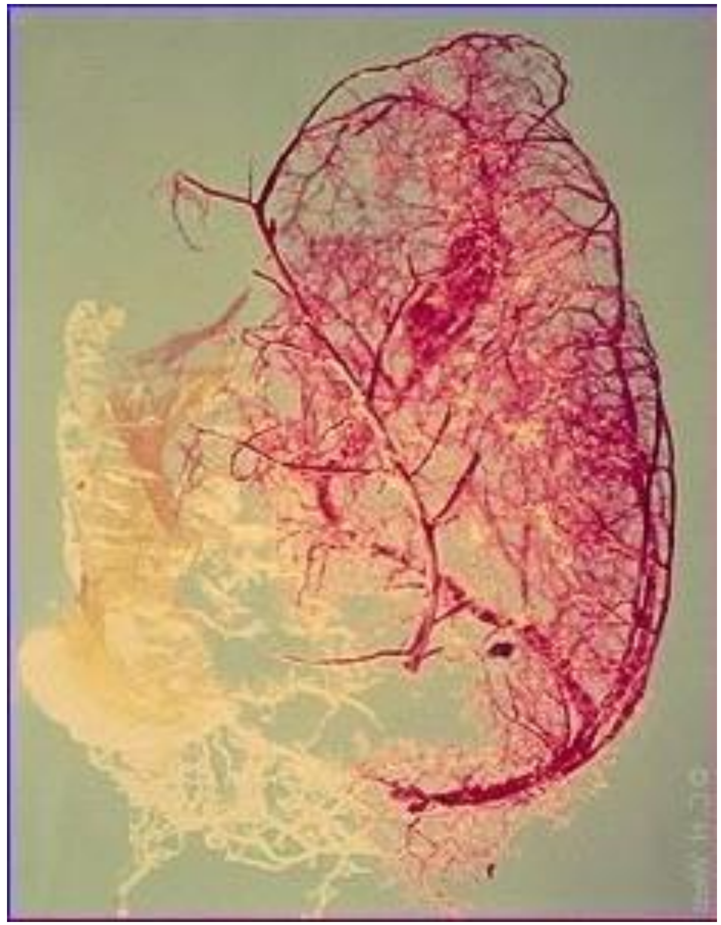
Coronary Anatomy



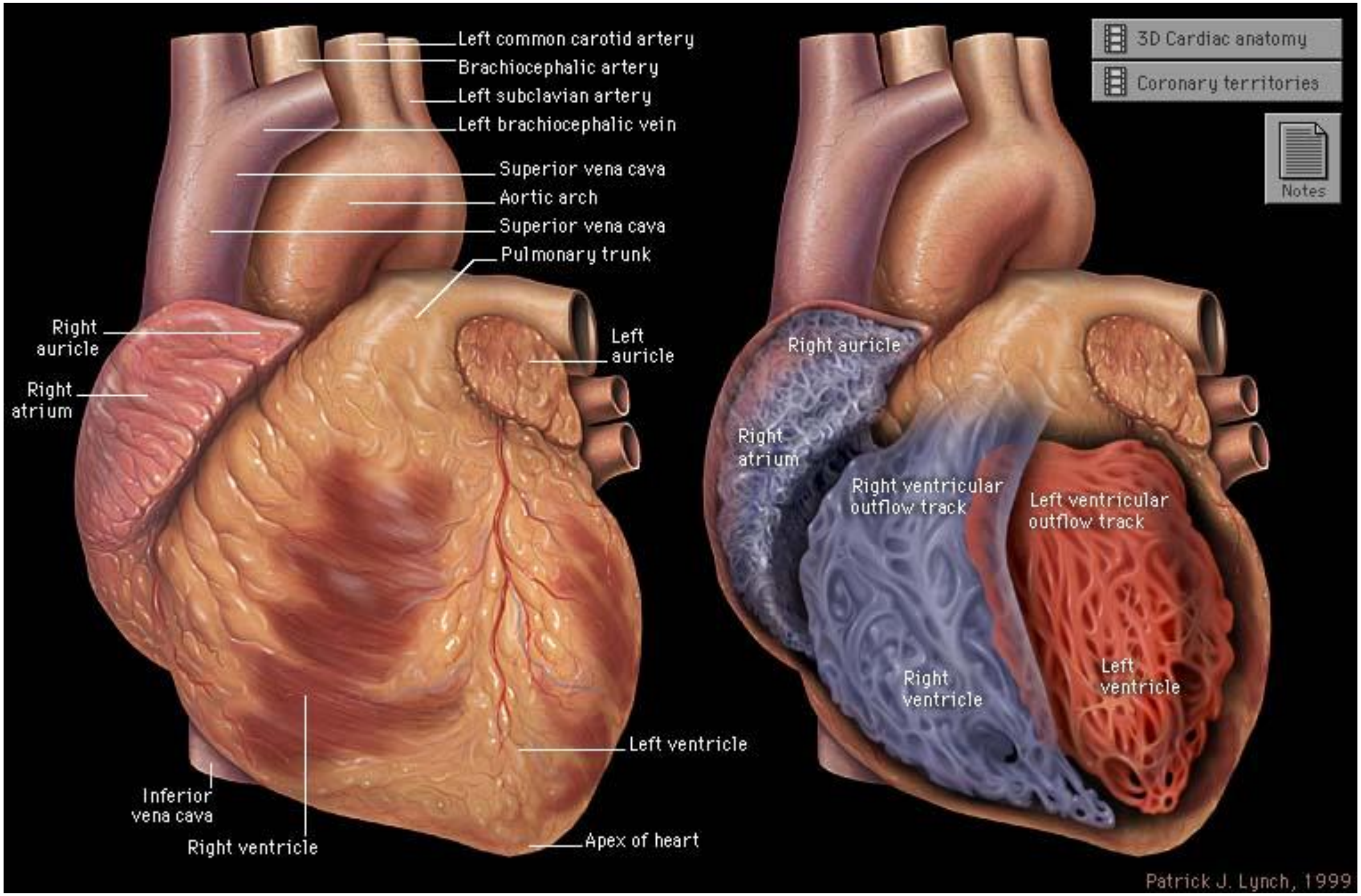
Coronary Anatomy



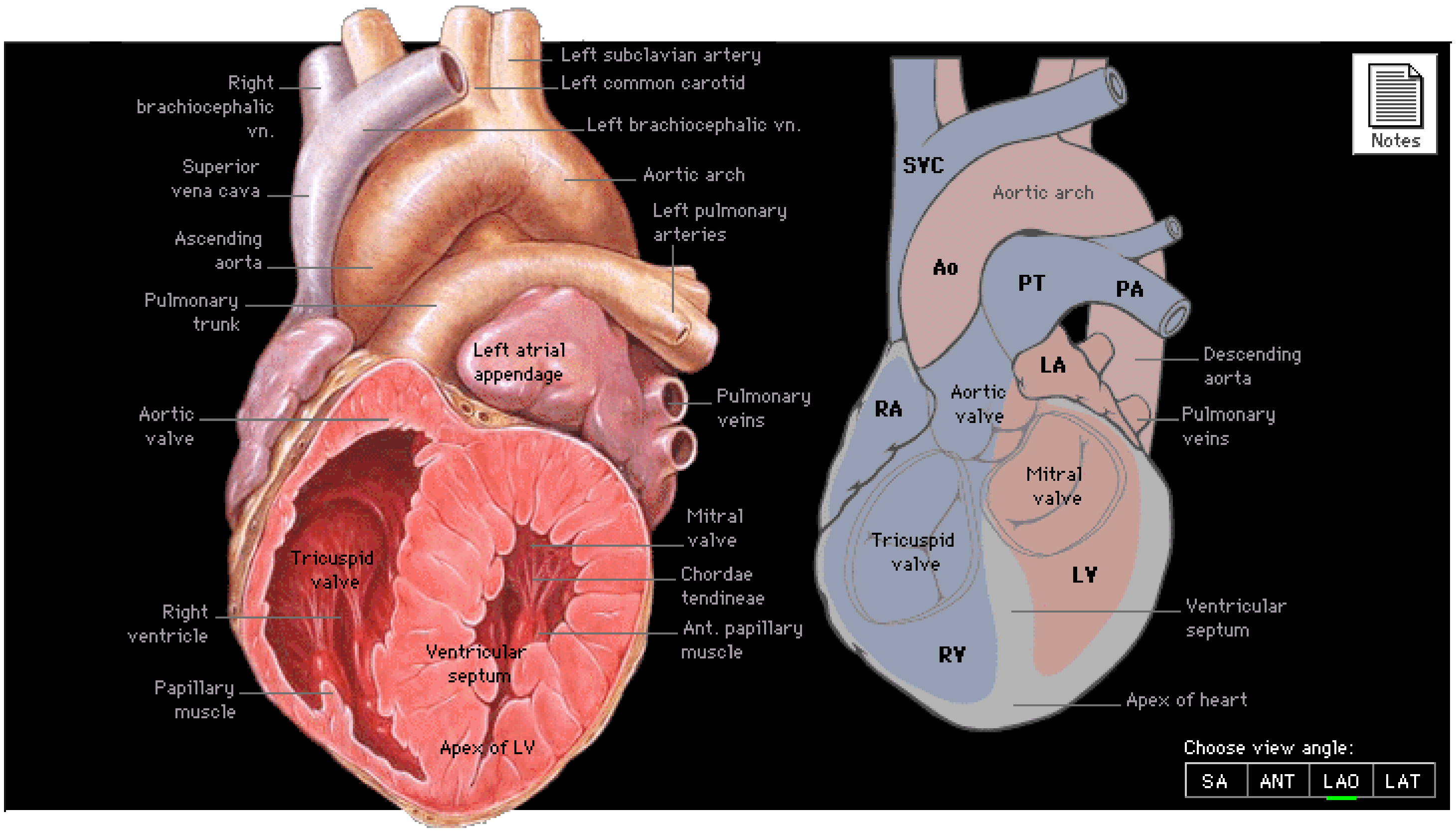
Coronary Anatomy



Ventricular Anatomy

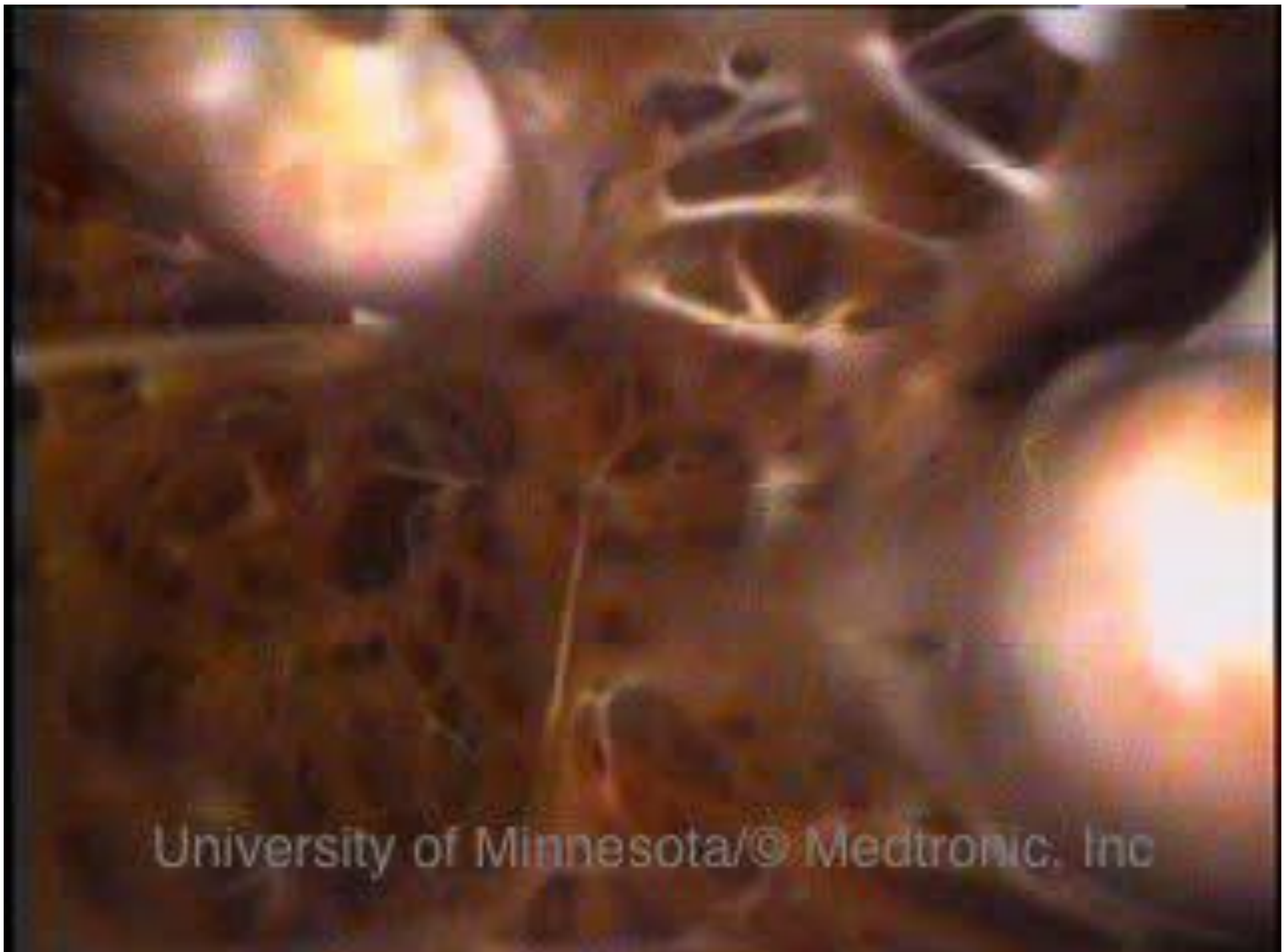

Left common carotid artery
Brachiocephalic artery
Left subclavian artery
Left brachiocephalic vein
Superior vena cava
Aortic arch
Superior vena cava
Pulmonary trunk
Right auricle
Right atrium
Left auricle
Left ventricle
Inferior vena cava
Right ventricle
Apex of heart
3D Cardiac anatomy
Coronary territories
Notes
Right auricle
Right atrium
Right ventricular outflow track
Left ventricular outflow track
Right ventricle
Left ventricle
Patrick J. Lynch, 1999

LAO


Left subclavian artery
Left common carotid
Right brachiocephalic vn.
Left brachiocephalic vn.
Superior vena cava
Aortic arch
Ascending aorta
Left pulmonary arteries
Pulmonary trunk
Left atrial appendage
Aortic valve
Pulmonary veins
Mitral valve
Tricuspid valve
Chordae tendineae
Right ventricle
Ant. papillary muscle
Ventricular septum
Papillary muscle
Apex of LV
Notes
SVC
Aortic arch
Ao
PT
PA
LA
Descending aorta
RA
Aortic valve
Pulmonary veins
Mitral valve
Tricuspid valve
LV
Ventricular septum
RV
Apex of heart
Choose view angle:
SA
ANT
LAO
LAT

Left Ventricle
Papillary Muscles

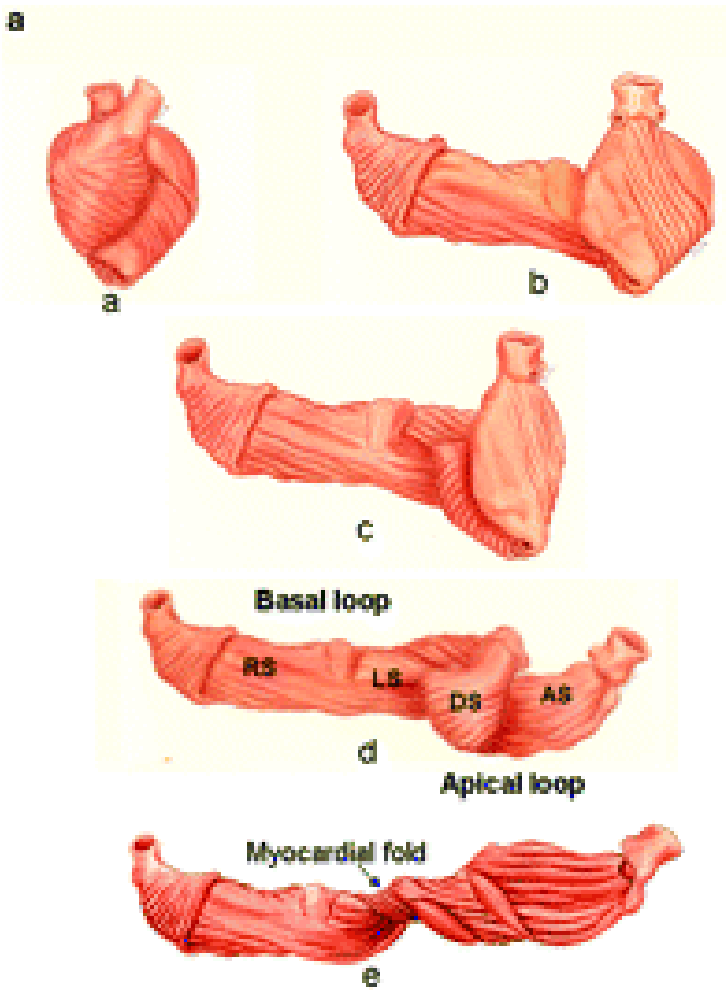
Left Ventricle
Trabeculated Endocardial Surface

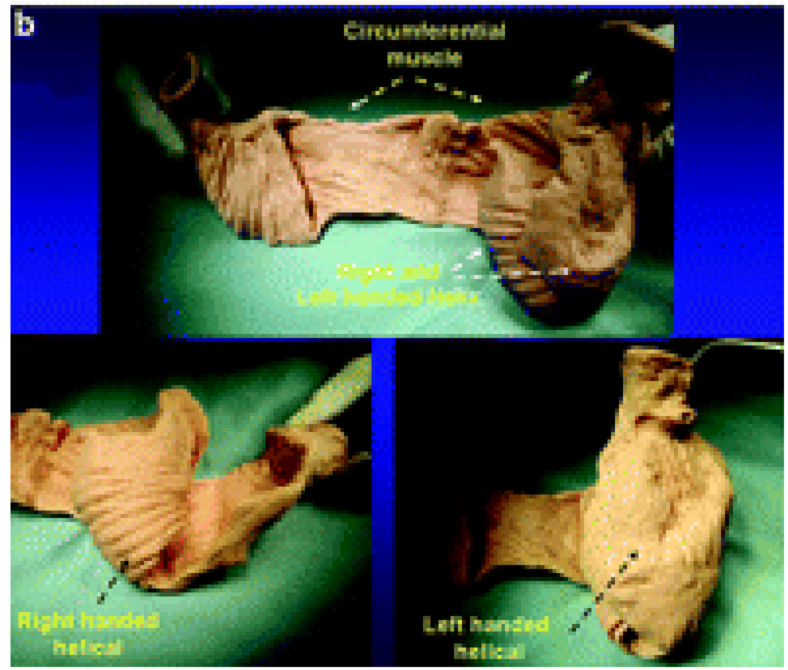


Right Ventricle

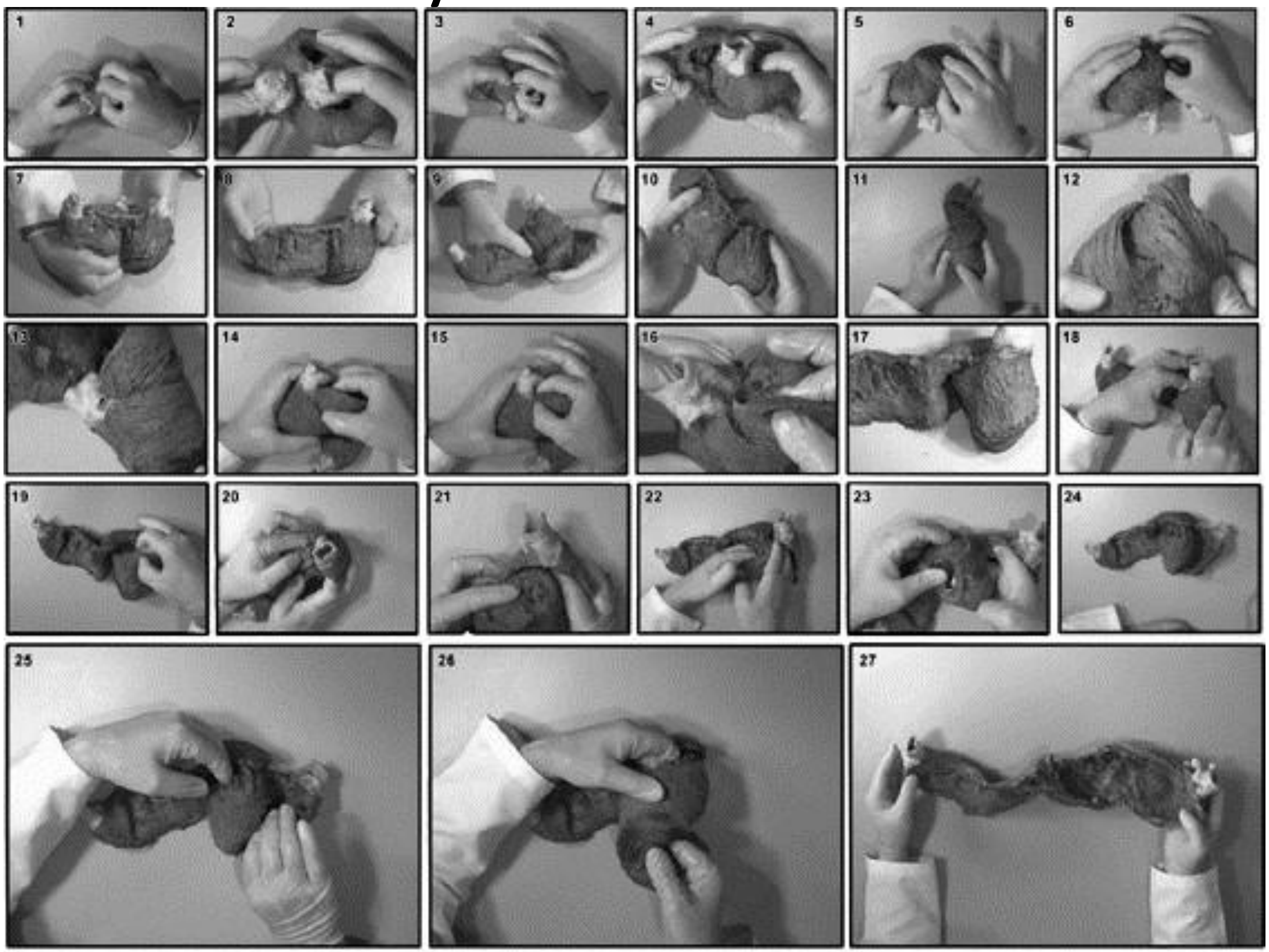
Right Ventricle
Endocardial Surface

The Helical Ventricular Myocardial Band (of Torrent-Guasp)



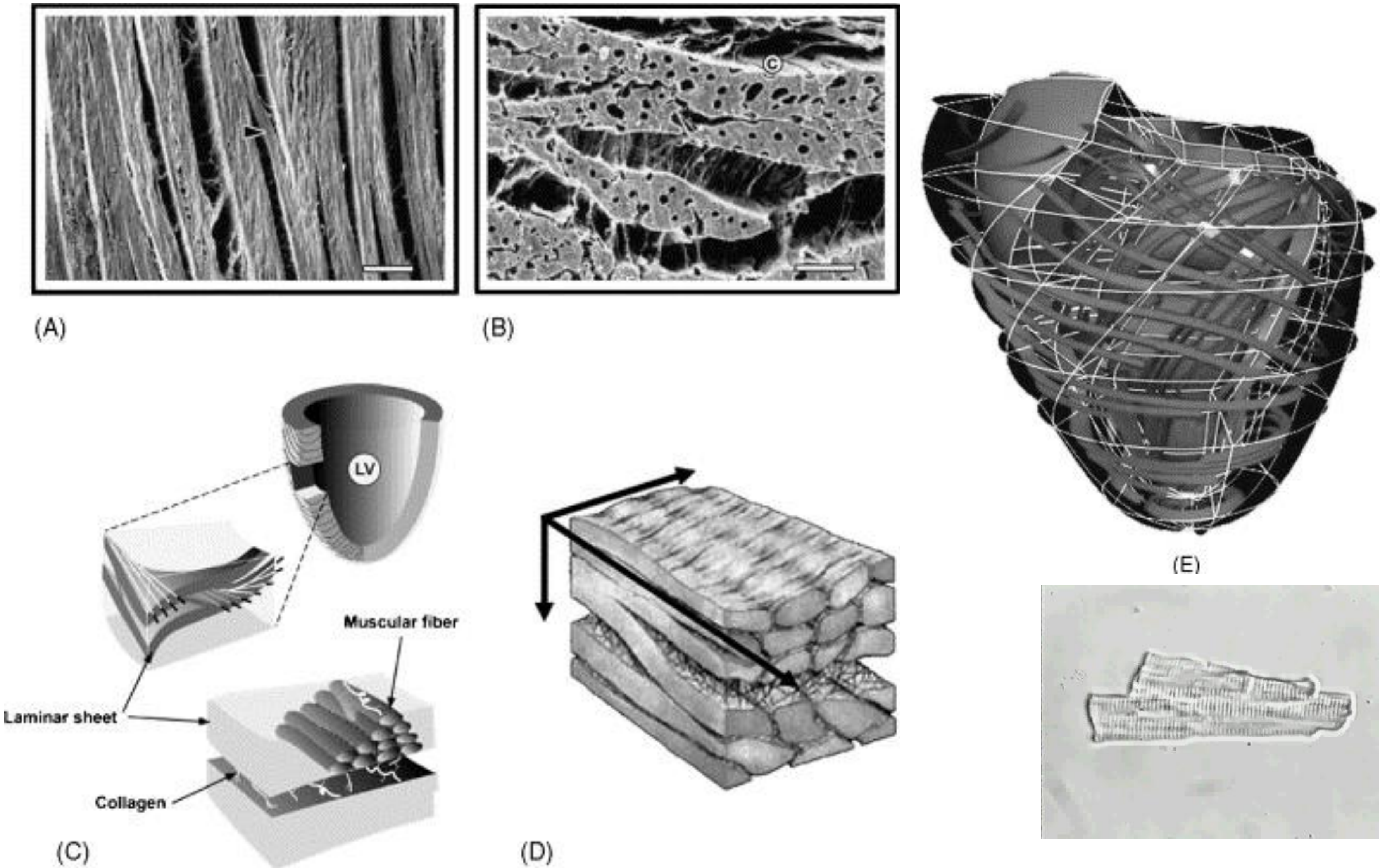


Unravelling the Helical Ventricular Myocardial band

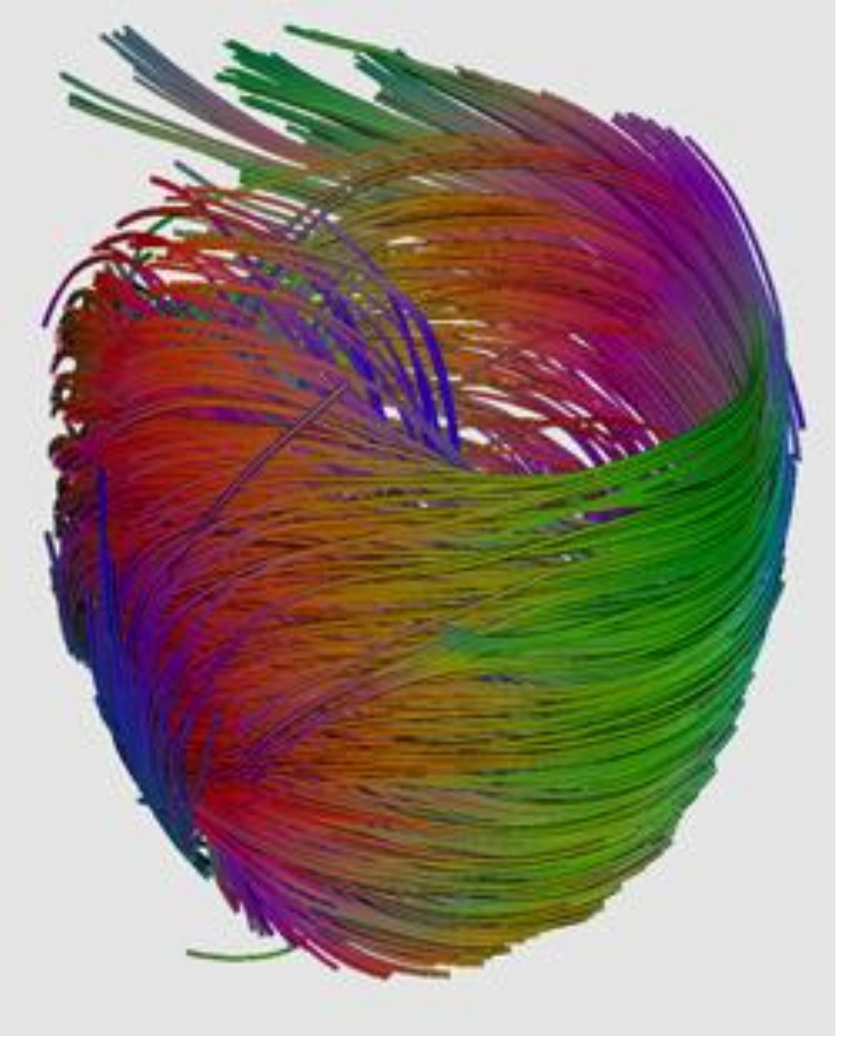


Francisco Torrent-Guasp, Denia 2004

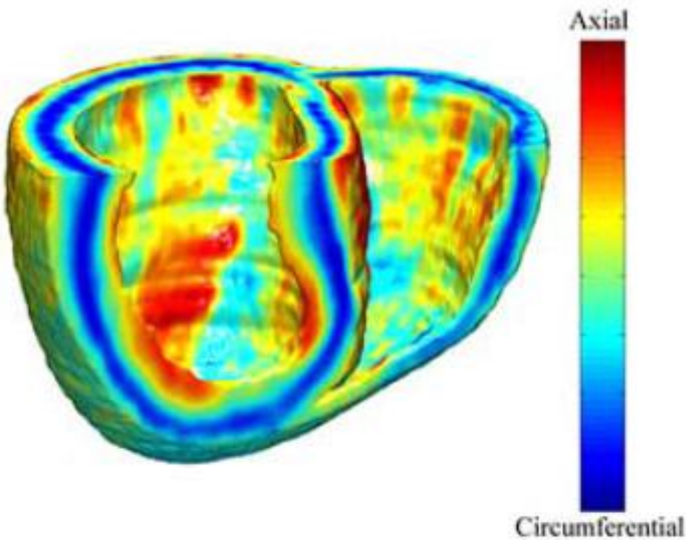
Complex Multicellular Structure

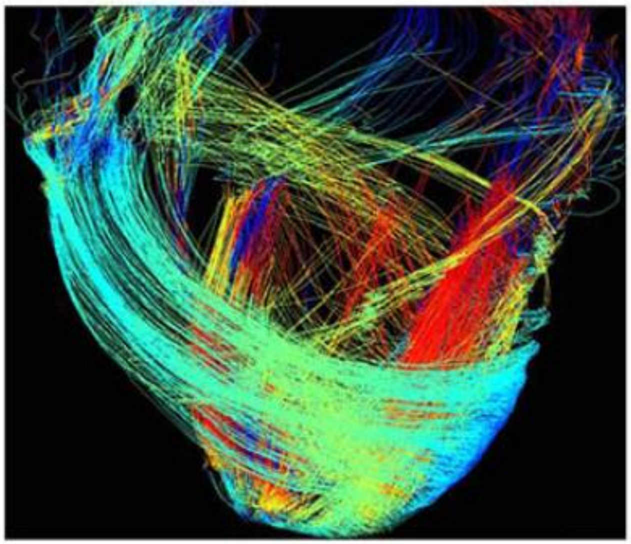


Cardiac Fibre Orientation DT-MRI



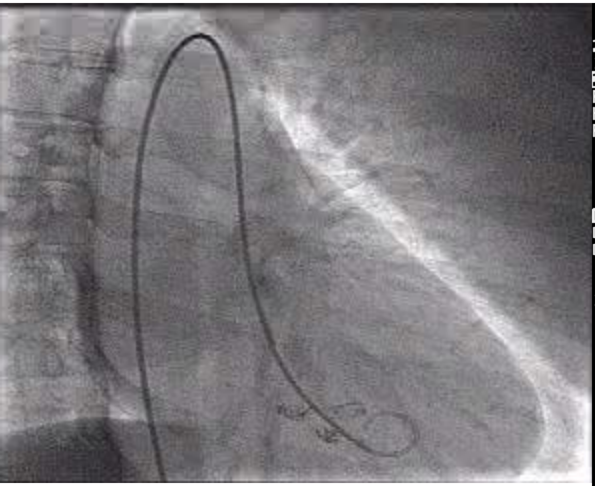
Cardiac Fibre Orientation
DT-MRI

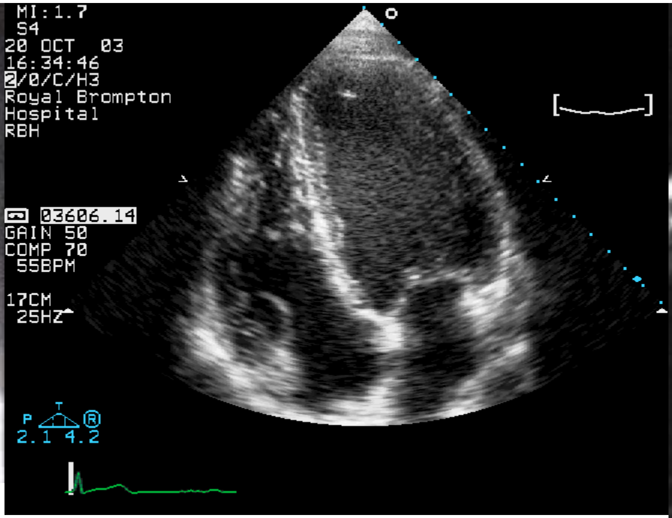


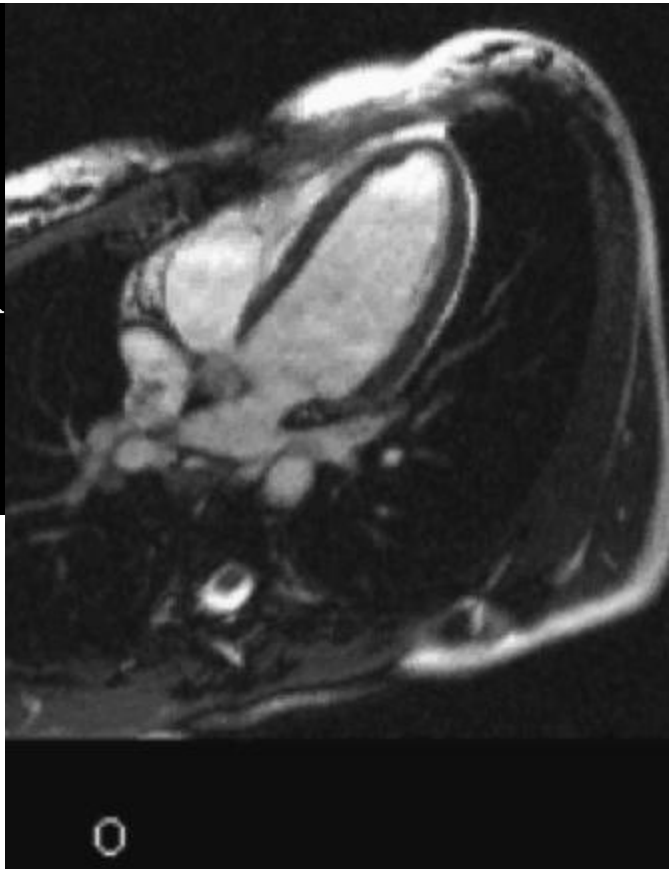


Helm et al Annals N.Y. Acad. Sci. 1047: 296–307 (2005).

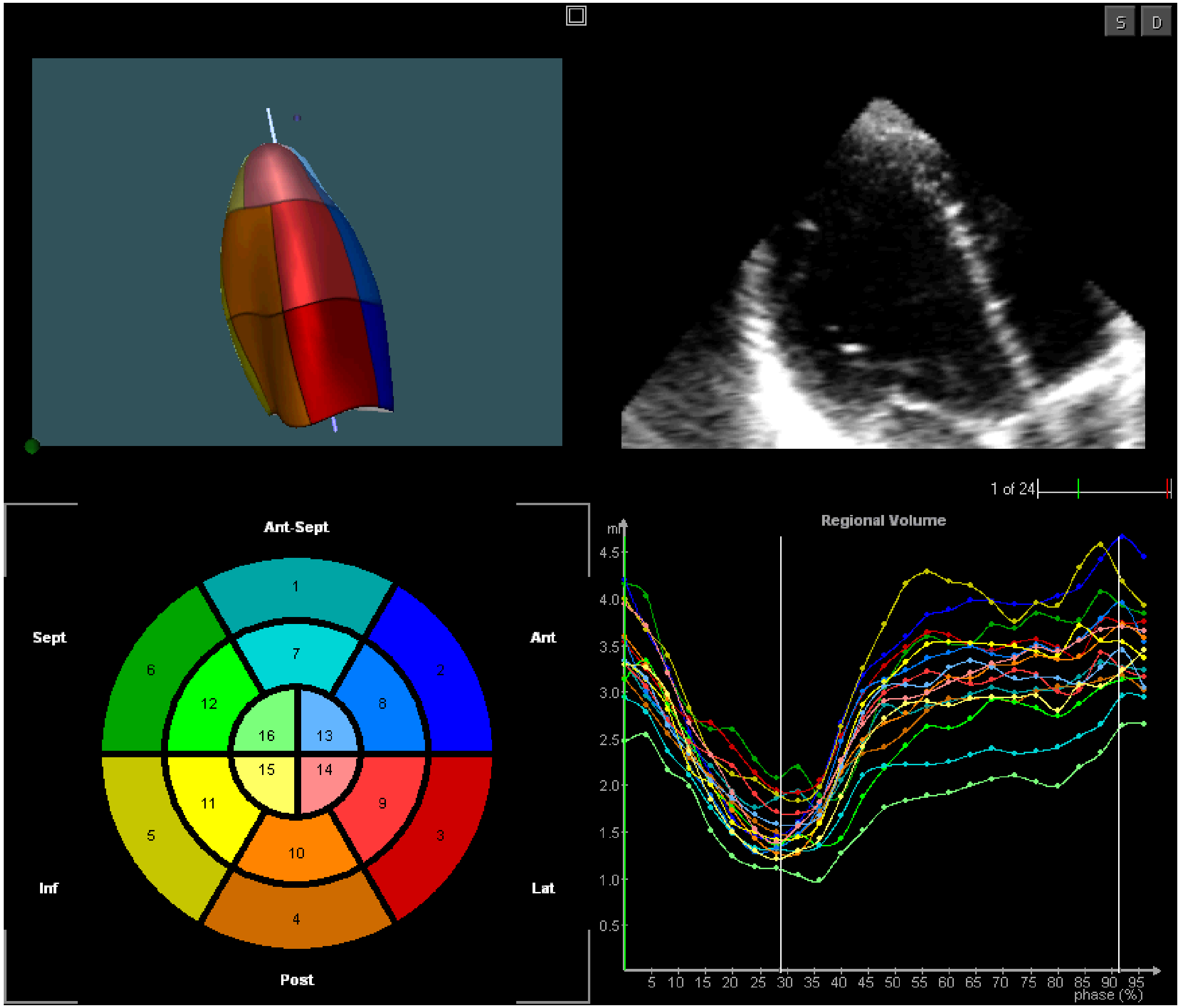
Left Ventricular Ejection





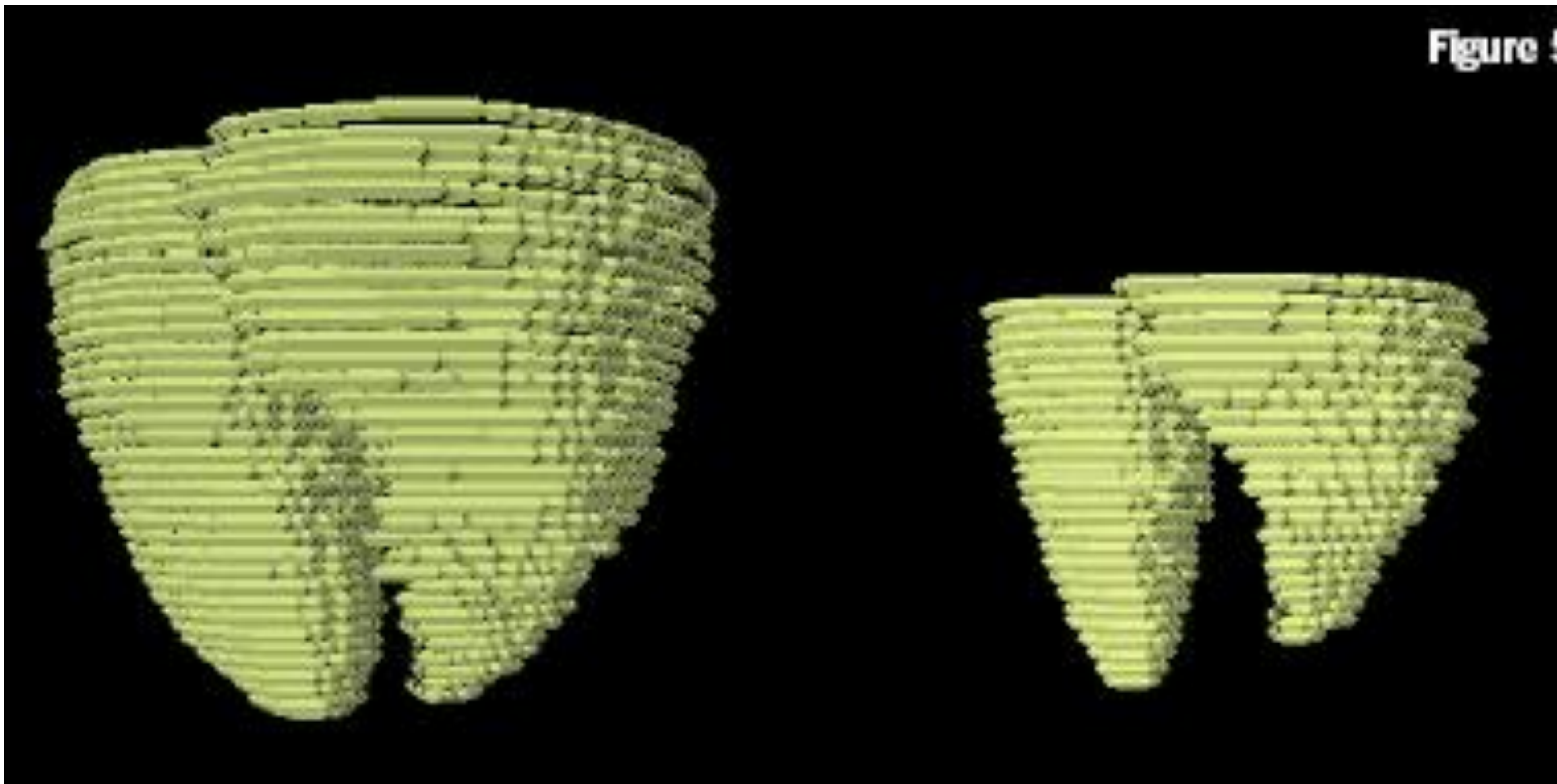


Left Ventricular Wall Motion



Ventricular Cavity / Blood Pool

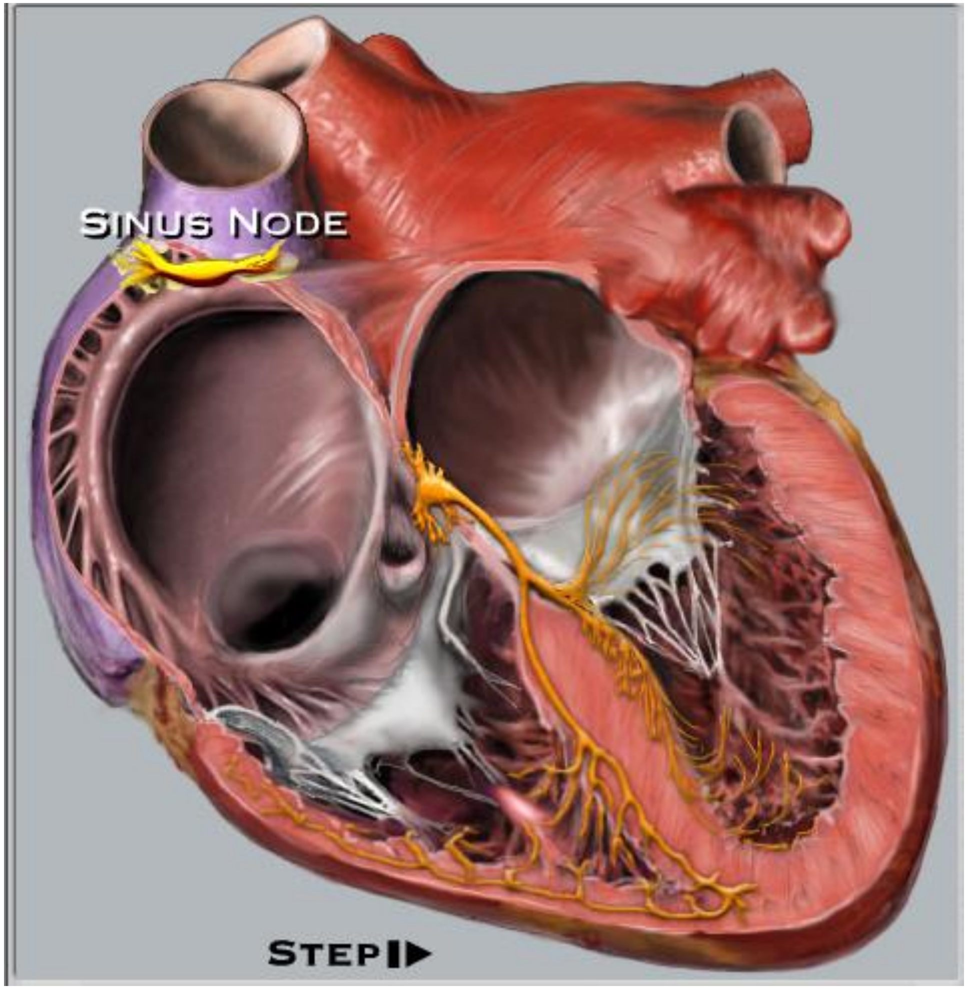
End Diastole   End Systole



Electrical Anatomy

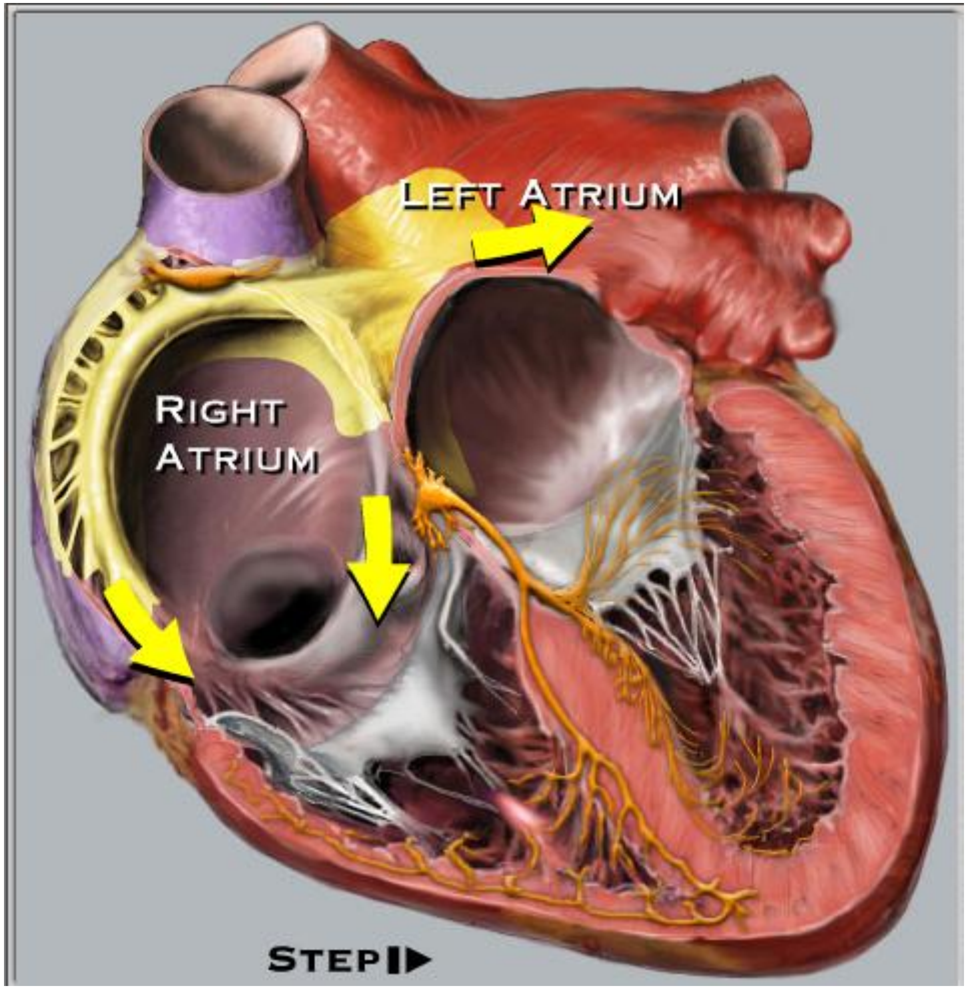
Cardiac Conduction System

Sinoatrial Node

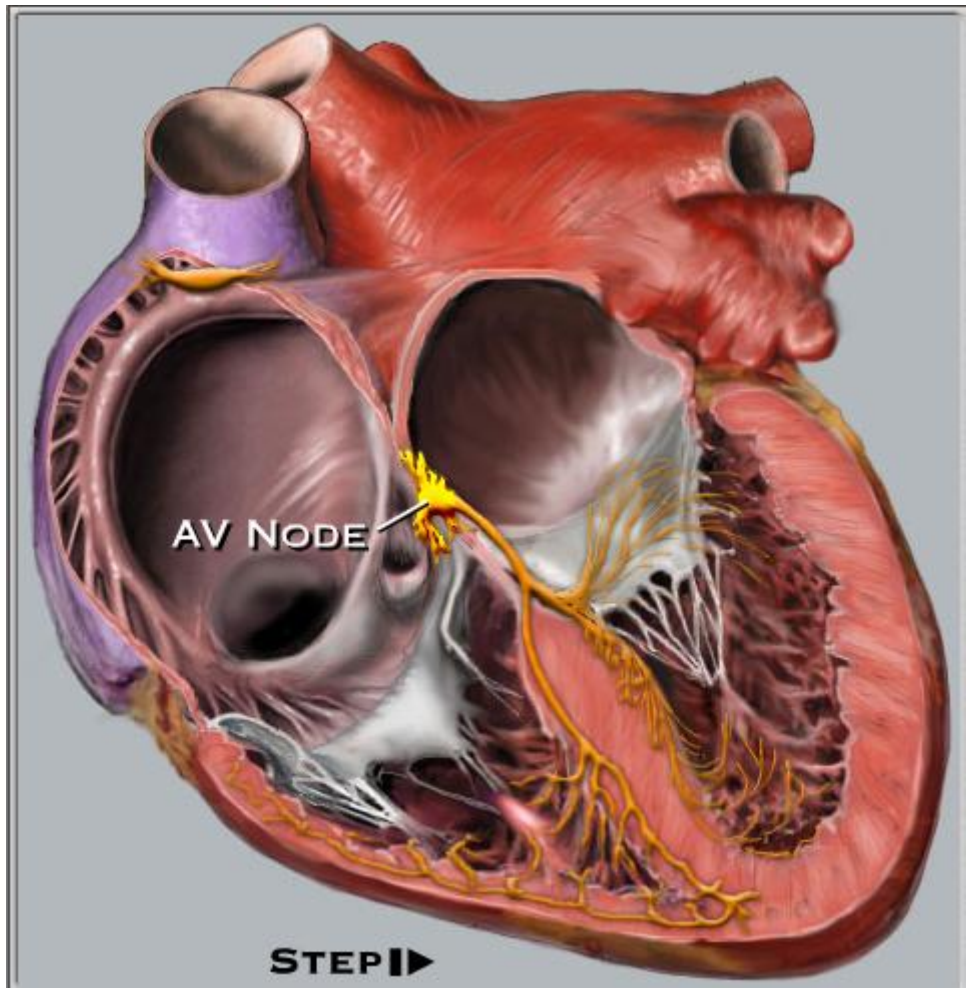


Cardiac Conduction System

Atrial Activation

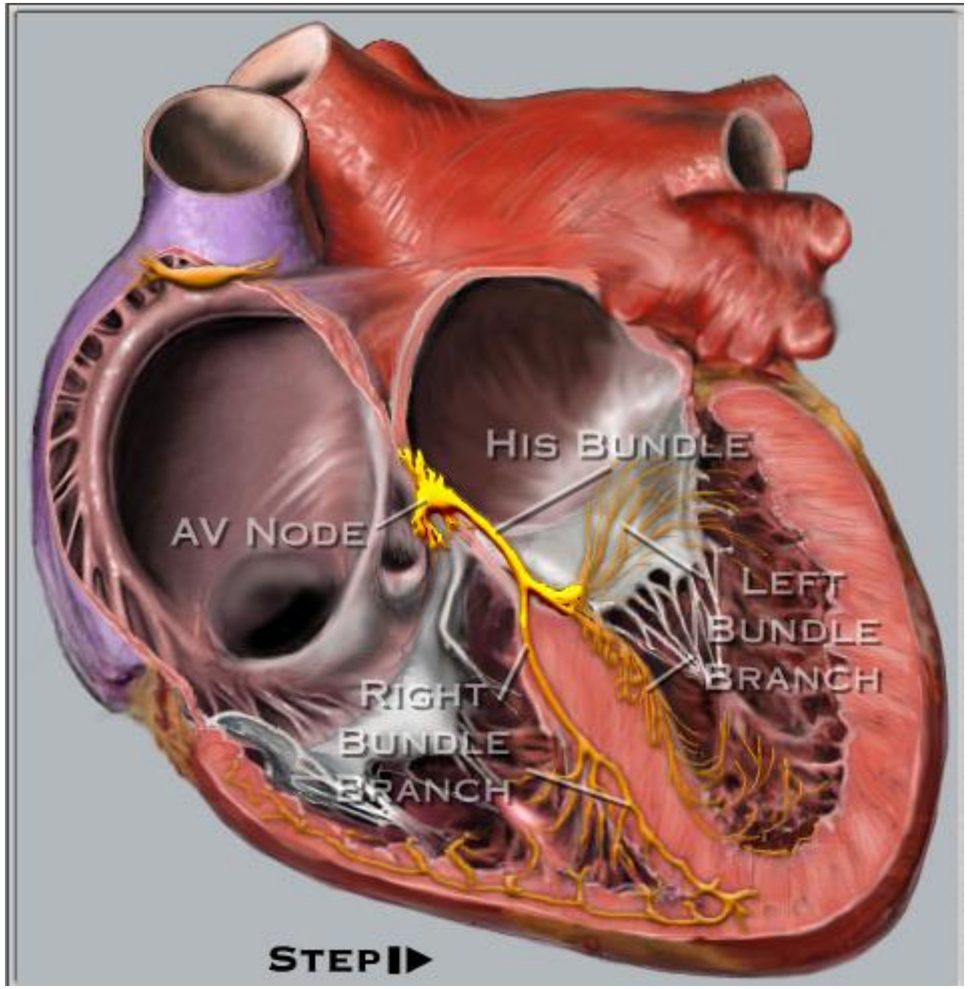


Cardiac Conduction System
Atrioventricular Nodal Conduction



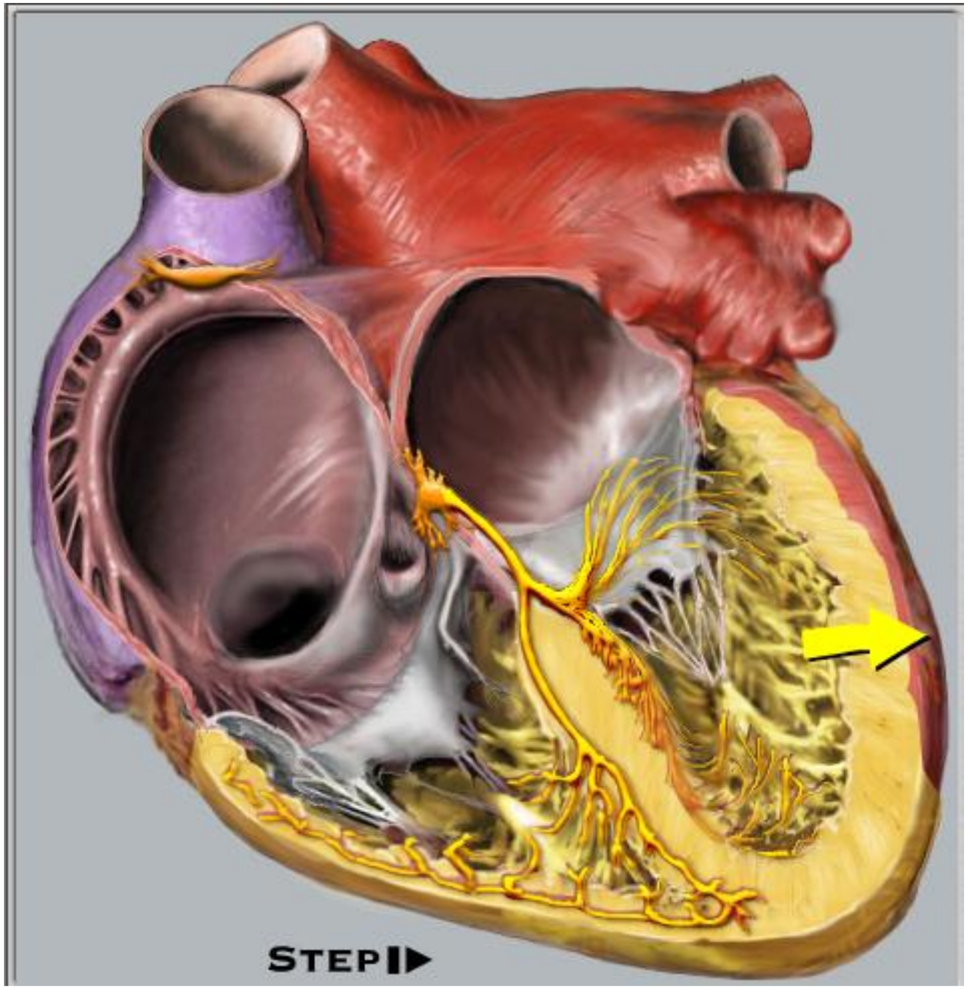
Cardiac Conduction System

Activation of His-Purkinje System

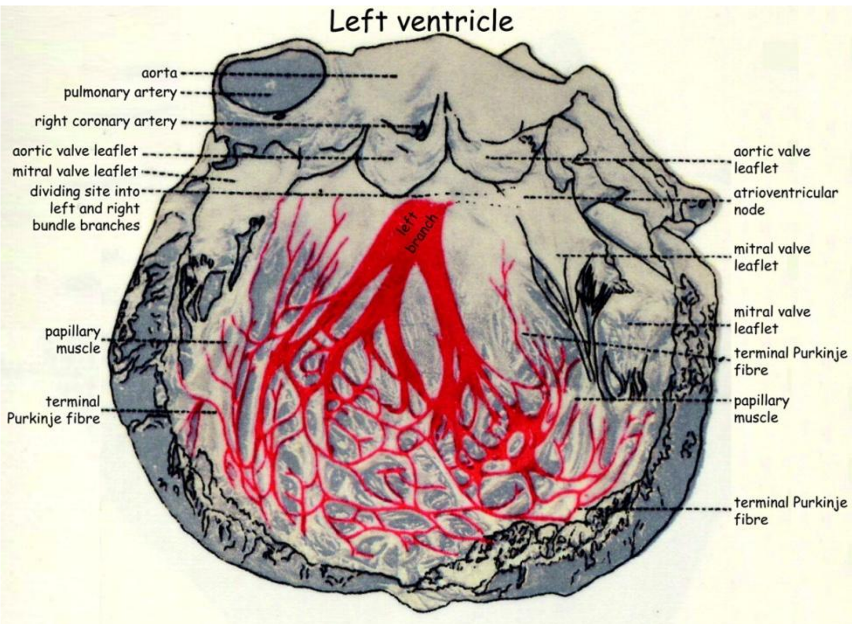


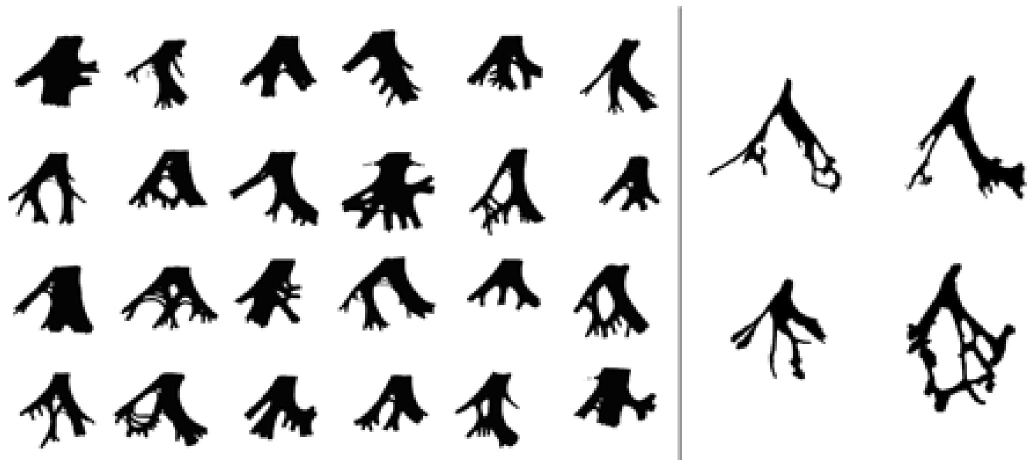
Cardiac Conduction System

Ventricular Activation

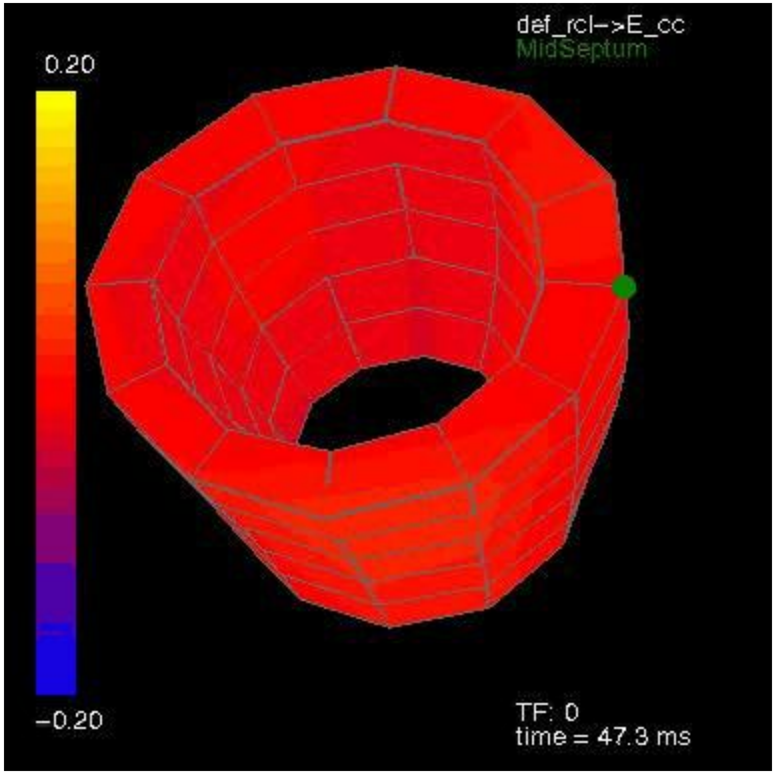


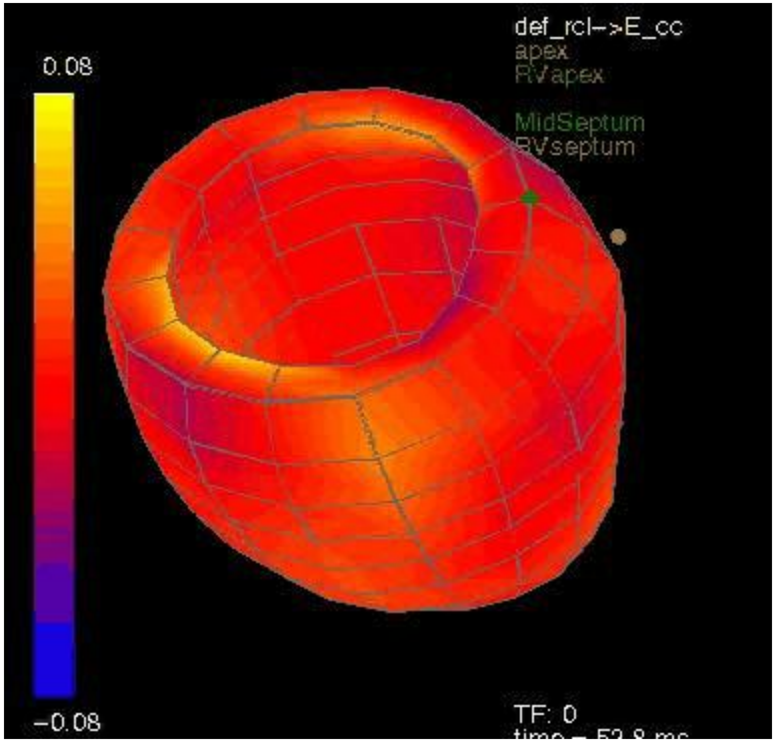
Left Bundle Branch



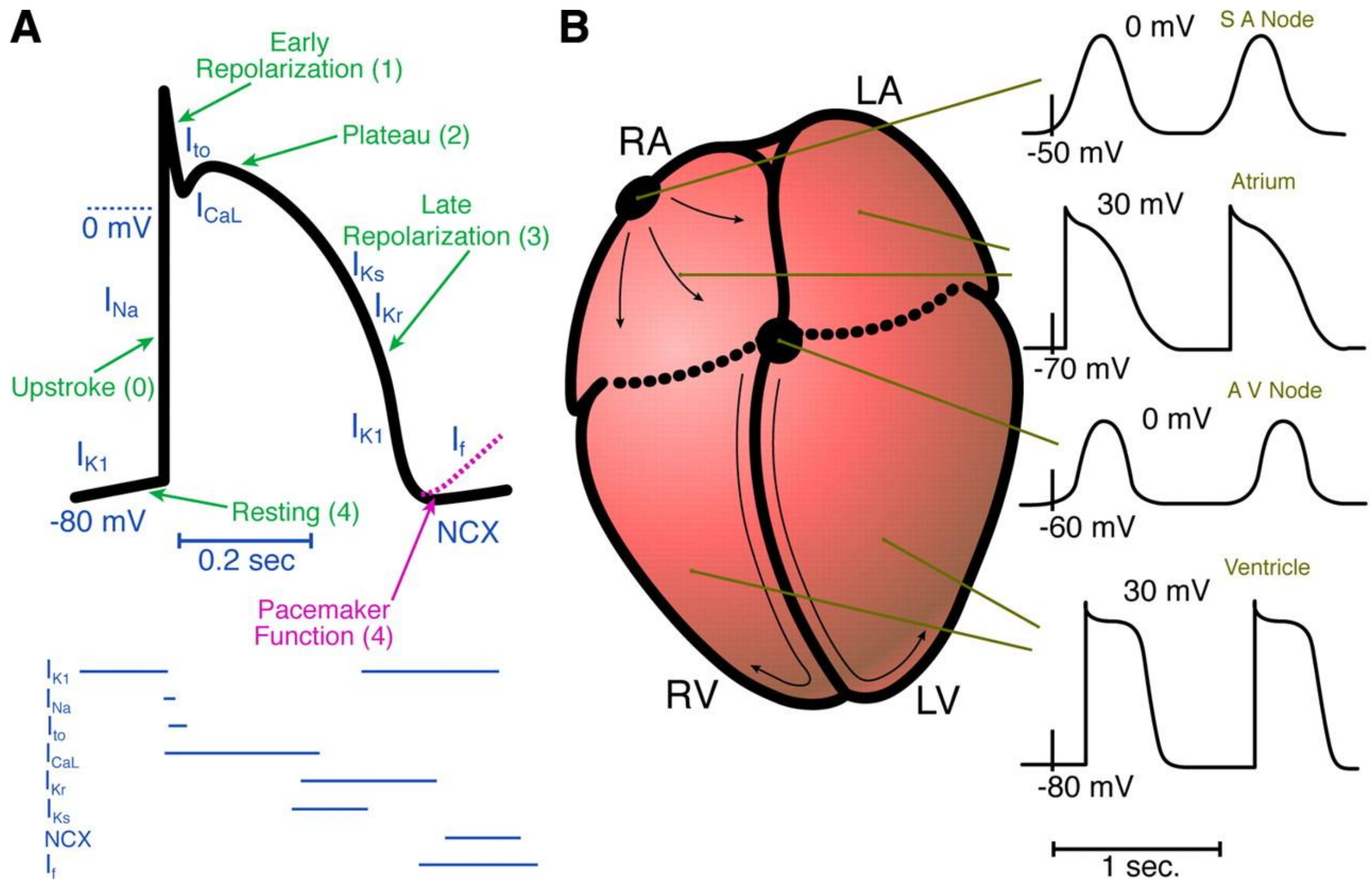


3D Left Ventricular Activation Normal (left) and Dyssynchrony (right)

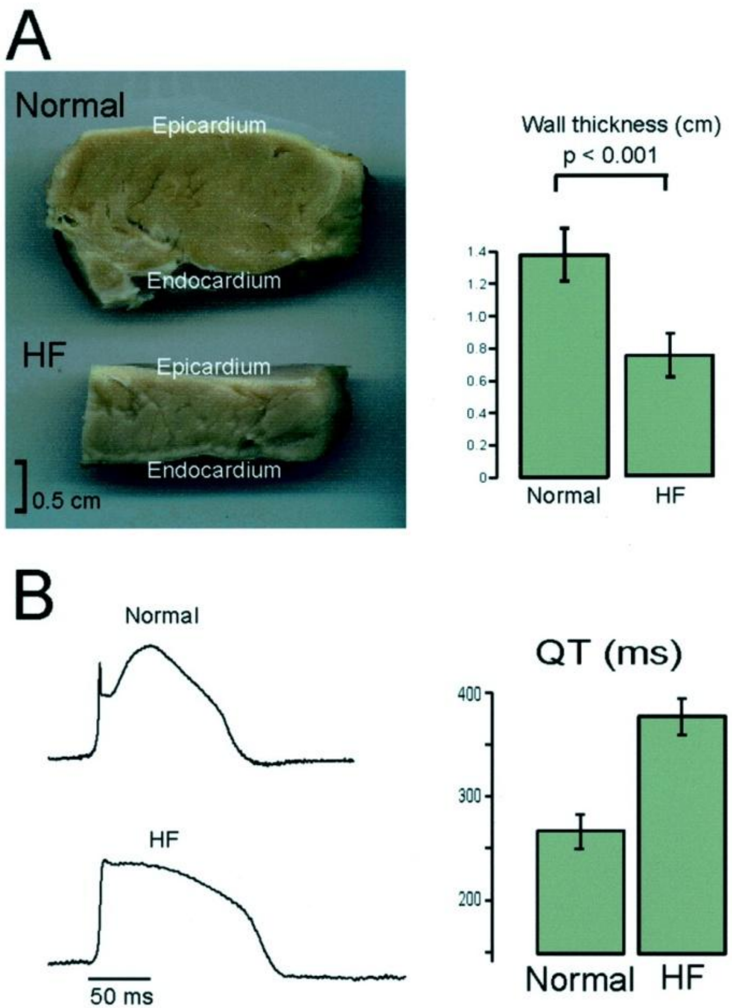


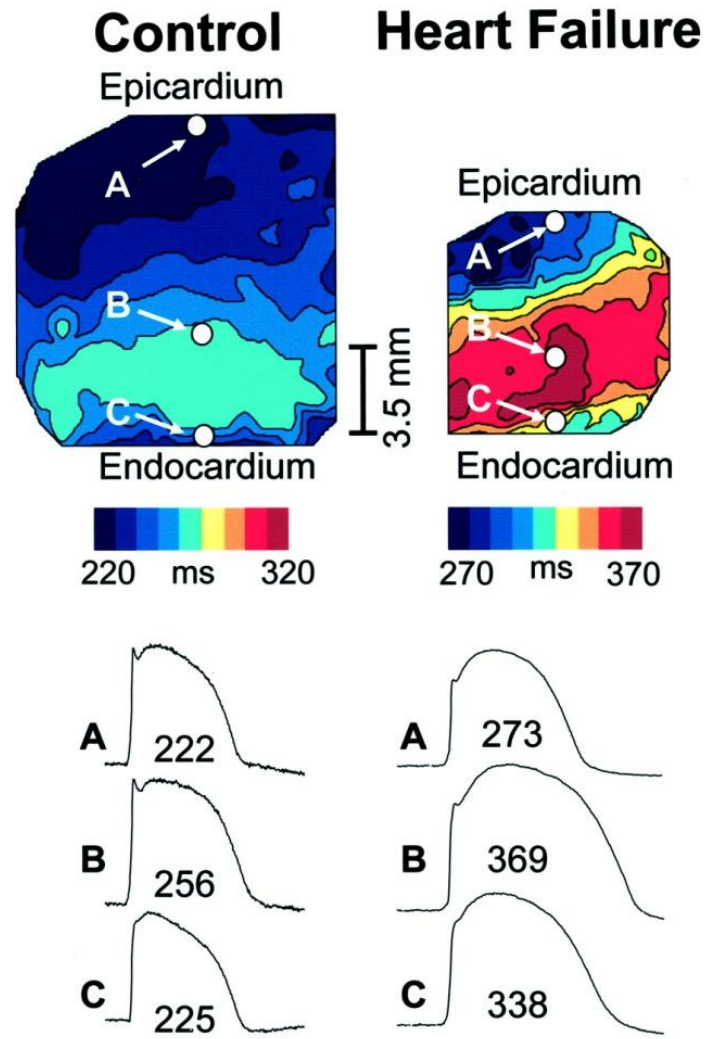


Functional Electrical Anatomy



Transmural Gradients
APD Dispersion





Akar, F. G. et al. Circ Res 2003;93:638-645

Apical-Basal Gradients
1. Sympathetic Innervation

Heart Vessels (2003) 18:32–39

Hiroaki Kawano · Ryozo Okada · Katsusuke Yano

Histological study on the distribution of autonomic nerves in the human heart

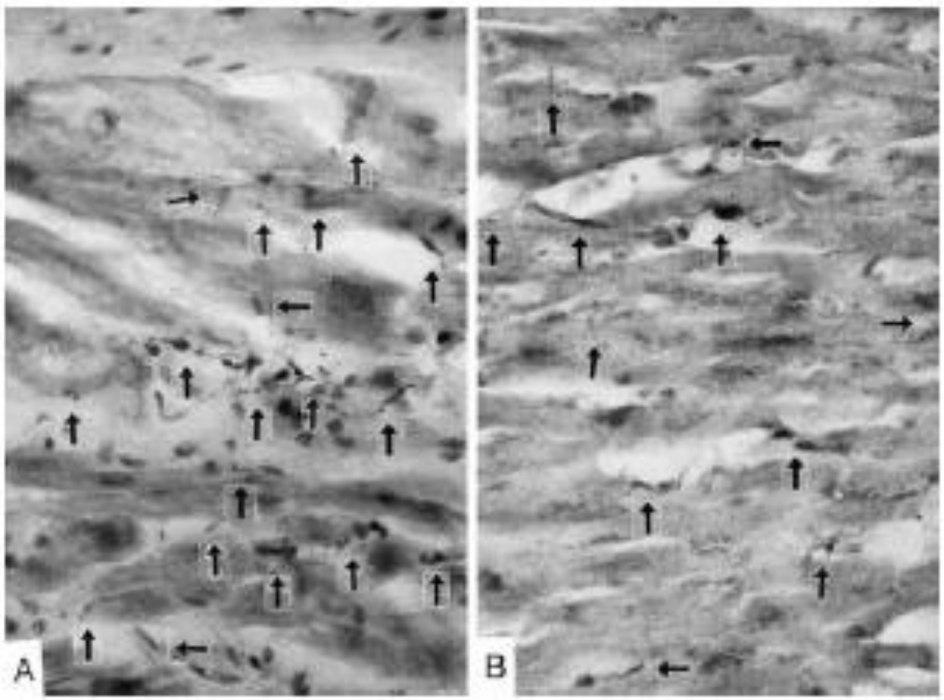


Fig. 7. TH-positive nerves at the base (**A**) and the apex (**B**) in the ventricle. TH-positive nerves (*arrows*) are distributed more at the base than at the apex

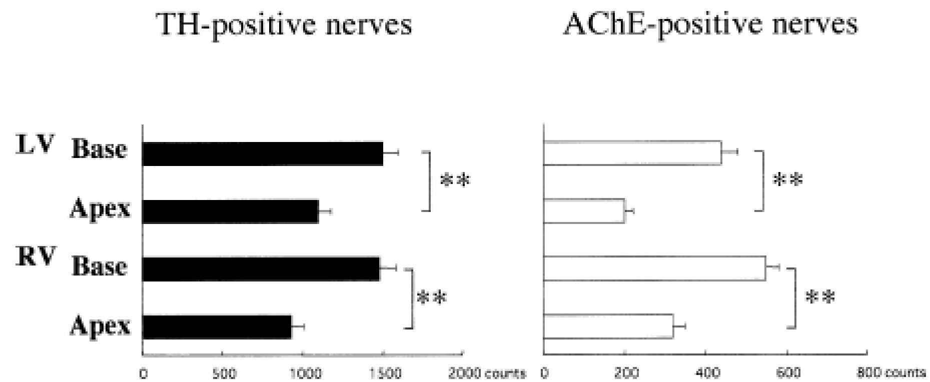


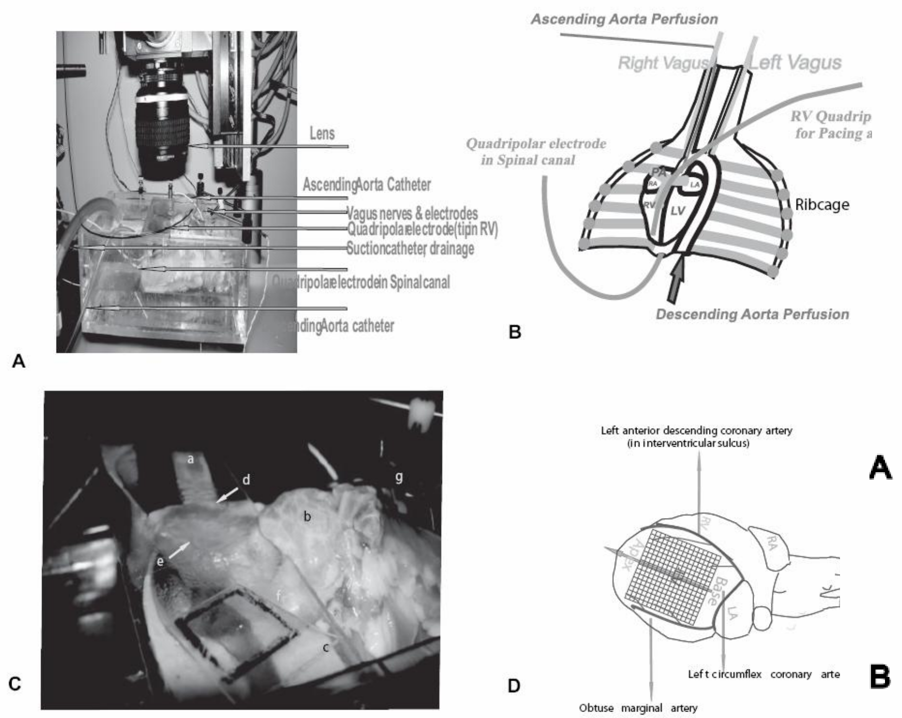
Fig. 11. Comparison of nerve distribution between the base and apex in the ventricle. Bar graph shows the total number of nerve-positive sections at the base and apex in the ventricle. *LV*, left ventricle; *RV*, right ventricle. $^{**}P < 0.01$

Apical-Basal Gradients
1. Sympathetic Innervation and APD
Ventricular Repolarisation

Autonomic Nerve Stimulation Reverses Ventricular Repolarization Sequence in Rabbit Hearts

Rajkumar Mantravadi, Bethann Gabris, Tong Liu, Bum-Rak Choi, William C. de Groat, G. André Ng, Guy Salama

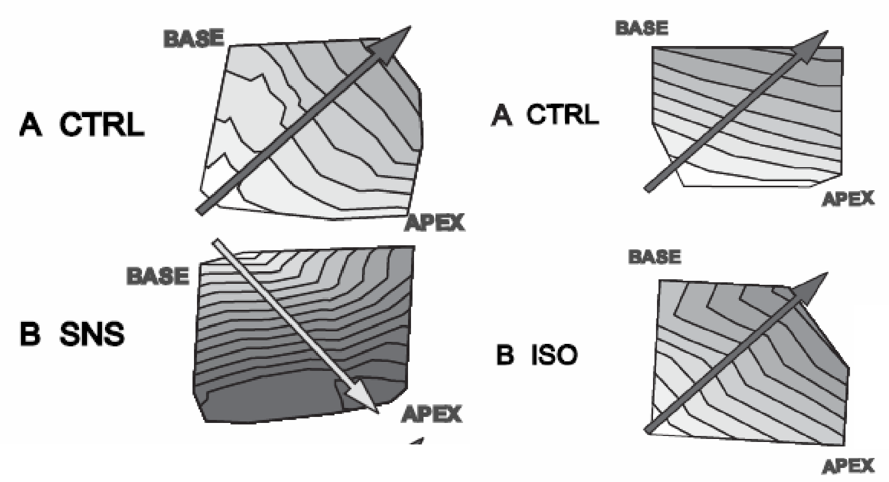
(*Circ Res*. 2007;100:e72–e80.)



DOR = Direction of repolarisation

Changes in Heart Rate, APDs, and DOR During SNS and VNS

	HR (beats/min)	APD Apex (ms)	APD Base (ms)	DOR (ms)
Control (n=14)	143±6.3	159±4.2	176±4.0	17±0.7
SNS (n=7)	229±13.2*	155±12.0	134±9.3*	−22±1.6*
ISO (n=5)	204±13.1*	115±4.4*	138±5.0*	23±1.6*



Apical-Basal Gradients
2. β Adrenoceptor Density

Dog

Increased responsiveness of left ventricular apical myocardium to adrenergic stimuli

Hidezo Mori, Shiro Ishikawa, Shoji Kojima, Junichi Hayashi, Yukihiko Watanabe, Julien I E Hoffman, and Haruka Okino

Cardiovascular Research 1993;27:192-198

Table IV Distribution of β adrenergic receptor density (n=5). Values are means (SEM).

	Basal segment	*Mid segment*	*Apical segment*
B_{max} (fmol·mg^{-1} protein)	341(35)*	377(32)*	455(45)
K_d (nM)	2.0(0.6)	2.3(0.4)	2.3(0.6)

B_{max}=density of receptors; K_d=dissociation constant.
*$p<0.05$ v apical segment, two way ANOVA

Cat

European Journal of Pharmacology, 130 (1986) 111–117
Elsevier

Regional distribution of myocardial β-adrenoceptors in the cat

Claire M. Lathers [1]*, Robert M. Levin [2] and William H. Spivey [3]
[1] *Department of Pharmacology and* [3] *Emergency Medicine, The Medical College of Pennsylvania, Philadelphia, PA, and* [2] *Department of Urology* [2], *School of Medicine, University of Pennsylvania, Philadelphia, PA, U.S.A.*

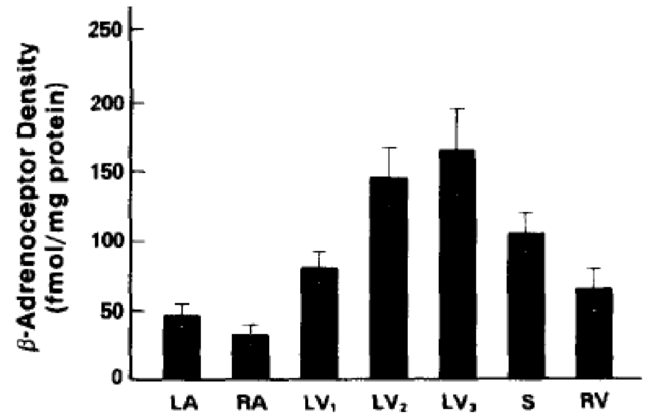


Fig. 2. Distribution of cardiac β-adrenoceptors. The density of β receptors (fmol/mg protein) is shown for the following areas of the heart: LA = left atria; RA = right atria; LV1 = proximal area of distribution of the left anterior descending artery (LAD); LV2 = distal area of distribution of the LAD; LV3 = posterior aspect of the left ventricle; S = septum and RV = right ventricle.

Apical-Basal Gradients
3. β Adrenoceptor Density

European Journal of Pharmacology 485 (2004) 227–234

Blockade of β_1- and desensitization of β_2-adrenoceptors reduce isoprenaline-induced cardiac fibrosis

Fazia Brouri[a], Naima Hanoun[b], Odile Mediani[a], Françoise Saurini[b], Michel Hamon[b], Paul M. Vanhoutte[c], Philippe Lechat[a,*]

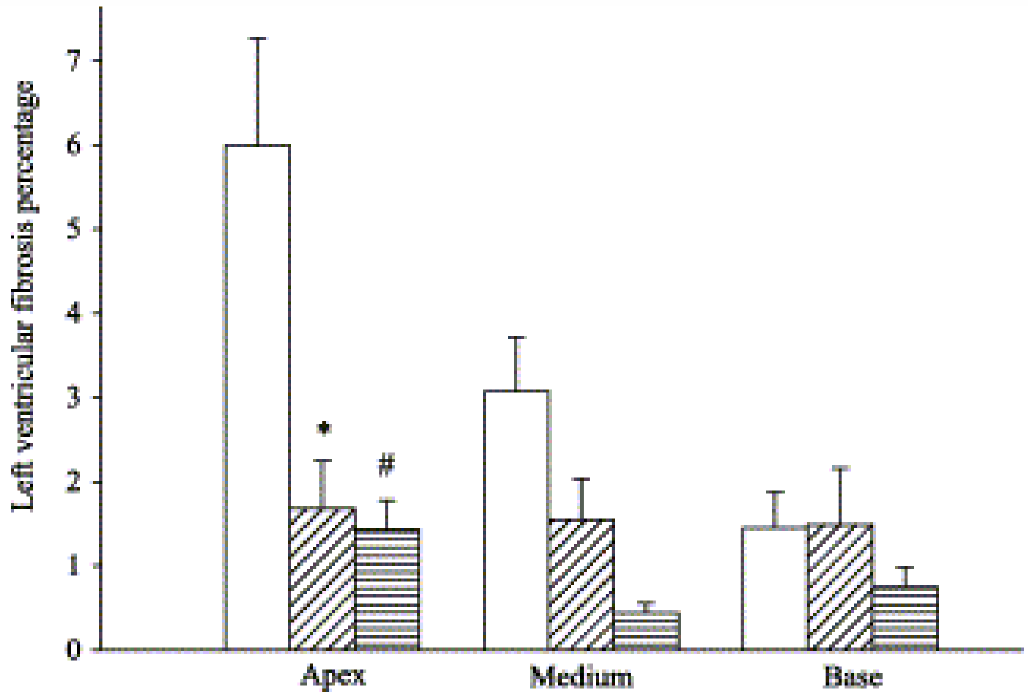


Fig. 4. Morphometric analysis performed at three levels of the heart in rats treated chronically with isoprenaline alone (30 μg/kg/h, *n*=9, □), in combination with bisoprolol (50 mg/kg/day, *n*=9,), or after a 1-week pretreatment with salbutamol (40 μg/kg/h, *n*=9,). (A) Left ventricular fibrosis expressed as percent of left ventricular area.