Pathophysiology of heart diseases – basic facts.

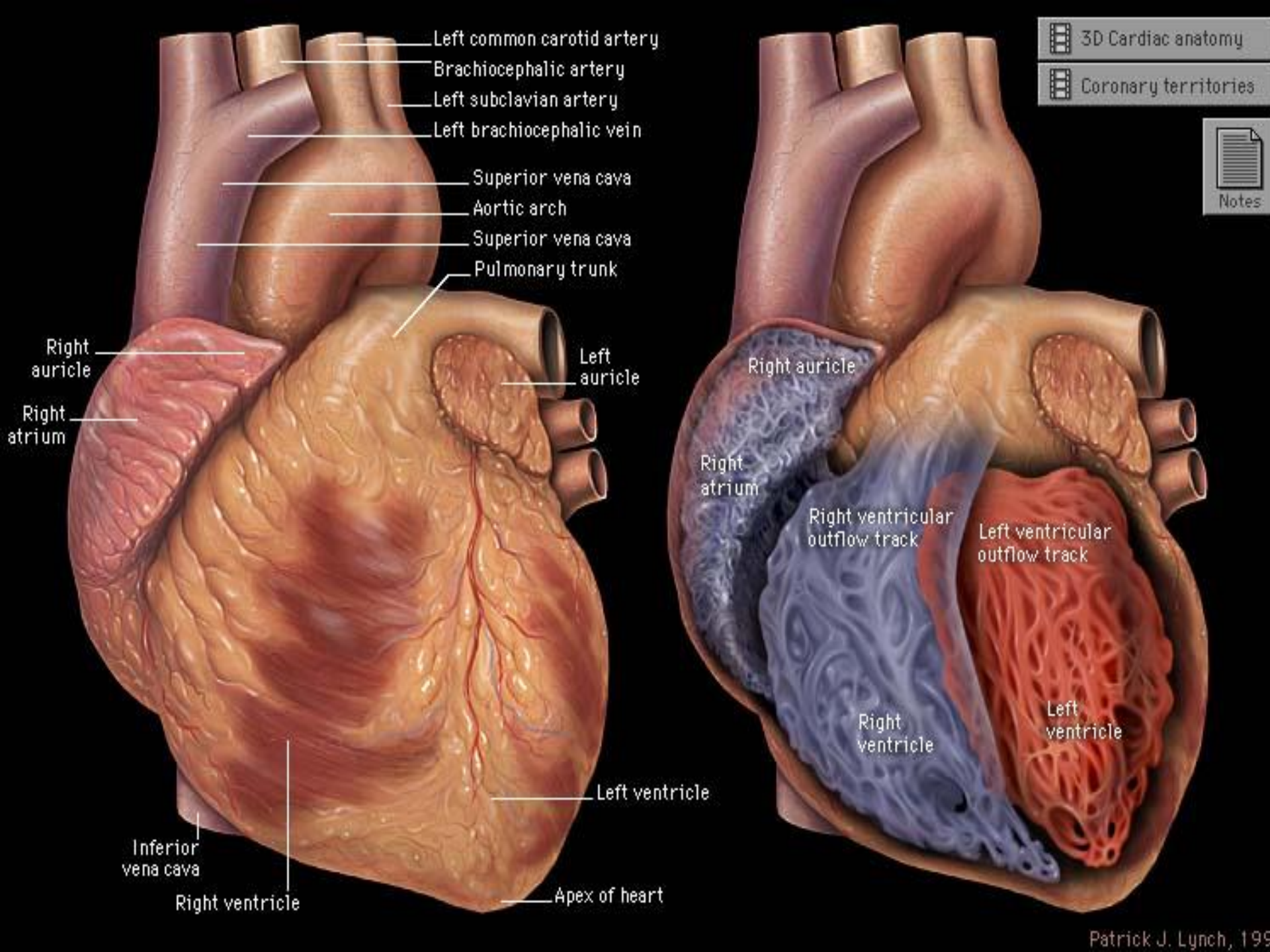
Second Chair and Clinic of Cardiology

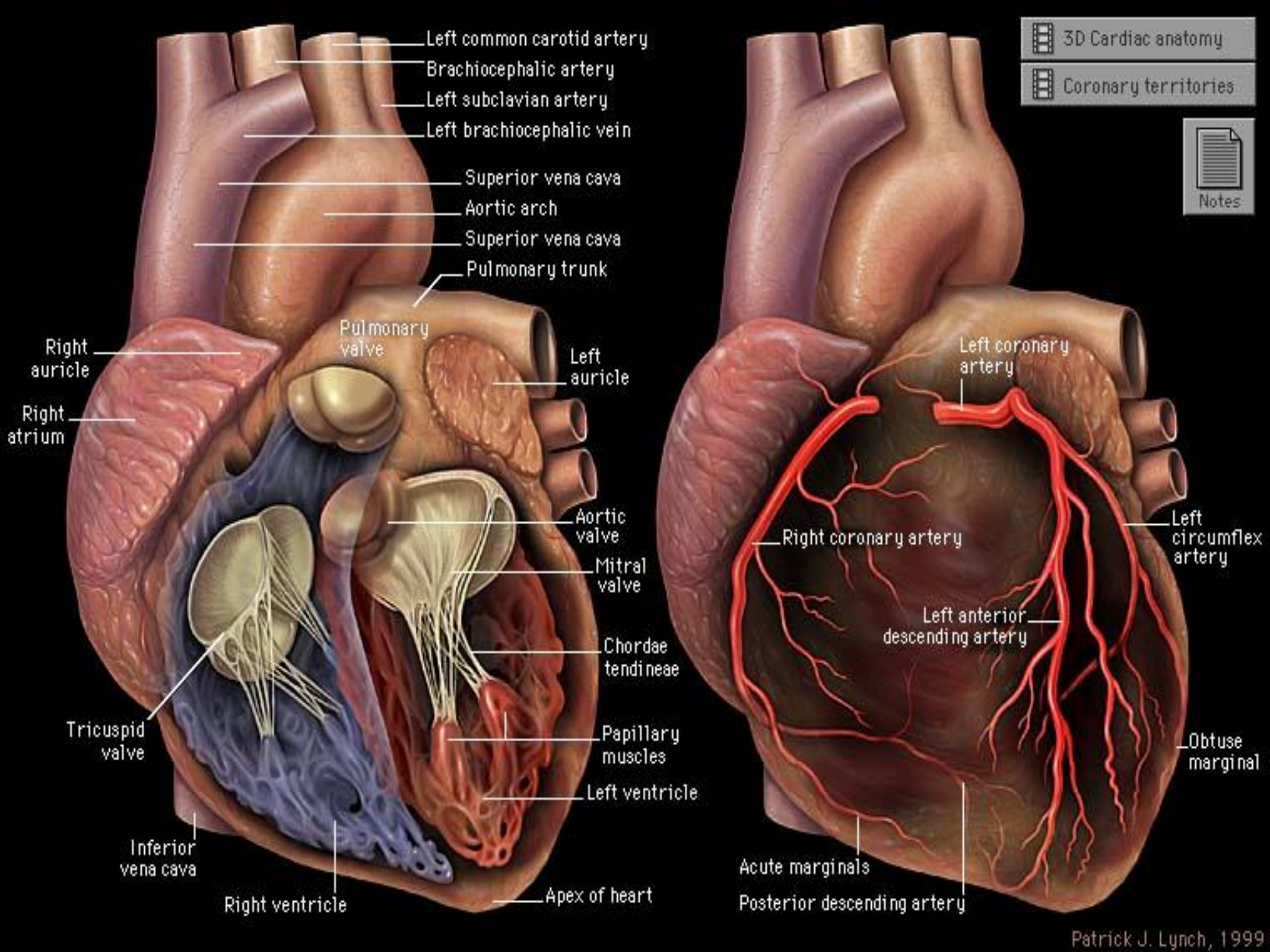
Heart anatomy

- Right atrium – receives blood from the systemic circulation
- Tricuspid valve – between the right atrium and the right ventricle
- Right ventricle – pumps blood into pulmonary circulation
- Pulmonary valve – semilunar
- Pulmonary trunk (main pulmonary artery)– begins at the base of the right ventricle and branches into two pulmonary arteries (left and right)

Heart anatomy

- Left atrium – receives blood from the pulmonary circulation
- Bicuspid valve (mitral) – between the left atrium and the left ventricle
- Left ventricle – pumps blood into systemic circulation
- Aortic valve– semilunar
- Aorta – originating at the base of left ventricle


Left common carotid artery
Brachiocephalic artery
Left subclavian artery
Left brachiocephalic vein
Superior vena cava
Aortic arch
Superior vena cava
Pulmonary trunk
Right auricle
Left auricle
Right atrium
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, 199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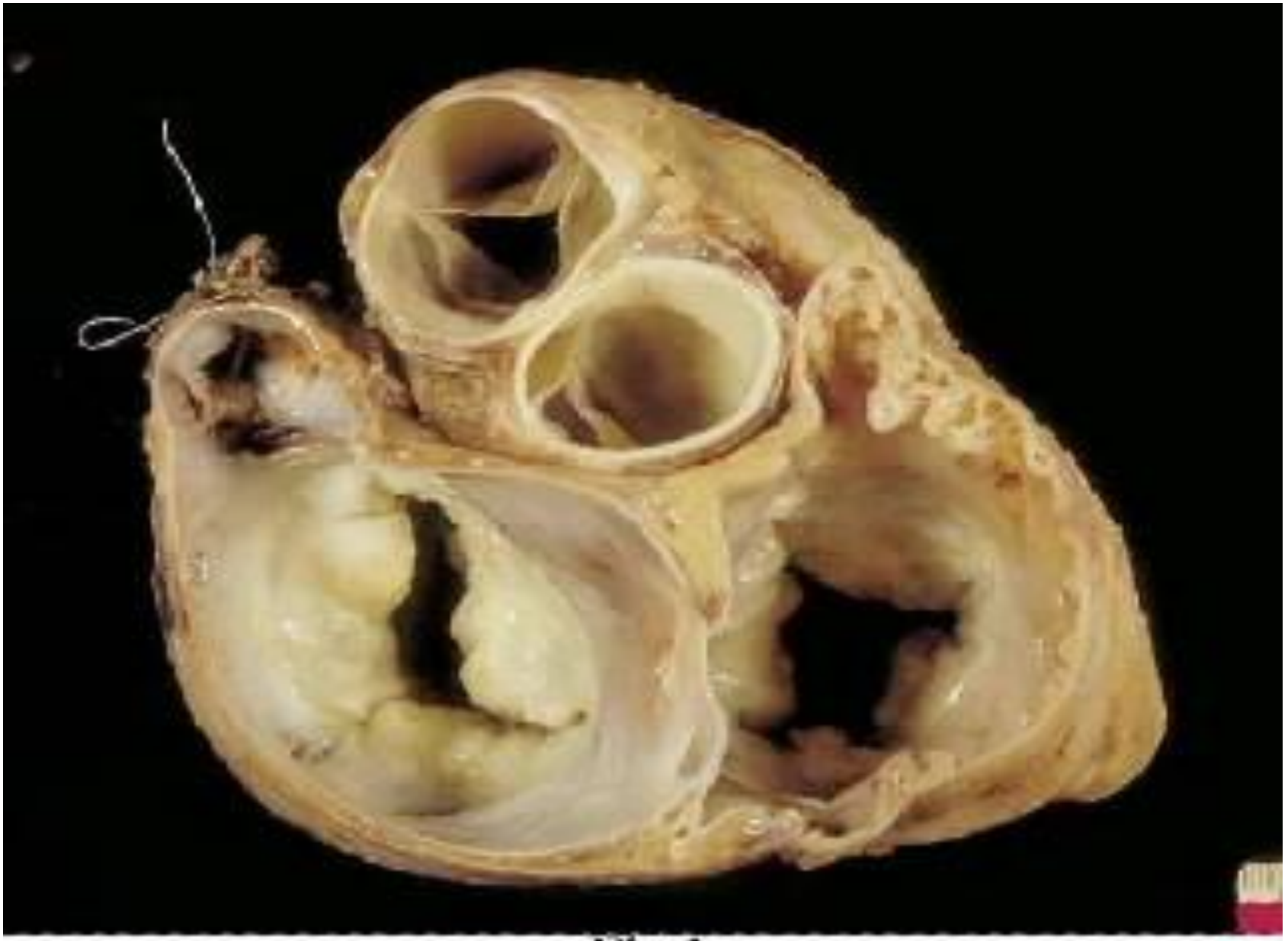
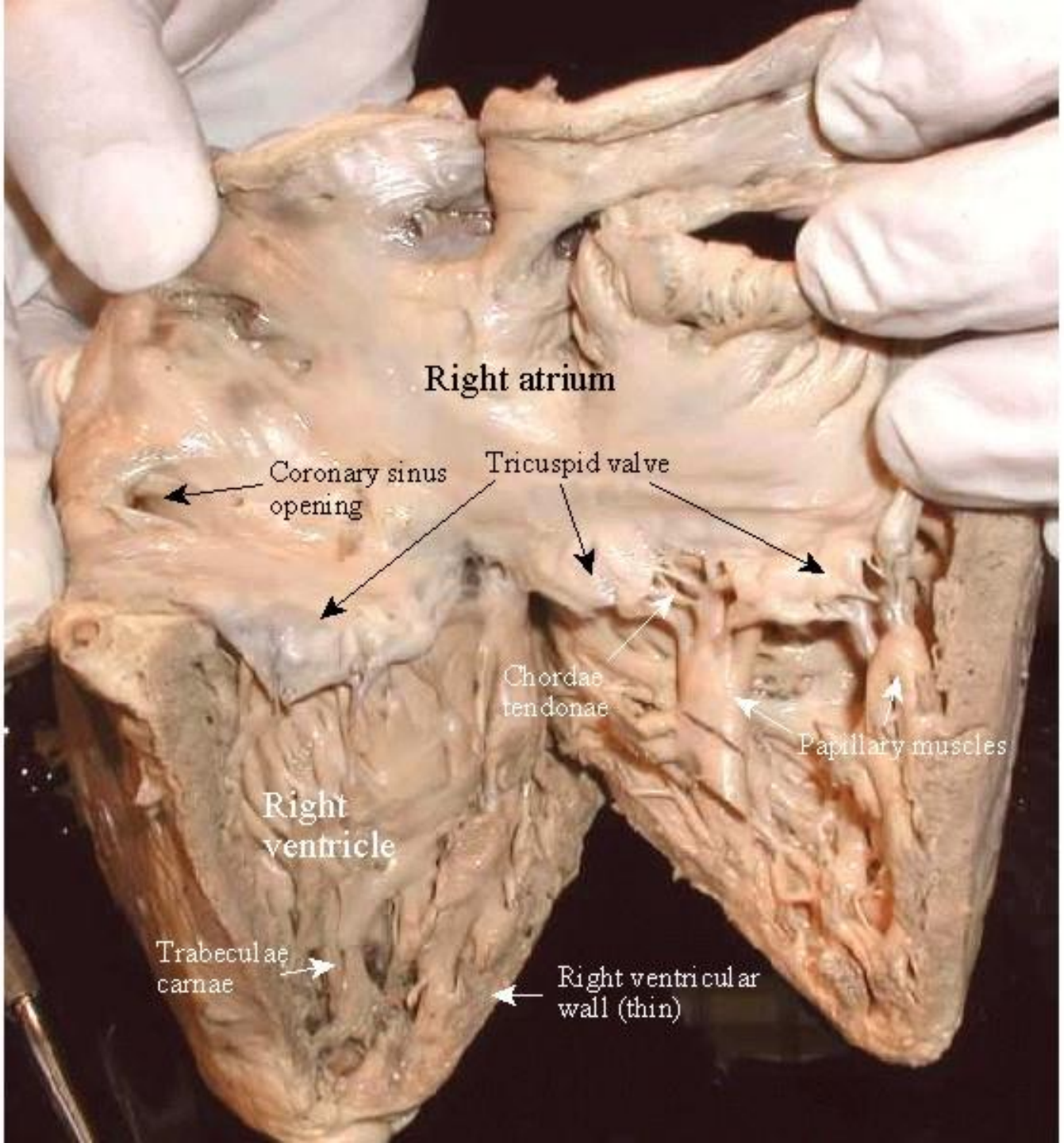
Aortic valve
Mitral valve
Chordae tendineae
Papillary muscles
Left ventricle
Tricuspid valve
Inferior vena cava
Right ventricle
Apex of heart
Left coronary artery
Right coronary artery
Left circumflex artery
Left anterior descending artery
Obtuse marginal
Acute marginals
Posterior descending artery
Patrick J. Lynch, 1999



-Fig. 1-


Right atrium
Coronary sinus opening
Tricuspid valve
Chordae tendonae
Papillary muscles
Right ventricle
Trabeculae carnae
Right ventricular wall (thin)

Heart anatomy

- Interatrial septum with foramen ovale
- Interventricular septum – parts:
  - muscular ventricular septum
  - membranous ventricular septum (septum membranaceum)

Heart wall structure

- Inner layer – endocardium – is in contact with the blood that the heart pumps
- Middle layer – myocardium – heart muscle
- Outer layer– pericardium – two layers, the parietal pericardium and the visceral pericardium (epicardium)


A-61-704

Cardiac cells

Cardiac pacemaker cells

generate and conduct electrical impulses

are not contractile

Cardiac myocytes

main function - contraction

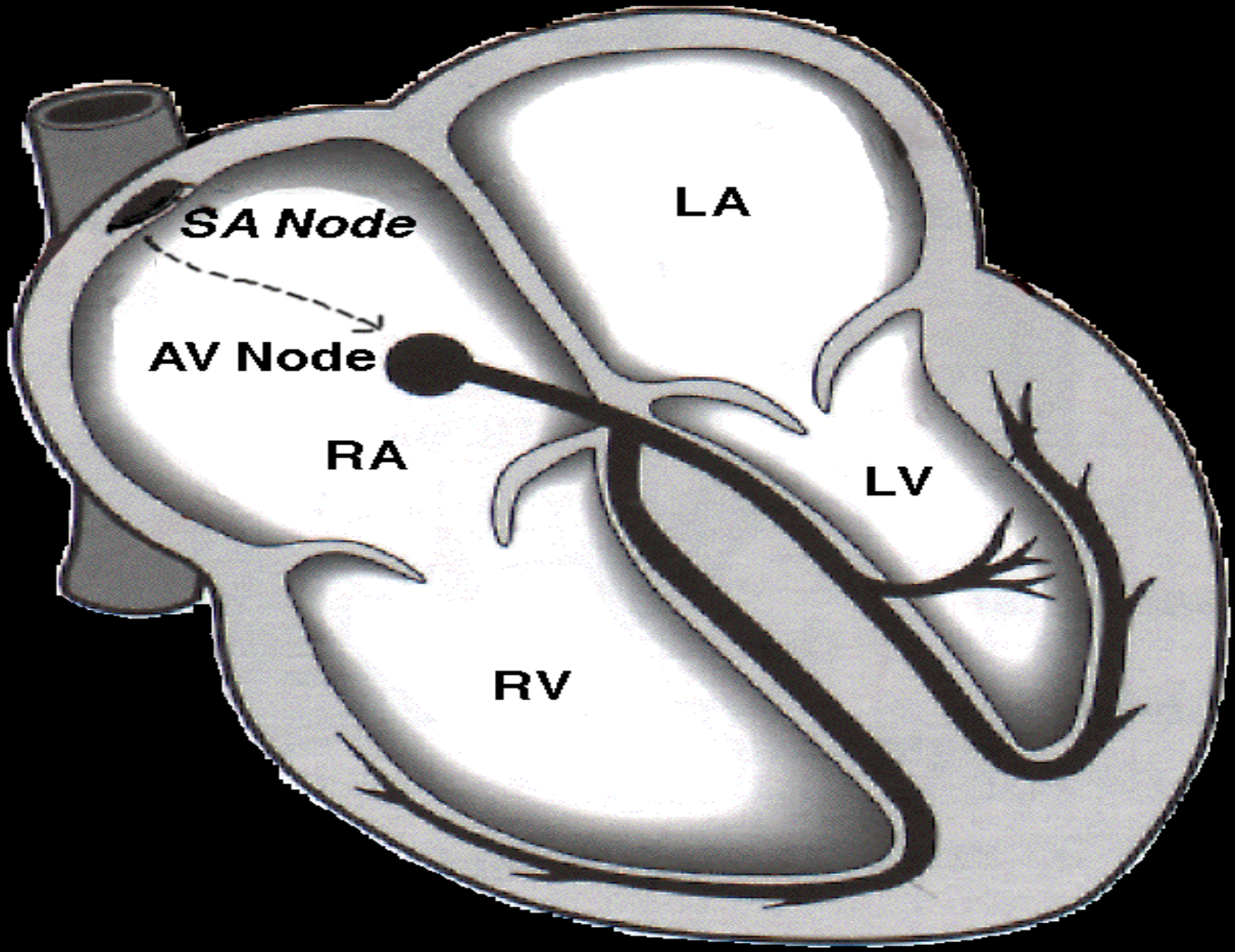
may conduct electrical activity

can generate electrical activity in specific circumstances

Anatomy of cardiac conduction system

Contains specific cells able to create electrical activity (action potential).

- Sinoatrial node (SA node)
- Atrioventricular node (AV node)
- His bundle- right and left bundle branch
- Purkinje fibres


SA Node
LA
AV Node
RA
LV
RV

Innervation of the heart

- Sympathetic – fibers arising from segments T2-T4 of the spinal cord and distributed through the middle cervical and cervico-thoracic ganglia and the first four ganglia of the thoracic sympathetic chain.
- Parasympathetic – from medulla oblongata via vagal nerve mediates involuntary heart reactions and influences automaticity and conductivity

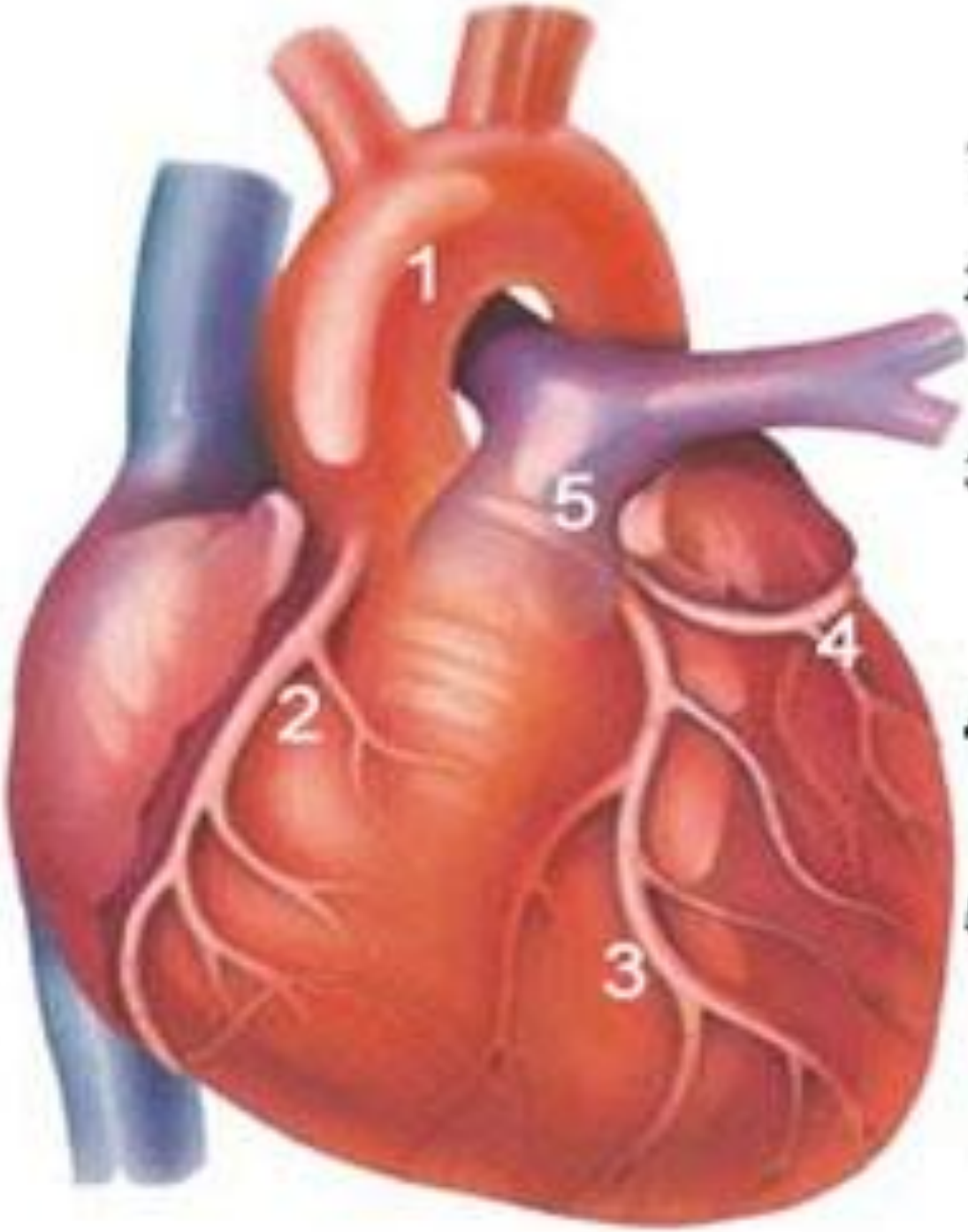
Coronary circulation

Left coronary artery (LCA)

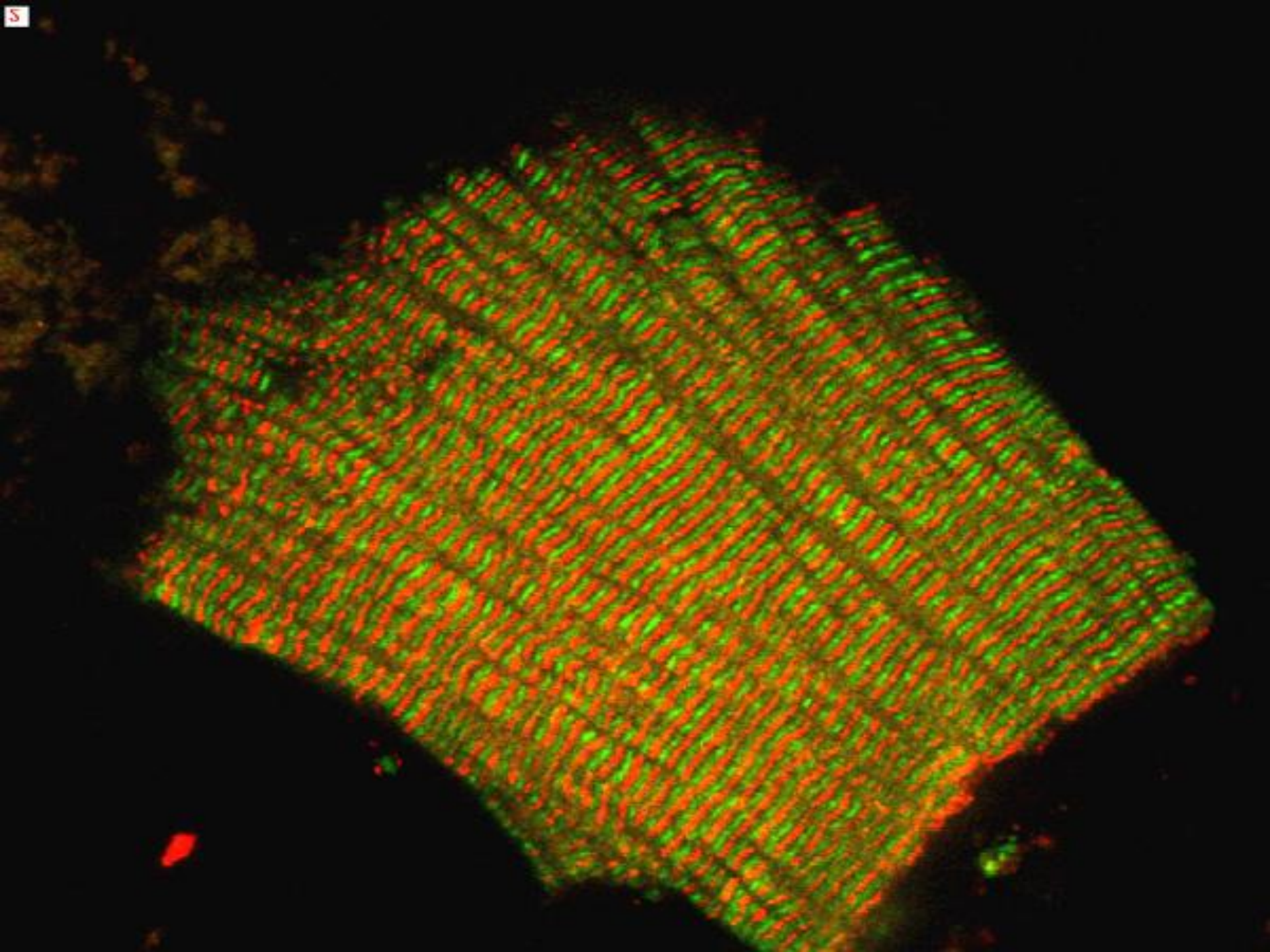
- # Left main coronary artery (LM)
- # left anterior descending artery (LAD)
- # circumflex artery (Cx)

Right coronary artery (RCA)

- # atrioventricular node artery
- # posterior descending artery (PDA)



1. Aorta
2. Right Coronary Artery
3. Left Anterior Descending Coronary Artery
4. Circumflex Coronary Artery
5. Left Main Coronary Artery



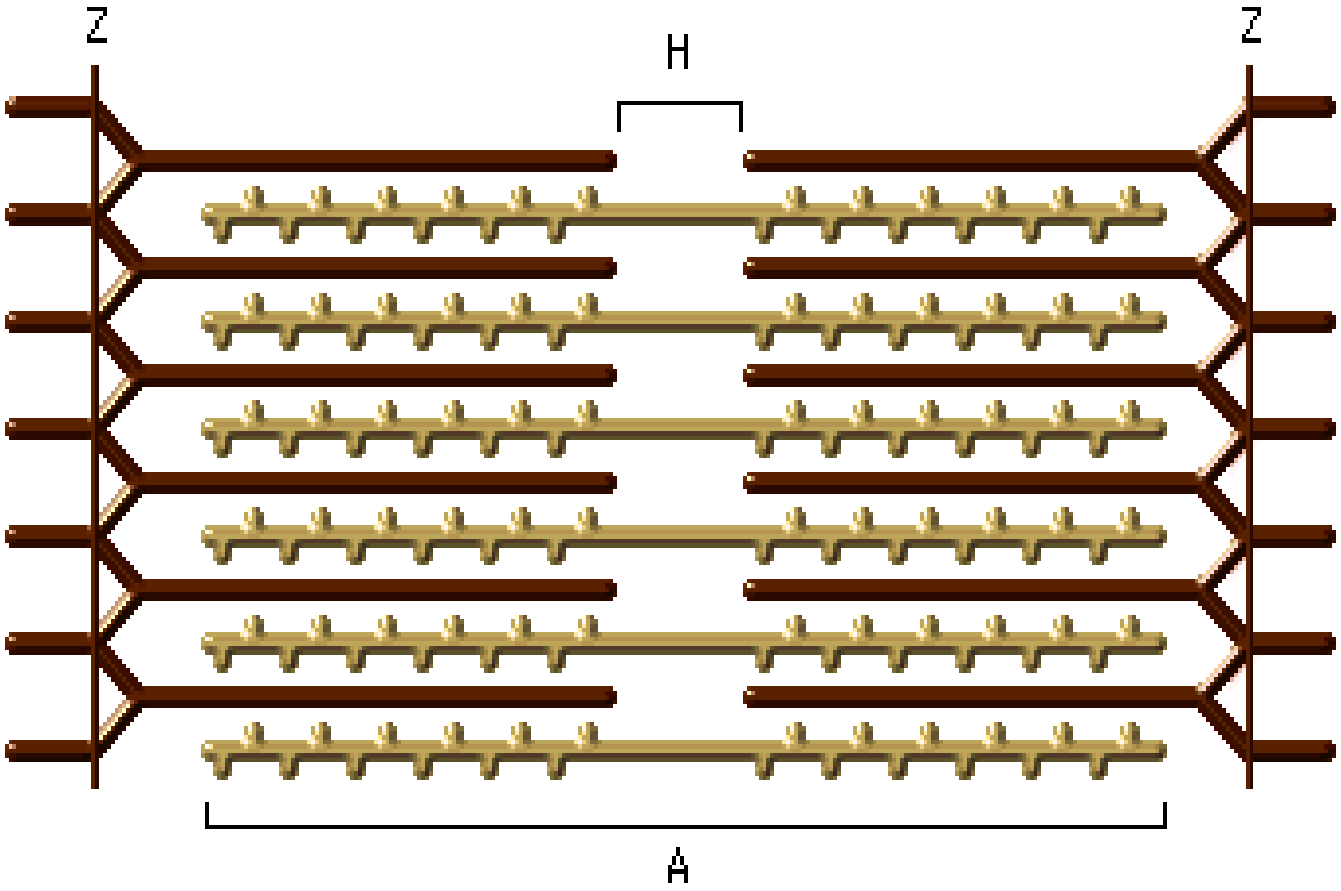
Cardiac myocytes

- type of striated muscle
- mononuclear or binuclear
- cardiac muscle exhibits cross striations formed by alternating segments of thick and thin protein filaments
- the primary structural proteins of cardiac muscle are actin and myosin

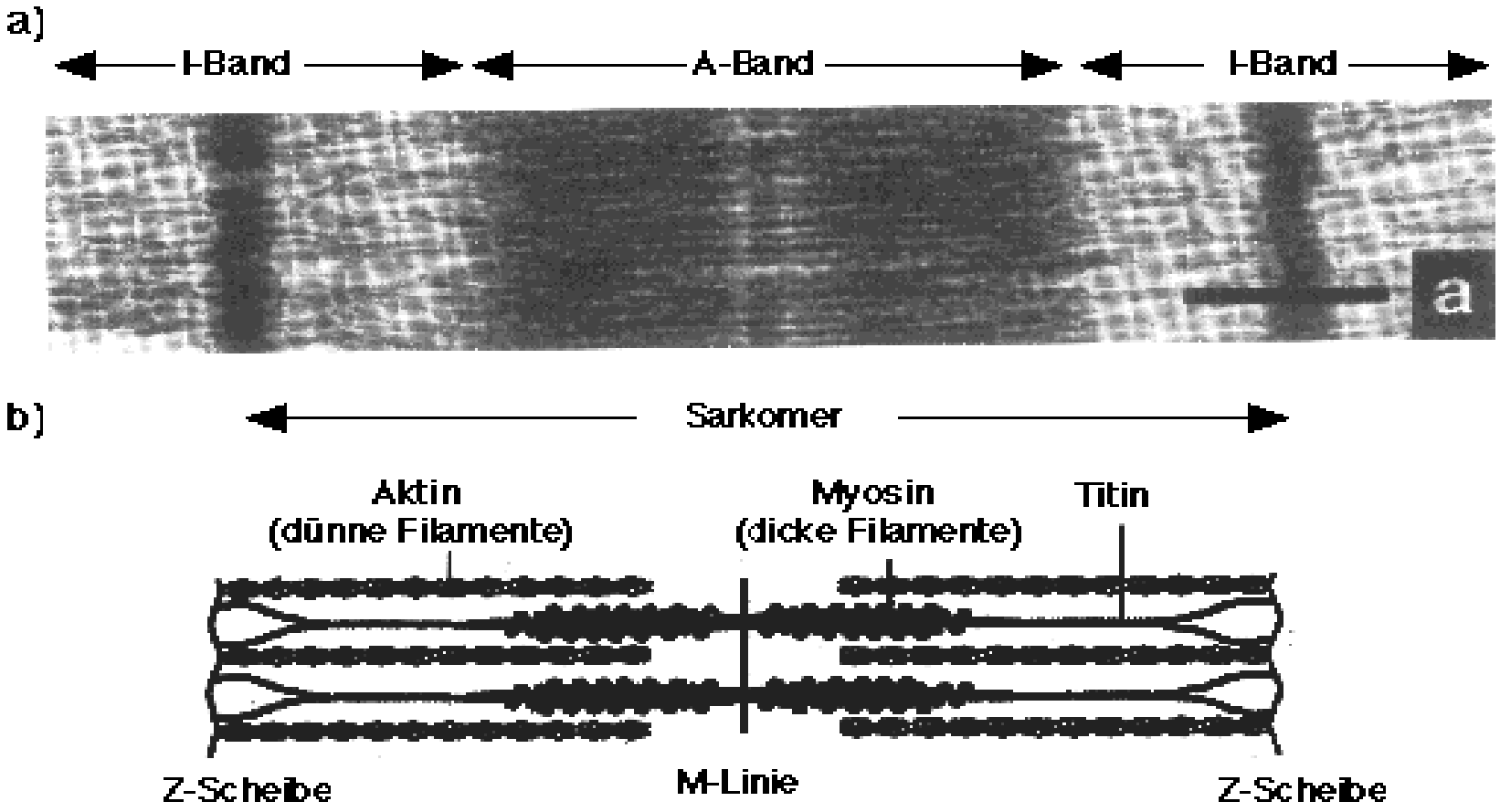
Sarcomer

- Z – line – place of actin filaments attachment
- A – line – correlates with myosin filament lenght
- H – line – part of myosin, without actin contact
- I – line – part of actin, without myosin contact

Sarcomer



Sarcomer


a)
I-Band
A-Band
I-Band
a
b)
Sarkomer
Aktin
(dünne Filamente)
Myosin
(dicke Filamente)
Titin
Z-Scheibe
M-Linie
Z-Scheibe

Electrophysiology

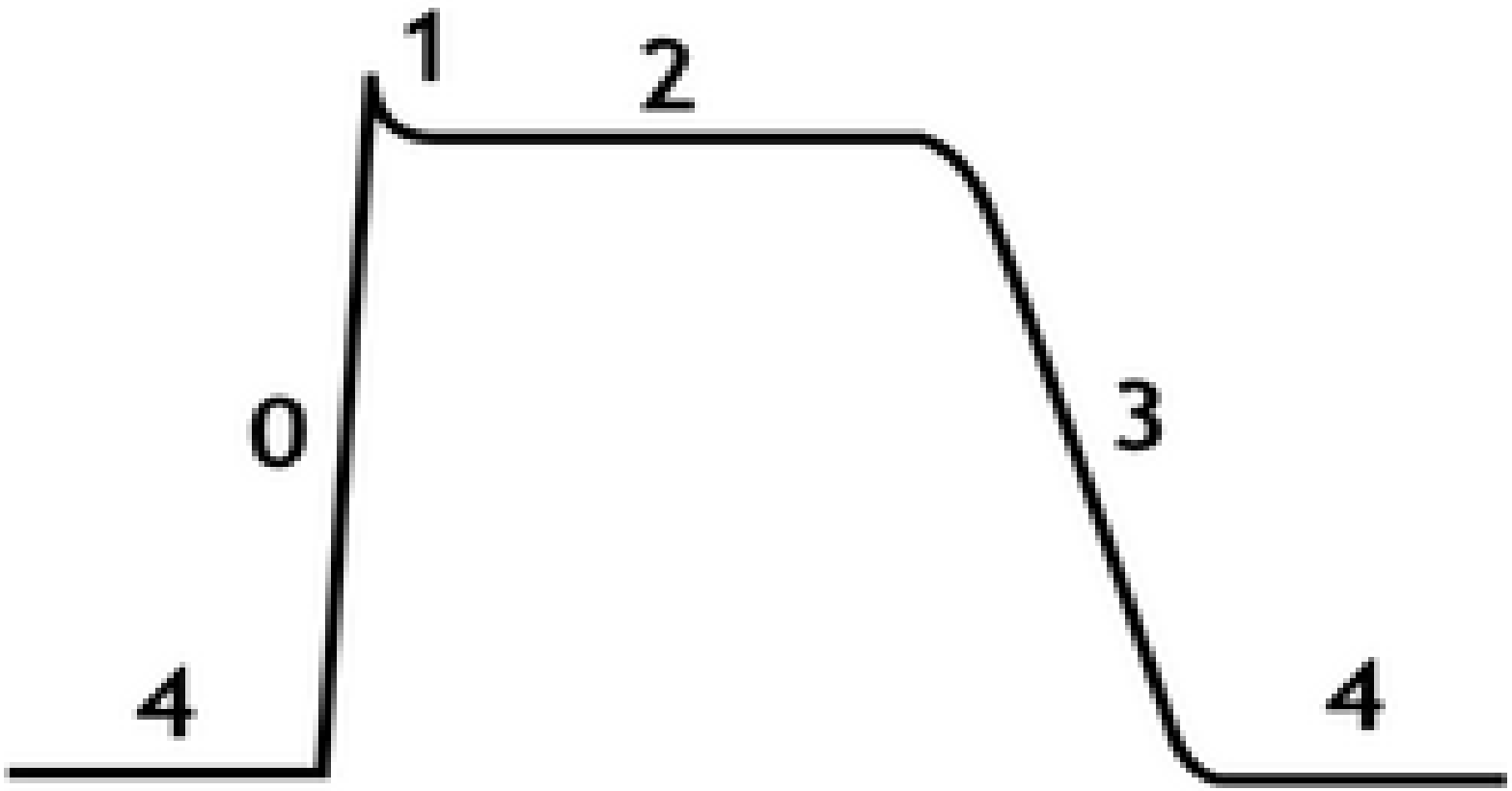
- Resting membrane potential – difference of the potentials between the inside of a cell compartment and the membrane
- At rest Ca^{2+} and Na^{+} ions are located outside the cell and K^{+} ions inside of the cell compartment
- Gradient of resting potential is maintained by the ion pumps/transporters and/or exchangers (using ATP)

Electrophysiology

Action potential

* Phase 0 – depolarisation – influx of Na+ ions into cardiac cells
* Phase 1 – initial repolarisation
* Phase 2 – plateau
* Phase 3 – final repolaryzacja
* Phase 4 – resting membrane potential

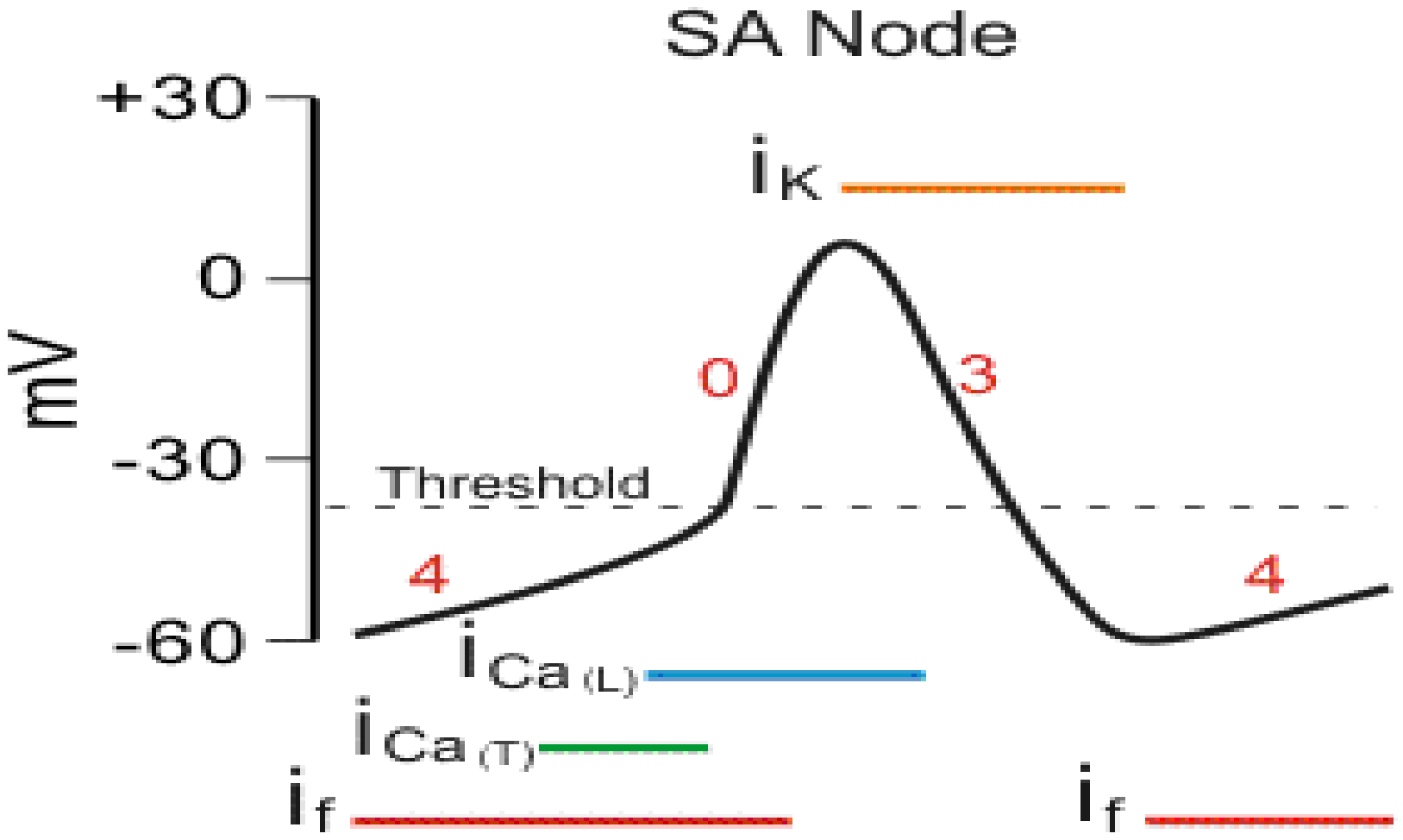
Action potential



Pacemaker cells and automaticity

- Pacemaker cells create action potential without any external stimulation
- automaticity – spontaneous pacemaker activity in phase 4 which leads the potential to the threshold value (resulting in action potential)

Spontaneus pacemaker activity



Electromechanical feedback

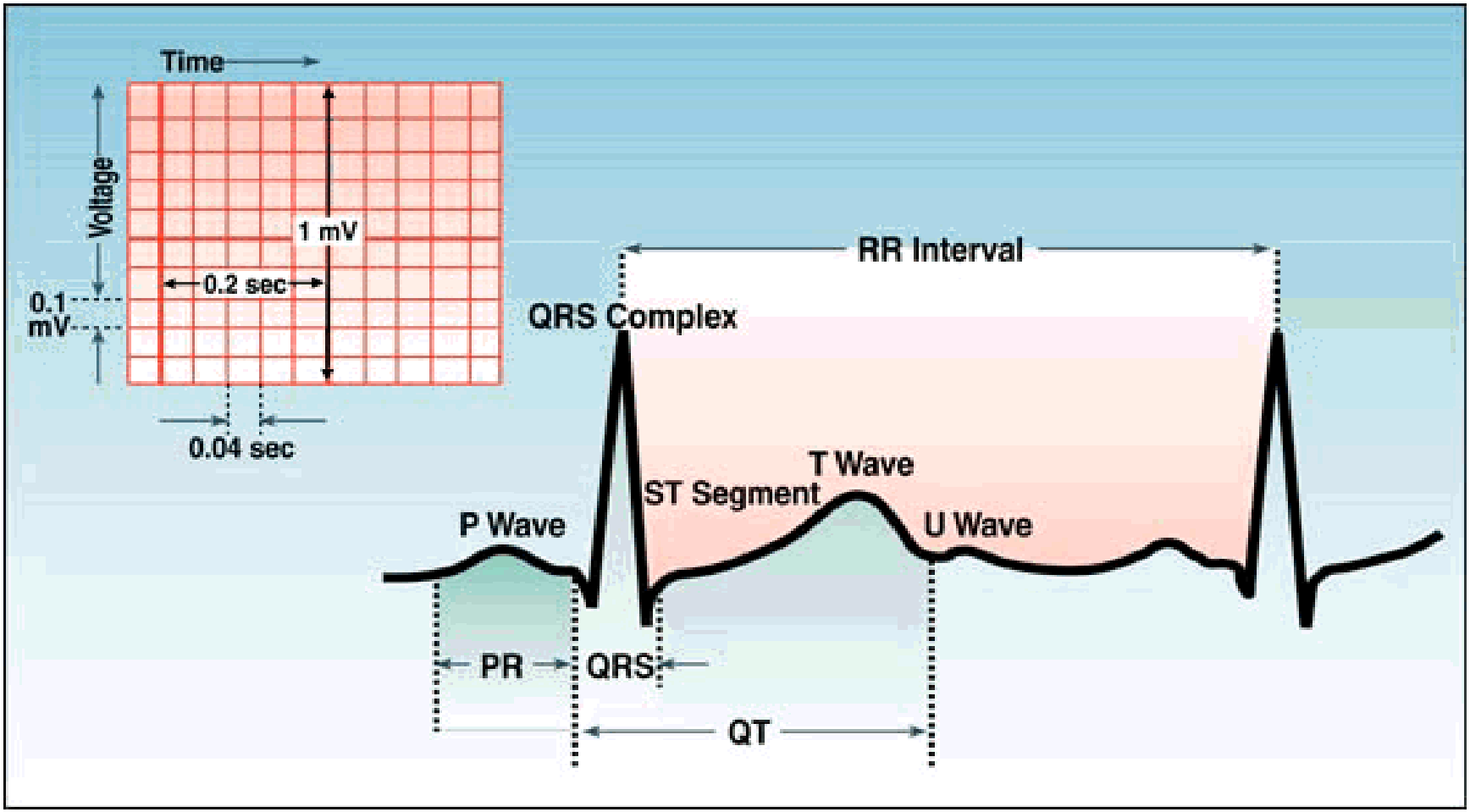
The ATP formed from substrate oxidation is the principal source of energy for almost all of the mechanical work of contraction performed by the myocardial cell.

The activity of myosin ATPase determines the rate of forming and breaking down the actin-myosin cross-bridges and ultimately the velocity of muscle contraction.

Electromechanical feedback

- During phase 2 there is a slow inward Ca^{2+} influx leading to additional calcium ions release from SR (sarcoplasmic reticulum)
- Calcium interaction with troponin C leads to the tropomyosin conformation change. Next step is actin and myosin interaction leading to myofilaments shortening – cell contraction.

ECG


Time
Voltage
1 mV
0.2 sec
0.1 mV
0.04 sec
RR Interval
QRS Complex
T Wave
ST Segment
P Wave
U Wave
PR
QRS
QT

Cardiac cycle

- diastole – blood flow from the atria into ventricles via opened atrioventricular valves – rapid ventricular filling
- „atrial kick” atrial contraction augments ventricular filling

Cardiac cycle

- Systole – ventricular systole induces increased pressure in the left and right ventricles. Ventricular pressure exceeds atrial pressure, thus closing the tricuspid and mitral valves (first heart sound). Ventricular pressure continues to rise - isovolumic ventricular contraction (semilunar valves closed) until the pulmonary and aortic valves open (ejection phase). At the end of ejection phase pressure in ventricles falls below pressure of the aorta and pulmonary trunc and semilunar valves close (second heart sound)

CO (cardiac output)

The volume of blood pumped by the heart, in particular by a left or right ventricle during one minute

$$CO = SV \times HR$$

- SV (stroke volume) - the volume of blood pumped from one ventricle of the heart with each beat
- HR (heart rate) - the number of heartbeats per unit of time, typically expressed as *beats per minute* (bpm)