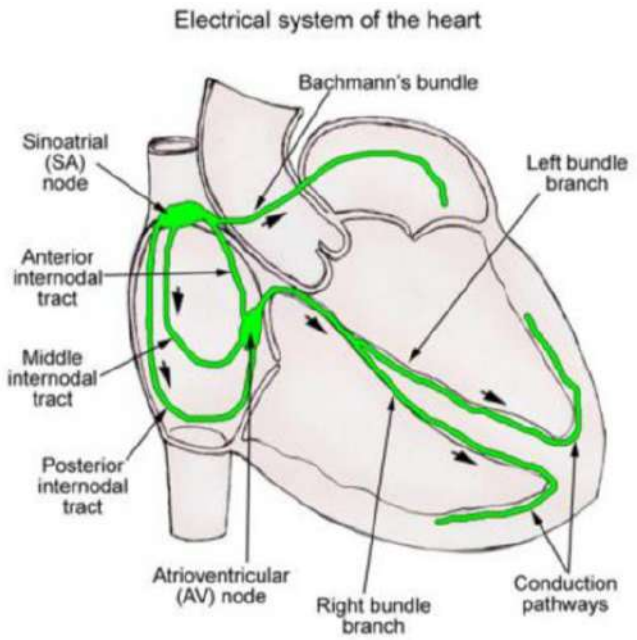
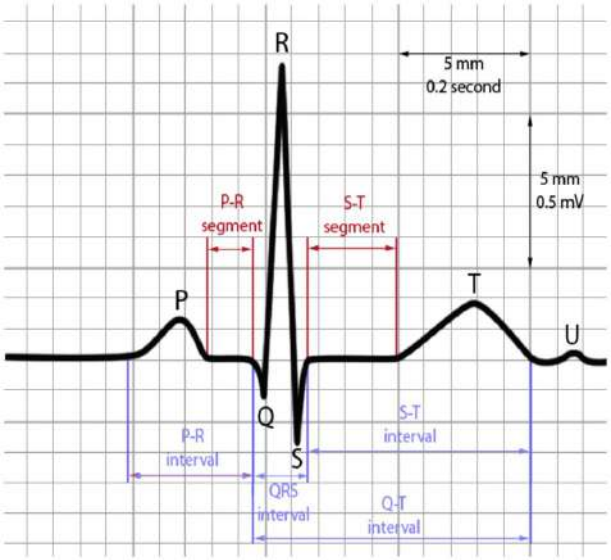
Electrocardiogram (ECG)

BME 360 Lecture Notes *Ying Sun*

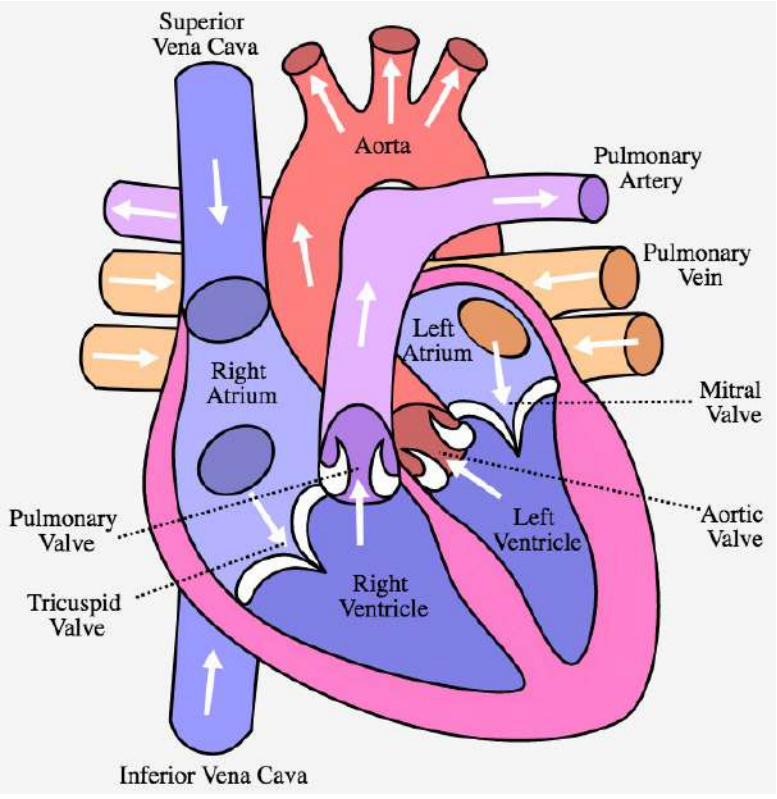
Anatomy and Physiology



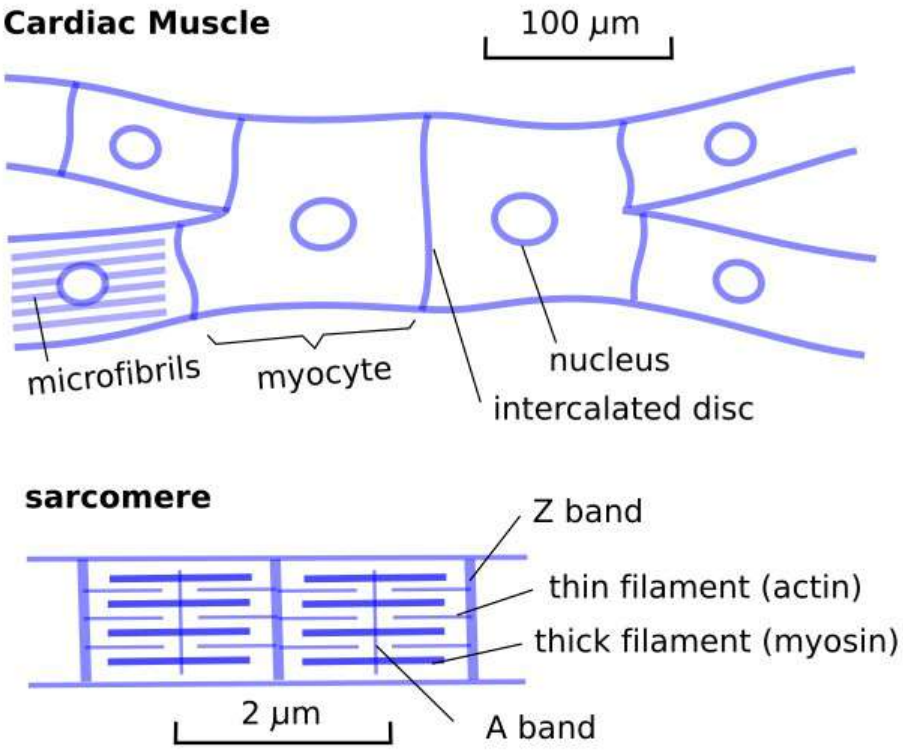


Cardiac conduction system is a group of specialized cardiac muscle cells in the walls of the heart that send signals to the heart muscle causing it to contract.

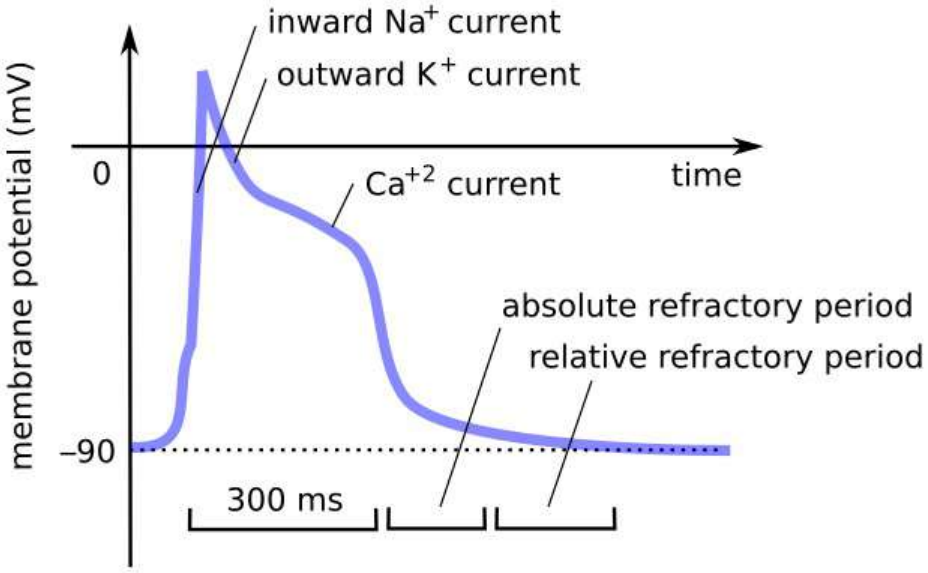
Hemodynamics is the dynamics of blood flows in the cardiovascular system, which includes the systemic circulation and the pulmonary circulation. The right heart (right atrium and right ventricle) pumps blood into the pulmonary circulation. The left heart (left atrium and left ventricle) pumps blood into the systemic circulation.



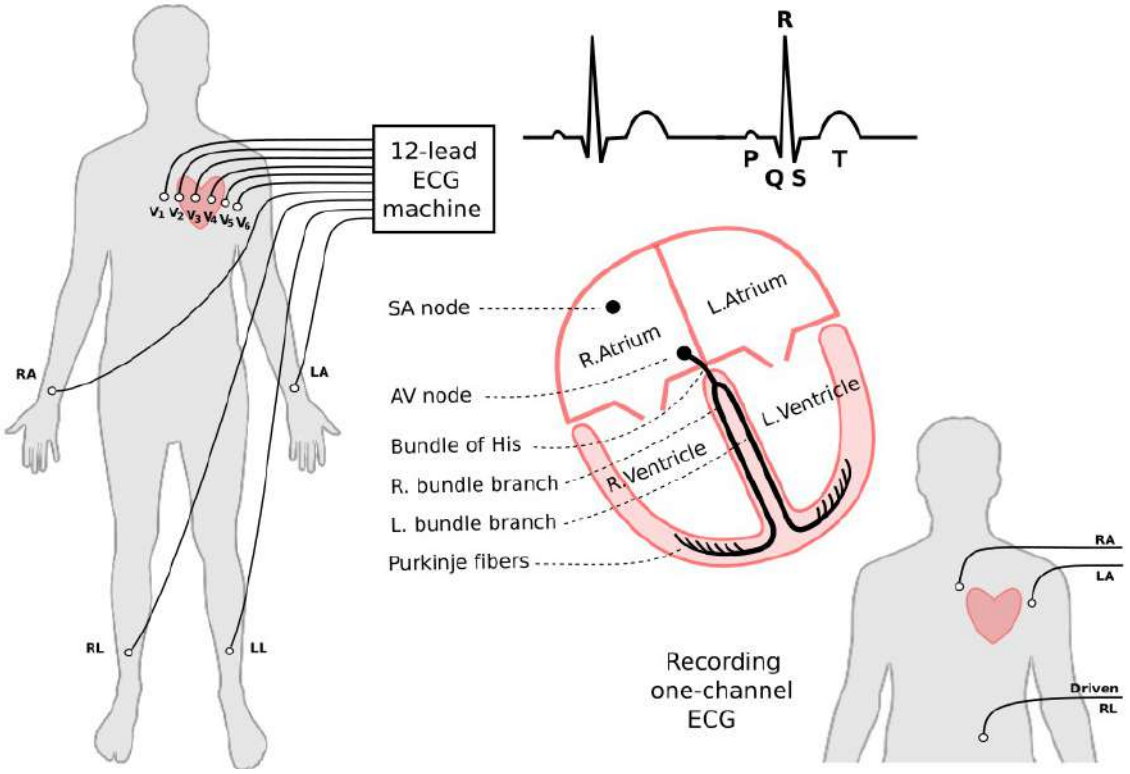
Cell Biology & Molecular Biology



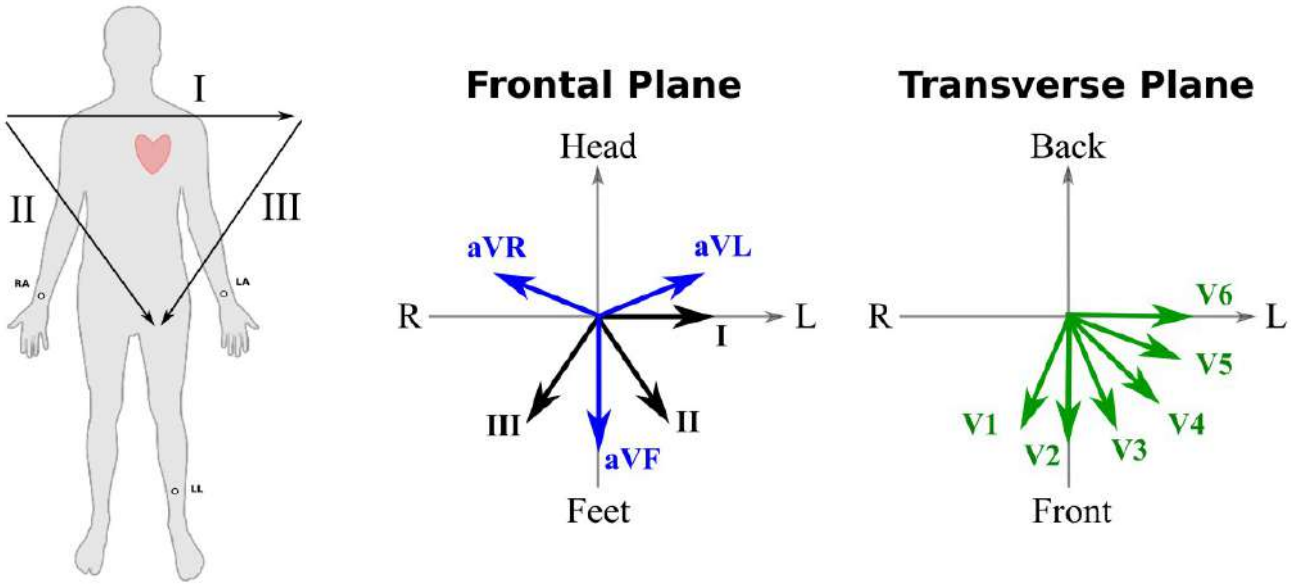
Action Potential



Instrumentation



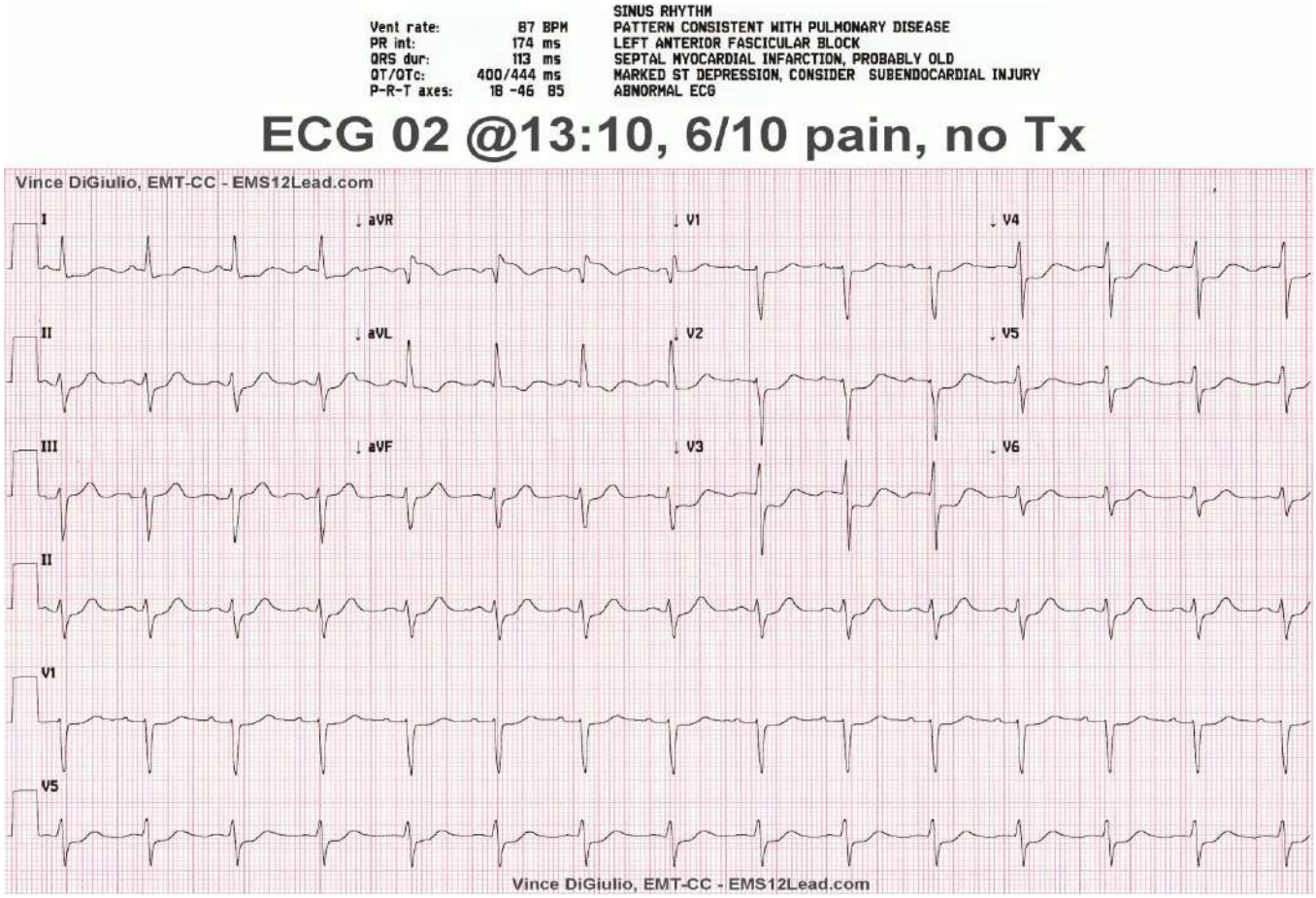
Dutch doctor and physiologist Willem Einthoven (1860–1927) invented the electrocardiogram (ECG) in 1903 and received the Nobel Prize in Medicine in 1924. The action potential propagation in the heart can be represented by a 3D dipole that changes its magnitude and direction over time. The 12-lead ECG uses 10 electrodes placed on the patient's limbs and on the surface of the chest. The overall magnitude of the 3D dipole is then measured from 12 different angles ("leads") and is recorded over a period of time (usually 10 seconds). The Einthoven's Triangle is an equal-lateral triangle on the frontal plane consisting of the three standard leads (I, II, and III). The six chest leads are on the transverse plane, which is orthogonal to the frontal plane.



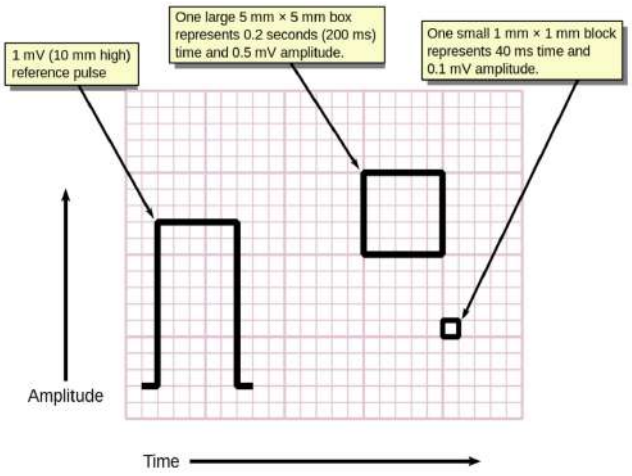
12-Lead ECG

PLANE	Lead Type	Lead Name	+	–	GND
FRONTAL	Standard leads	Lead I Lead II Lead III	LA LL LL	RA RA LA	RL
	Augmented leads	aVL aVR aVF	LA RA LL	RA, LL tied together LA, LL tied together LA, RA tied together	
TRANSVERSE	Chest leads	V1 V2 V3 V4 V5 V6	V1 V2 V3 V4 V5 V6	Wilson central (LA, RA, LL tied together)	

Pathophysiology & Clinical Applications



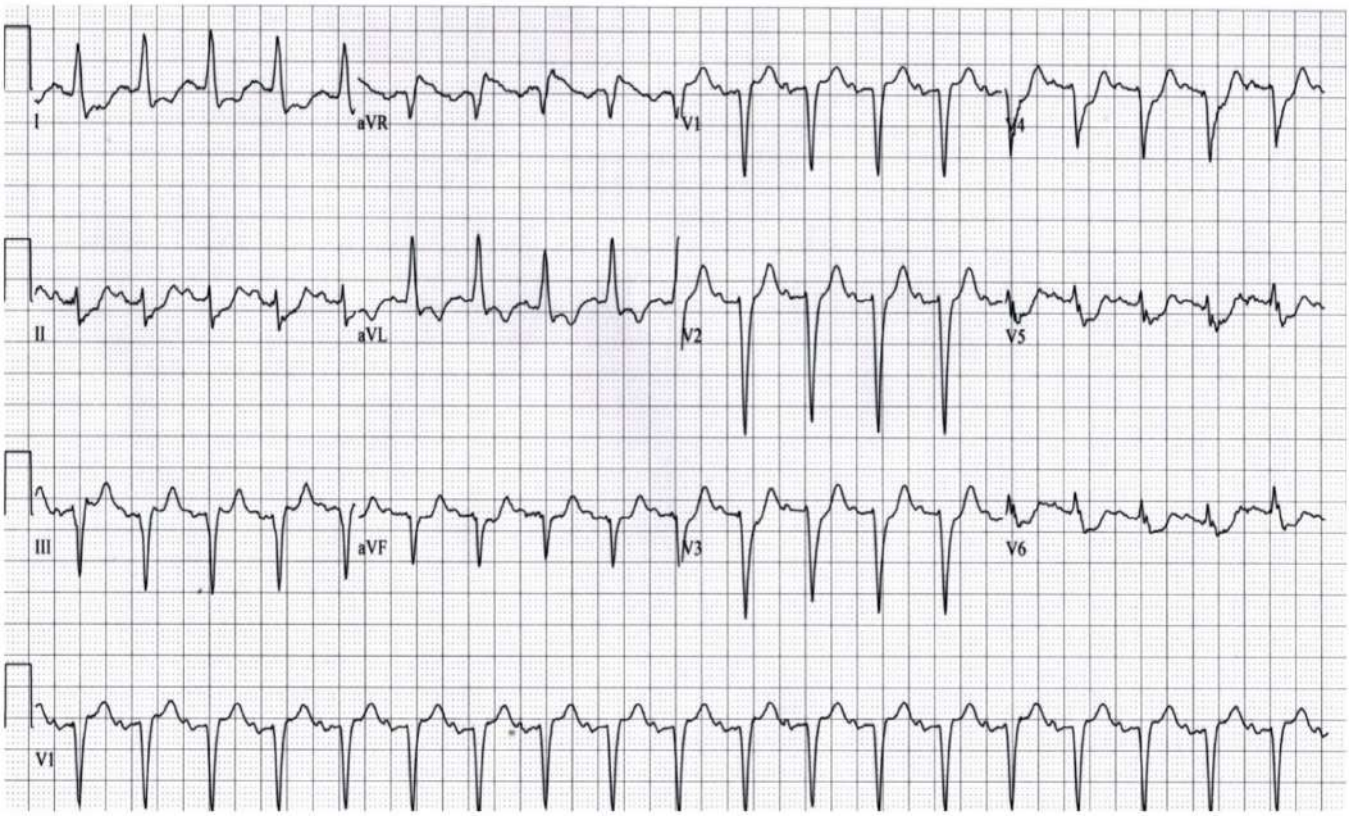
ECGs are normally printed on a grid. The horizontal axis represents time and the vertical axis represents voltage. The standard values on this grid are as follows: A small box is 1 mm × 1 mm and represents 0.1 mV × 0.04 seconds. A large box is 5 mm × 5 mm and represents 0.5 mV × 0.20 seconds. The "large" box is represented by a heavier line weight than the small boxes. The ECG waveform is usually proceeded by a reference pulse, which has a amplitude of 1mV and a duration of 0.2 s.



Example of an ECG board exam question

A 55-year-old woman with chest pain and unstable vital signs is brought in to you by emergency medical services. The paramedics obtained electrocardiography (ECG) en route to your facility (see Figure). What do the ECG findings demonstrate?

- O Pericarditis
- O De Winter syndrome
- O left bundle branch block with Sgarbossa criteria
- O left main coronary occlusion



Answer: left main coronary occlusion

ECG Sample Case: A 51-year-old woman with fatigue

GENERAL FEATURES

- □ 1. Normal ECG
- □ 2. Normal variant
- □ 3. Incorrect electrode placement
- □ 4. Artifact

P WAVE ABNORMALITIES

- □ 5. Right atrial abnormality/enlargement
- □ 6. Left atrial abnormality/enlargement

ATRIAL RHYTHMS

- □ 7. Sinus rhythm
- □ 8. Sinus arrhythmia
- □ 9. Sinus bradycardia (<60)
- □ 10. Sinus tachycardia (>100)
- □ 11. Sinus pause or arrest
- □ 12. Sinoatrial exit block
- □ 13. Atrial premature complexes
- □ 14. Atrial tachycardia
- □ 15. Atrial tachycardia, multifocal
- □ 16. Supraventricular tachycardia
- □ 17. Atrial flutter
- □ 18. Atrial fibrillation

AV JUNCTIONAL RHYTHMS

- □ 19. AV junctional premature complexes
- □ 20. AV junctional escape complexes
- □ 21. AV junctional rhythm/tachycardia

VENTRICULAR RHYTHMS

- □ 22. Ventricular premature complex(es)
- □ 23. Ventricular parasystole
- □ 24. Ventricular tachycardia (3 or more consecutive complexes)
- □ 25. Accelerated idioventricular rhythm
- □ 26. Ventricular escape complexes or rhythm
- □ 27. Ventricular fibrillation

AV CONDUCTION

- □ 28. AV block, 1°
- □ 29. AV block, 2°–Mobitz type I (Wenckebach)
- □ 30. AV block, 2°–Mobitz type II
- □ 31. AV block, 2:1
- □ 32. AV block, 3°
- □ 33. Wolff-Parkinson-White pattern
- □ 34. AV dissociation

ABNORMALITIES OF QRS VOLTAGE OR AXIS

- □ 35. Low voltage, limb leads
- □ 36. Low voltage, precordial leads
- □ 37. Left axis deviation (> –30°)
- □ 38. Right axis deviation (> +100°)
- □ 39. Electrical alternans

VENTRICULAR HYPERTROPHY

- □ 40. Left ventricular hypertrophy
- □ 41. Right ventricular hypertrophy
- □ 42. Combined ventricular hypertrophy

INTRAVENTRICULAR CONDUCTION

- □ 43. RBBB, complete
- □ 44. RBBB, incomplete
- □ 45. Left anterior fascicular block
- □ 46. Left posterior fascicular block
- □ 47. LBBB, complete
- □ 48. LBBB, incomplete
- □ 49. Aberrant conduction (including rate-related)
- □ 50. Intraventricular conduction disturbance, nonspecific type

Q WAVE MYOCARDIAL INFARCTION

	Age recent, or probably acute	Age indeterminate, or probably old
Anterolateral	□ 51.	□ 52.
Anterior or anteroseptal	□ 53.	□ 54.
Lateral	□ 55.	□ 56.
Inferior	□ 57.	□ 58.
Posterior	□ 59.	□ 60.

ST, T, U WAVE ABNORMALITIES

- □ 61. Normal variant, early repolarization
- □ 62. Normal variant, juvenile T waves
- □ 63. Nonspecific ST and/or T wave abnormalities
- □ 64. ST and/or T wave abnormalities suggesting myocardial ischemia
- □ 65. ST and/or T wave abnormalities suggesting myocardial injury
- □ 66. ST and/or T wave abnormalities suggesting electrolyte disturbances
- □ 67. ST and/or T wave abnormalities secondary to hypertrophy
- □ 68. Prolonged Q-T interval
- □ 69. Prominent U waves

CLINICAL DISORDERS

- □ 70. Brugada syndrome
- □ 71. Digitalis toxicity
- □ 72. Torsades de pointes
- □ 73. Hyperkalemia
- □ 74. Hypokalemia
- □ 75. Hypercalcemia
- □ 76. Hypocalcemia
- □ 77. Dextrocardia, mirror image
- □ 78. Acute cor pulmonale including pulmonary embolus
- □ 79. Pericardial effusion
- □ 80. Acute pericarditis
- □ 81. Hypertrophic cardiomyopathy
- □ 82. Central nervous system disorder
- □ 83. Hypothermia

PACEMAKER FUNCTION

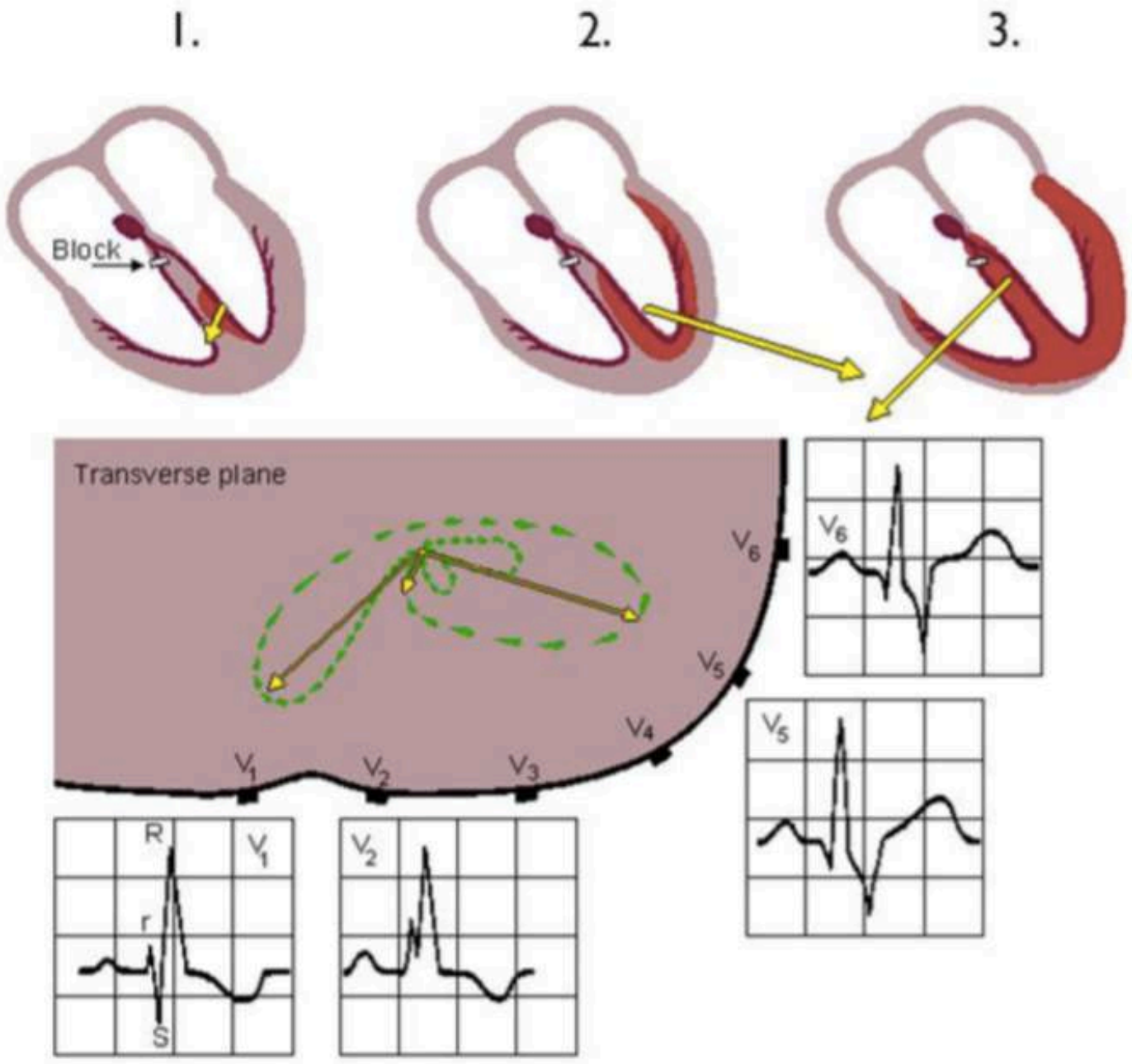
- □ 84. Atrial or coronary sinus pacing
- □ 85. Ventricular demand pacemaker (VVI), normally functioning
- □ 86. Dual-chamber pacemaker (DDD), normally functioning
- □ 87. Pacemaker malfunction, not constantly capturing (atrium or ventricle)
- □ 88. Pacemaker malfunction, not constantly sensing (atrium or ventricle)
- □ 89. Paced morphology consistent with biventricular pacing or cardiac resynchronization therapy

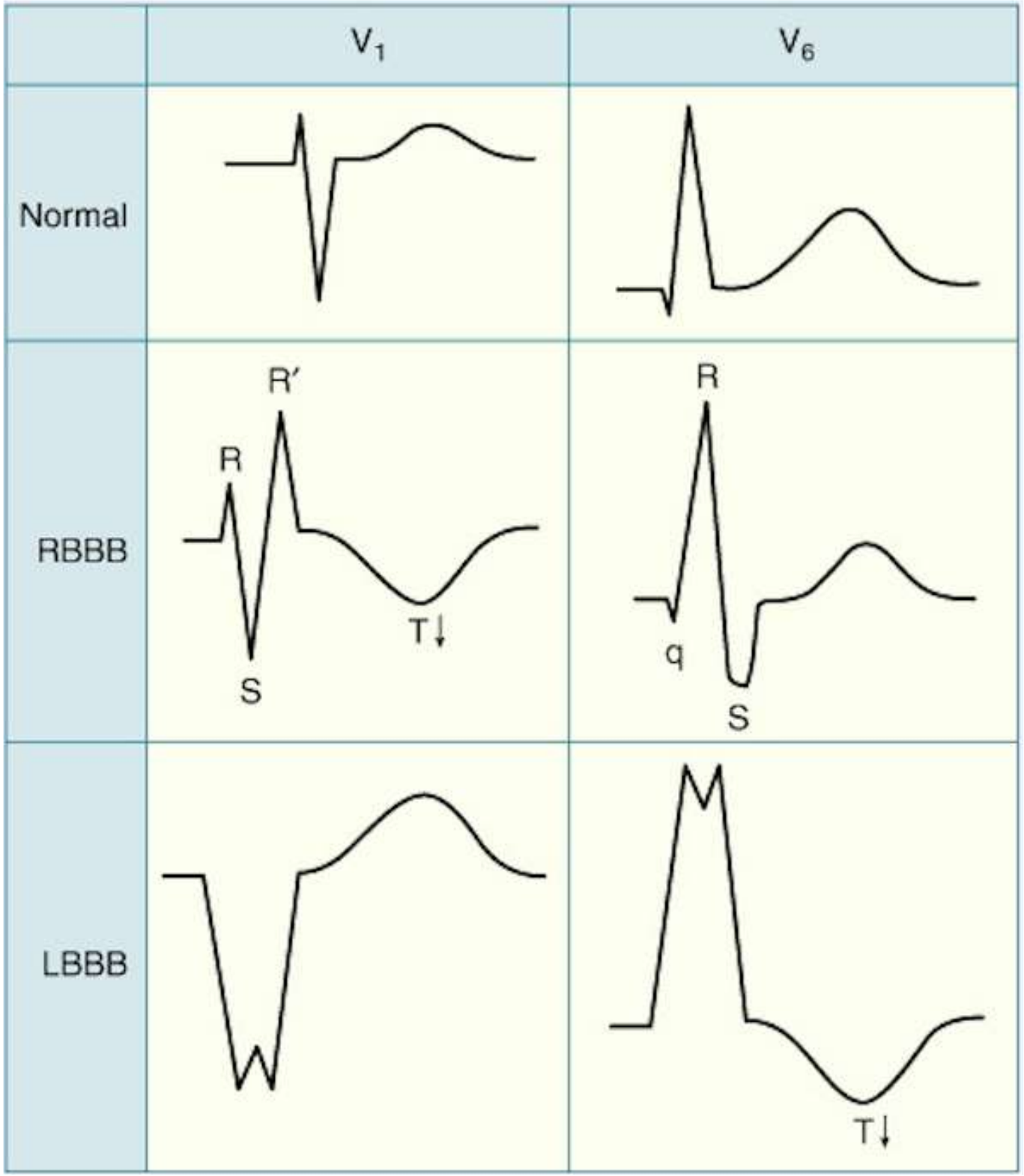
Right Bundle Branch Block

1. r wave in V1
   q wave in V6

2. S wave in V1
   R wave in V6

3. R' wave in V1
   S wave in V6




V1
V6
Normal
RBBB
R′
R
S
T↓
R
q
S
LBBB
T↓