Système cardiovasculaire

- Fonction cardiaque Unités motrices
- Fonction cardiaque déclenchement contraction
- Fonction cardiaque propagation contraction - cycle cardiaque
- Fonction cardiaque organe entier (pompe cardiaque)

Système cardiovasculaire

Propriétés: Fibres cardiaques	Fibres muscle squelettique
1) Contraction globale	1) Contraction sélective
2) Régularité et reproductibilité contraction	2) Recrutement sélectif
3) Robustesse système (automatisme)	3) Dépendance du SNC

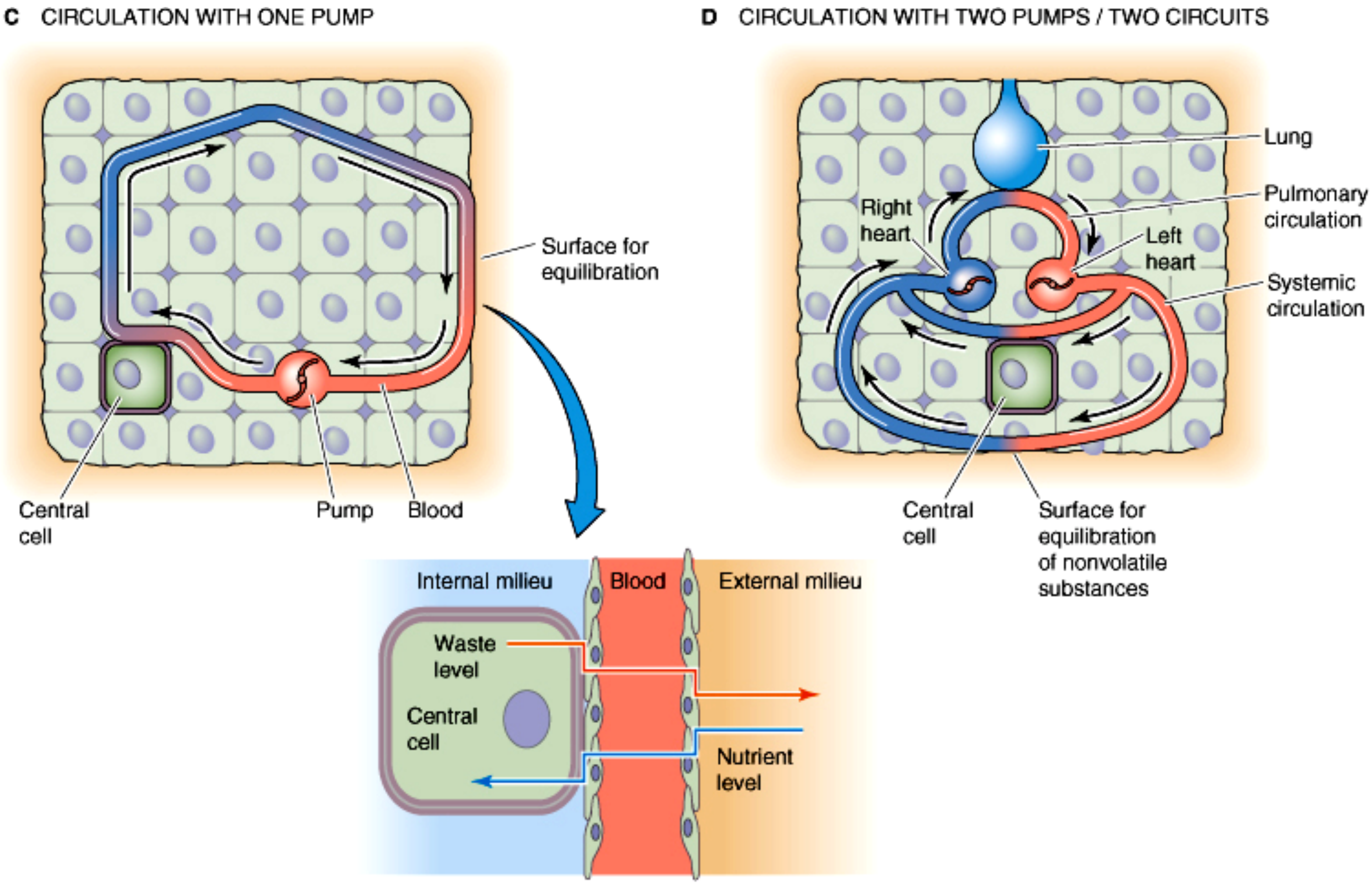
Système cardiovasculaire

CHART 3.1 COMPARISION OF MUSCLE STRUCTURE AND FUNCTION

	Skeletal Muscle	Cardiac Muscle	Smooth Muscle
Structure			
Morphology	Long; cylindrical	Branched	Spindle or fusiform
Nuclei	Multiple; located peripherally	One (sometimes two); located centrally	One; located centrally
Sarcomere	Yes; striated pattern	Yes; striated pattern	No
T tubules	Yes; forms triad with sarcoplasmic reticulum	Yes; forms dyad with sarcoplasmic reticulum	No; caveolae
Electrical coupling of cells	No	Yes; intercalated discs contain gap junctions	Yes; gap junctions
Regeneration	Yes; via satellite cells	No	Yes
Mitosis	No	No	Yes
Physiology			
Extracellular Ca^{2+} required for contraction	No	Yes	Yes
Regulation of cross-bridge formation	Ca^{2+} binding to troponin	Ca^{2+} binding to troponin	Ca^{2+}-calmodulin activation of myosin kinase and phosphorylation of myosin
Control of contraction	Motor neurons	Autonomic nerves; β-adrenergic agonists	Autonomic nerves; hormones
Summation of twitches by increased stimulus frequency	Yes	No*	Yes
Tension varies with filament overlap	Yes	Yes	Yes

Major differences in structure and function of skeletal, cardiac, and smooth muscle are indicted.
*Cardiac muscle cannot be tetanized, but the force of contraction will increase at high stimulus frequency because of an increase in intracellular $[Ca^{2+}]$, a phenomenon termed "Treppe."

Coeur Mécanisme général de la distribution sanguine



Coeur Distribution sanguine dans l'organisme

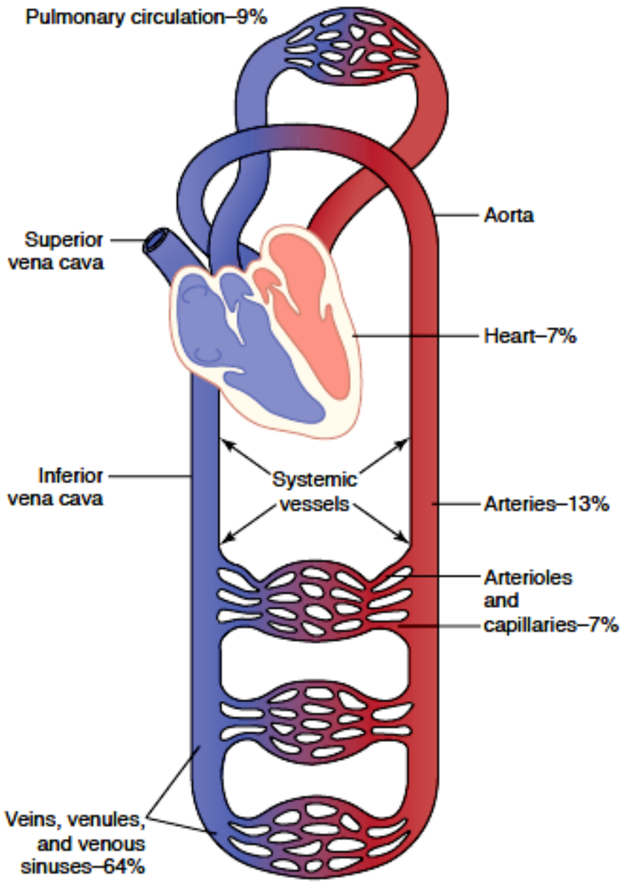
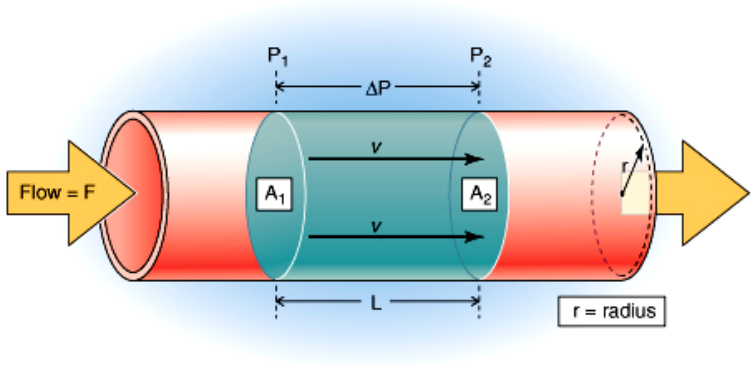


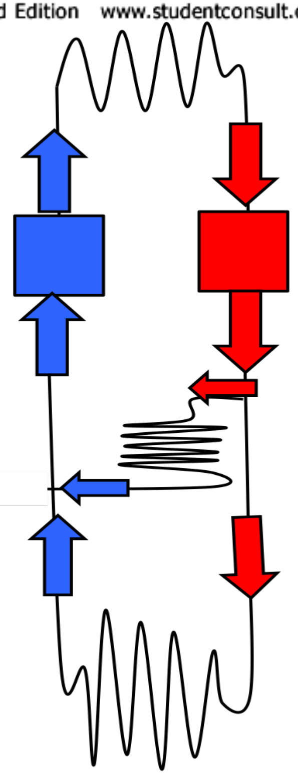
Figure 14–1

Distribution of blood (in percentage of total blood) in the different parts of the circulatory system.



$$\boxed{Q = \frac{\Delta P}{R}}$$

Q = Flow
P = Pressure
R = Resistance



Coeur 2 circulations sanguines dans l'organisme

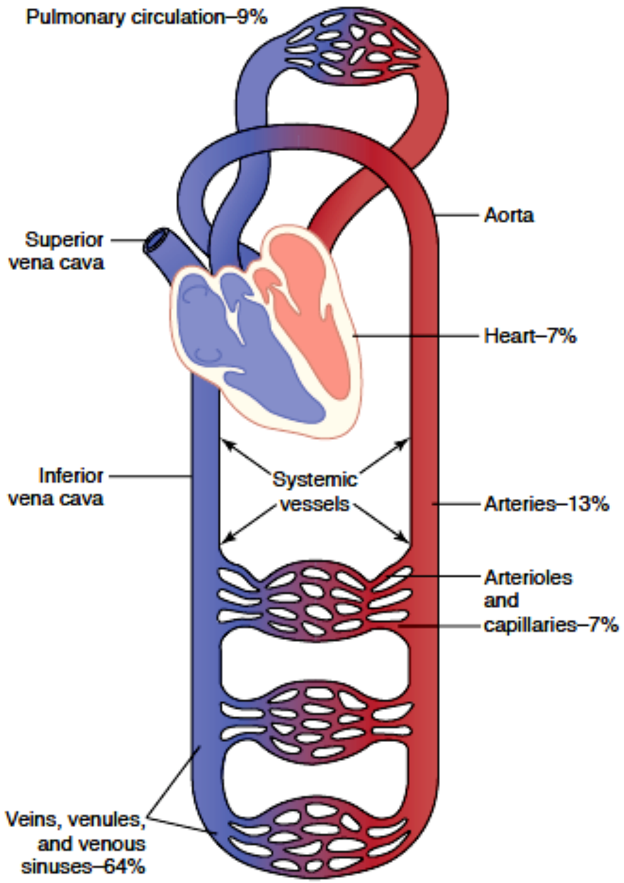
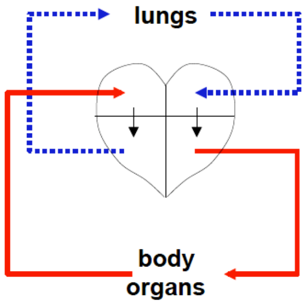


Figure 14–1

Distribution of blood (in percentage of total blood) in the different parts of the circulatory system.

Blood circulation: **heart** + **vessels** + **blood**

heart	vessels	blood
4 contractile chambers	arteries	plasma
automaticity & periodicity:	arterioles	red blood cells
<u>passive filling</u>	capillaries	white blood cells
active ejection	veins	~ 5-6 liters
volume transfer & pressure Δ	lymphatics	



Sense of flow: VALVES

Pulmonary circulation: low pressure (~ 2.2 kPa)
low resistance
high compliance

Systemic circulation: high pressure (~ 13 kPa)
high resistance
low compliance

$$Q_{pulm} = Q_{syst} = 5\text{-}6 \text{ l/min}$$

Compliance is a measure of the tendency of a hollow organ to resist recoil toward its original dimensions upon removal of a distending or compressing force.

Coeur: contraction musculaire régulière → pompage
De la génération du signal au pompage mécanique

CARDIAC FUNCTION

1) Automatic and rhythmic generation of action potential = electrical excitation
2) Propagation of action potentials along the conduction apparatus
3) Propagation of action potentials from Purkinje fibres to working myocardium
4) Excitation-contraction coupling
5) Contraction of working cells ➔ pumping

Coeur: excitabilité et activité rythmique

Excitation cardiaque par la propagation du potentiel d'action

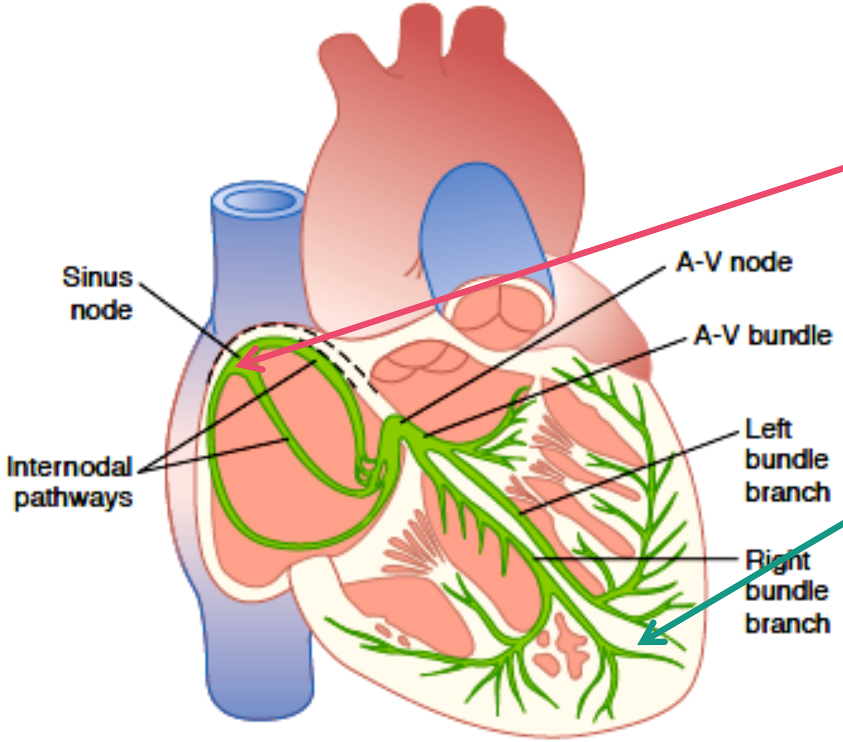


Figure 10–1

Sinus node, and the Purkinje system of the heart, showing also the A-V node, atrial internodal pathways, and ventricular bundle branches.

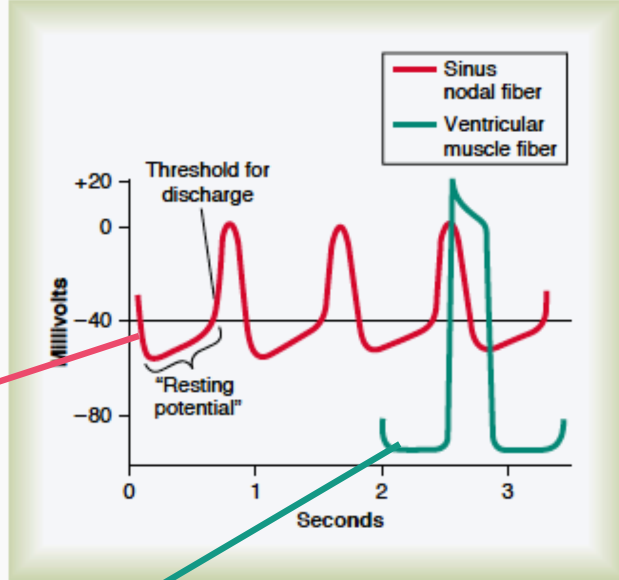


Figure 10–2

Rhythmical discharge of a *sinus nodal fiber*. Also, the sinus nodal action potential is compared with that of a ventricular muscle fiber.

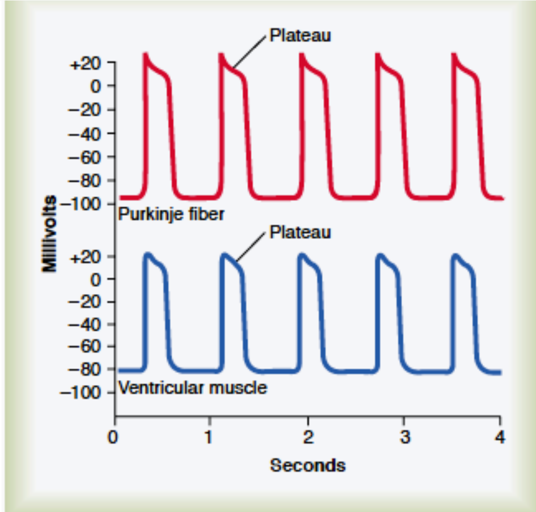


Figure 9–3

Rhythmical action potentials (in millivolts) from a Purkinje fiber and from a ventricular muscle fiber, recorded by means of microelectrodes.

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Coeur: conductibilité du signal électrique

Rôle des différents composants

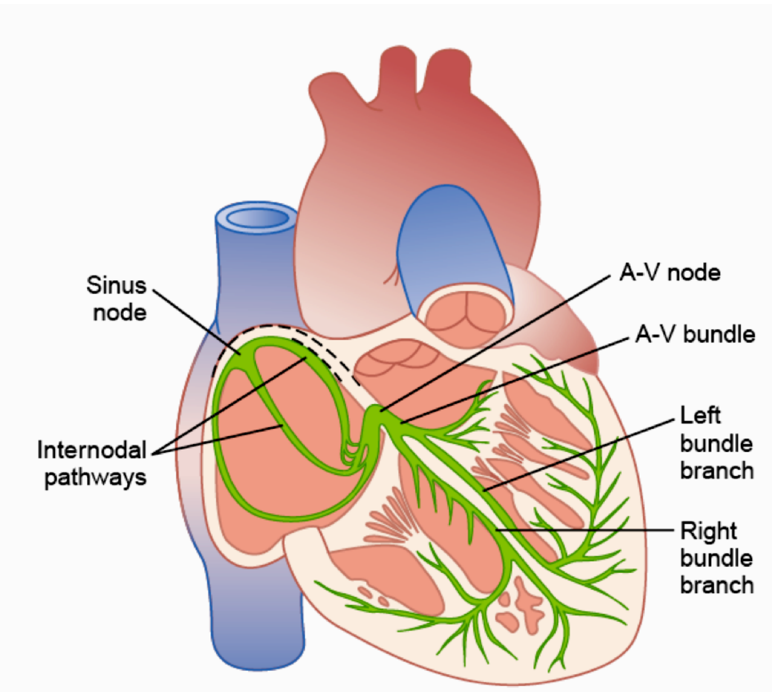


Figure 10–1

Sinus node, and the Purkinje system of the heart, showing also the A-V node, atrial internodal pathways, and ventricular bundle branches.

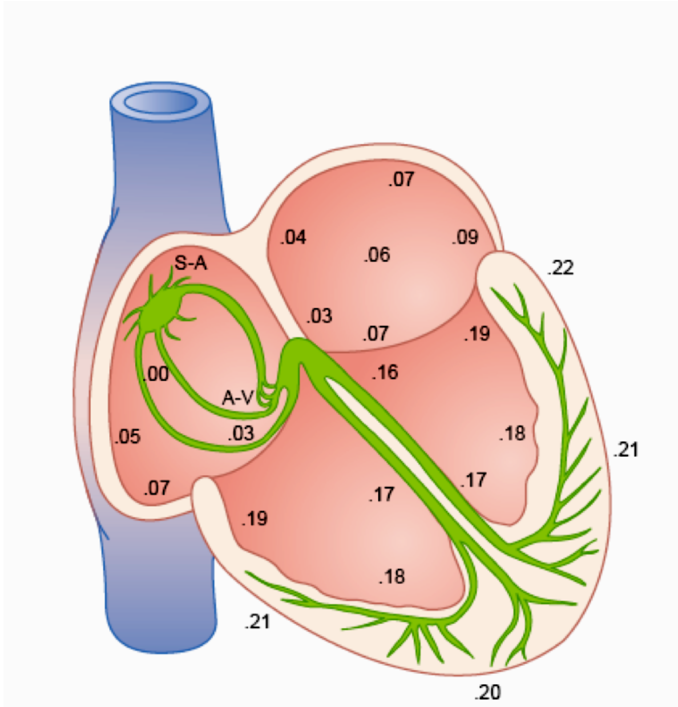
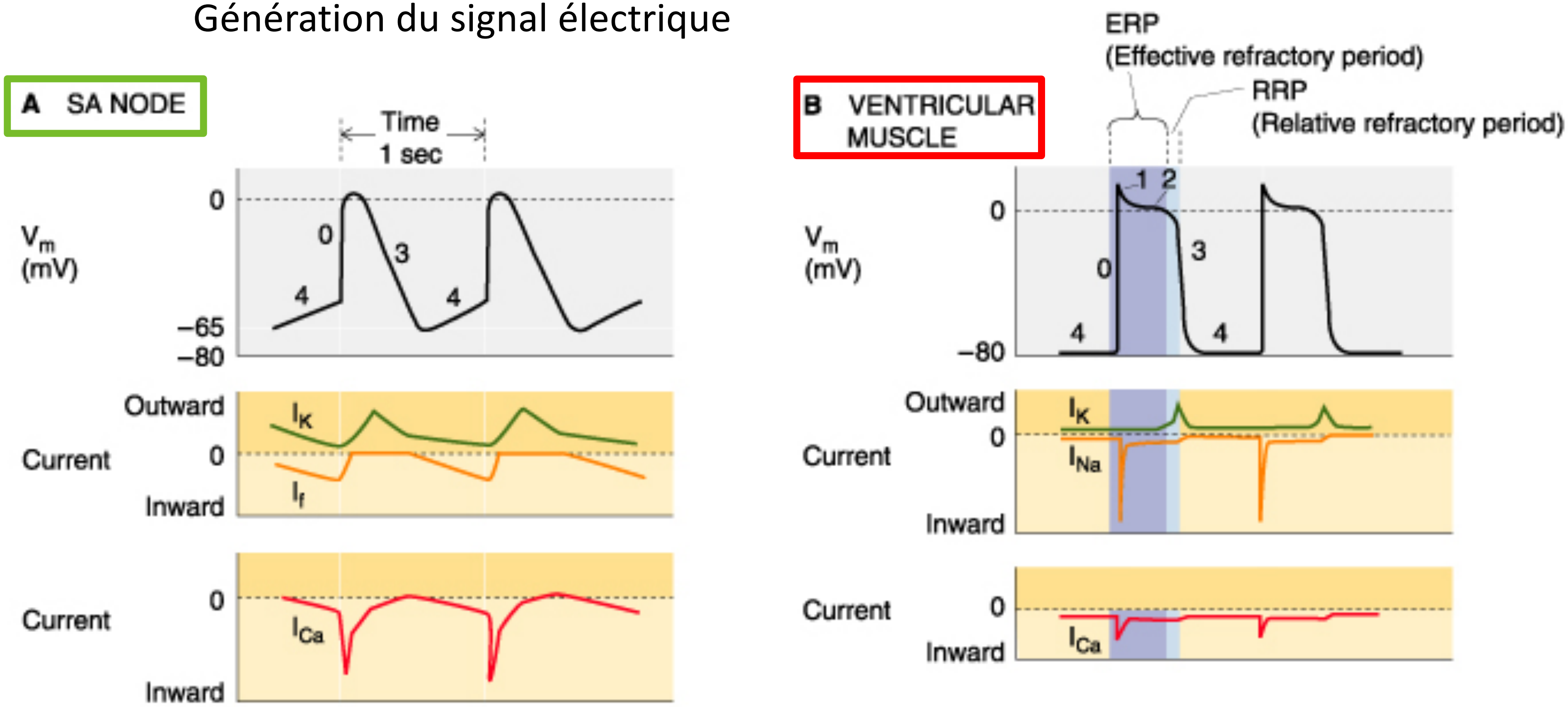


Figure 10–4

Transmission of the cardiac impulse through the heart, showing the time of appearance (in fractions of a second after initial appearance at the sinoatrial node) in different parts of the heart.

Coeur: excitation cardiaque par potentiel d'action

Génération du signal électrique

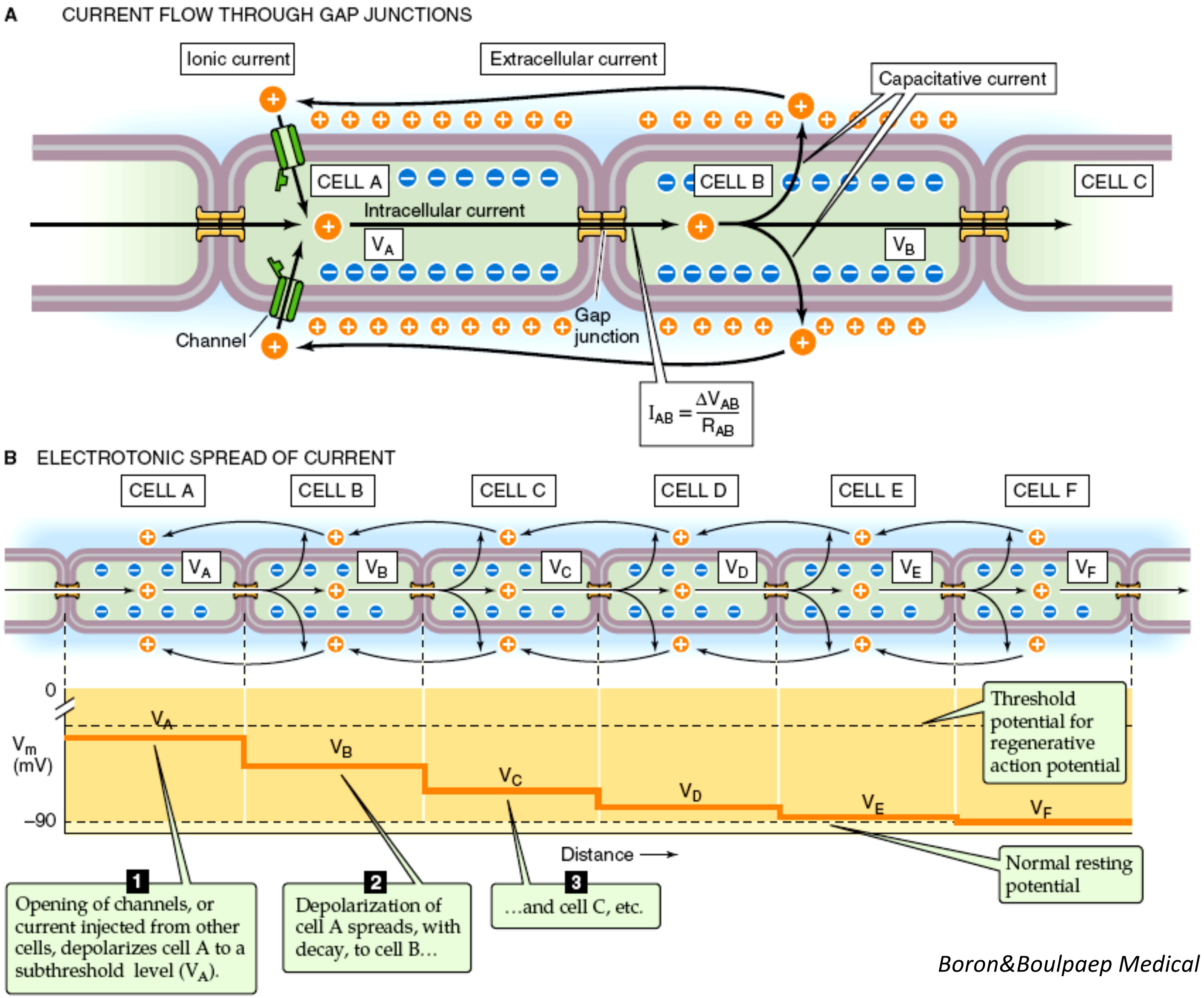


Phases of cardiac action potentials. The records in this figure are idealized. I_K, I_{Na}, I_{Ca}, and I_f are currents through K^+, Na^+, Ca^{2+}, and nonselective cation channels, respectively.

I_f is the pacemaker current

Boron&Boulpaep Medical Physiology

Coeur: transmission du signal électrique par les potentiels d'action



$V_A = R_A \cdot I_A$

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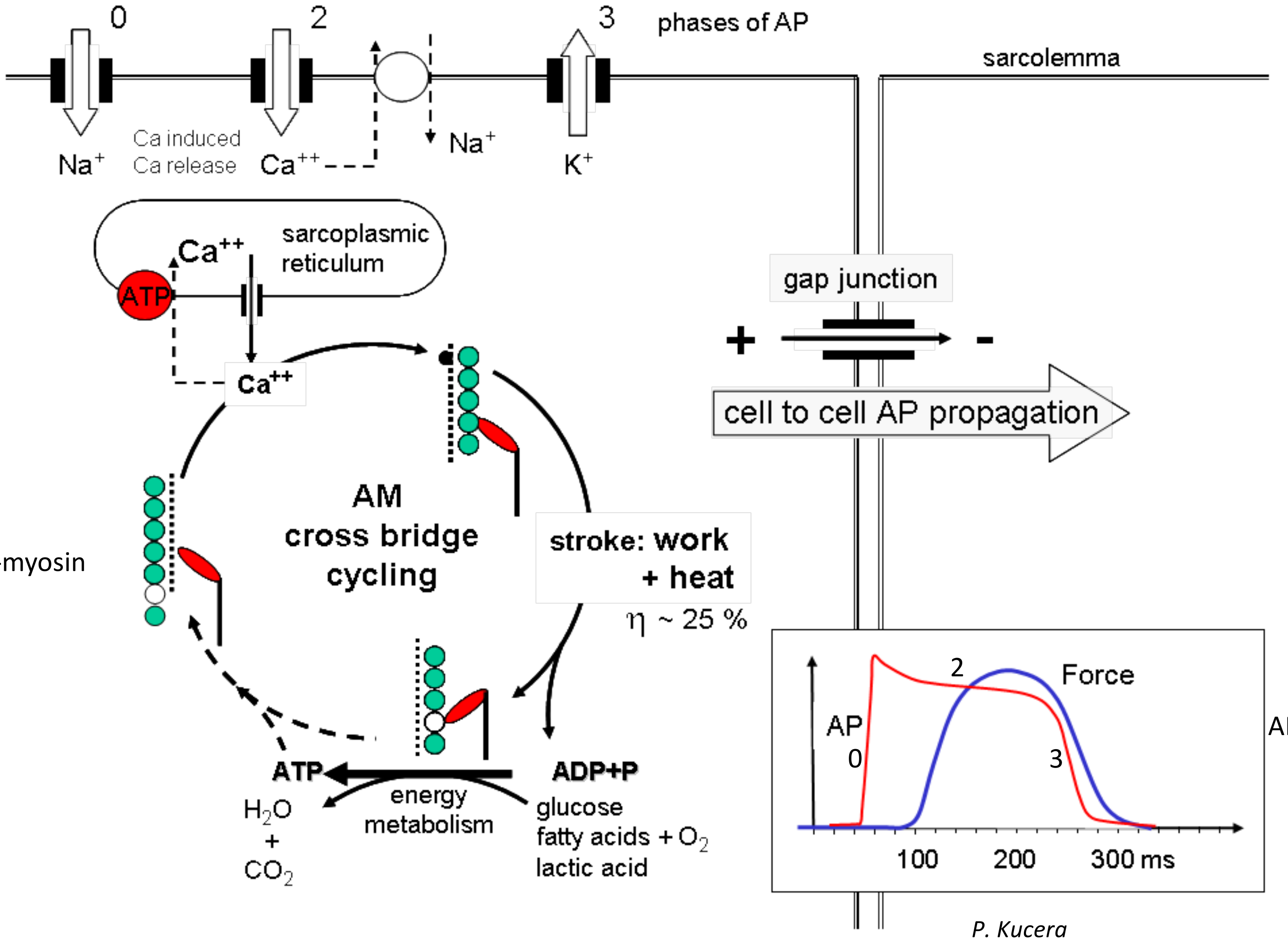
Coeur: couplage électromécanique dans le muscle cardiaque

Relations entre le courant ionique et la contraction du myocarde



AM: Actin-myosin

AP: Action potential

P. Kucera

Coeur: le cycle cardiaque durant la systole et la diastole

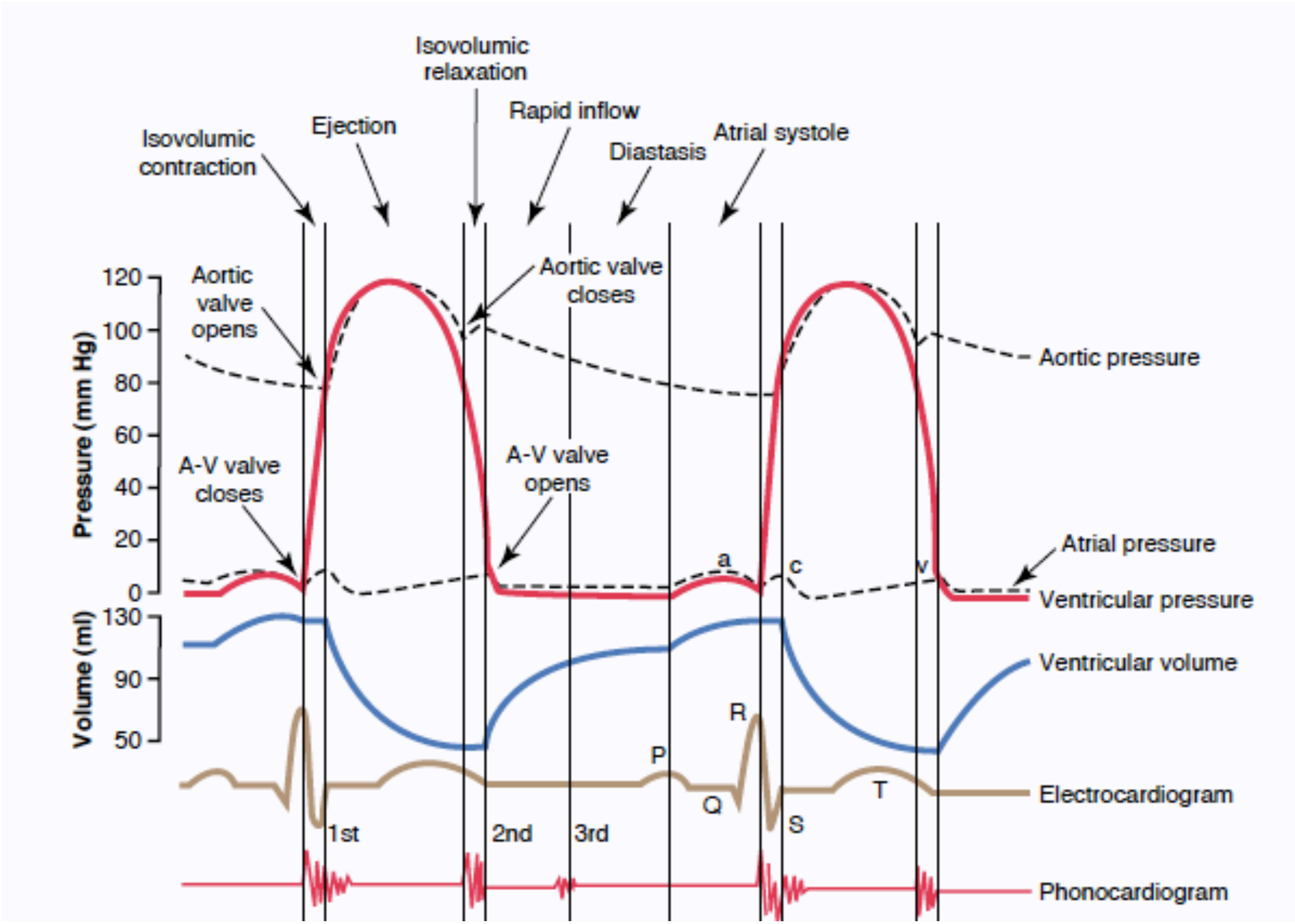


Figure 9–5

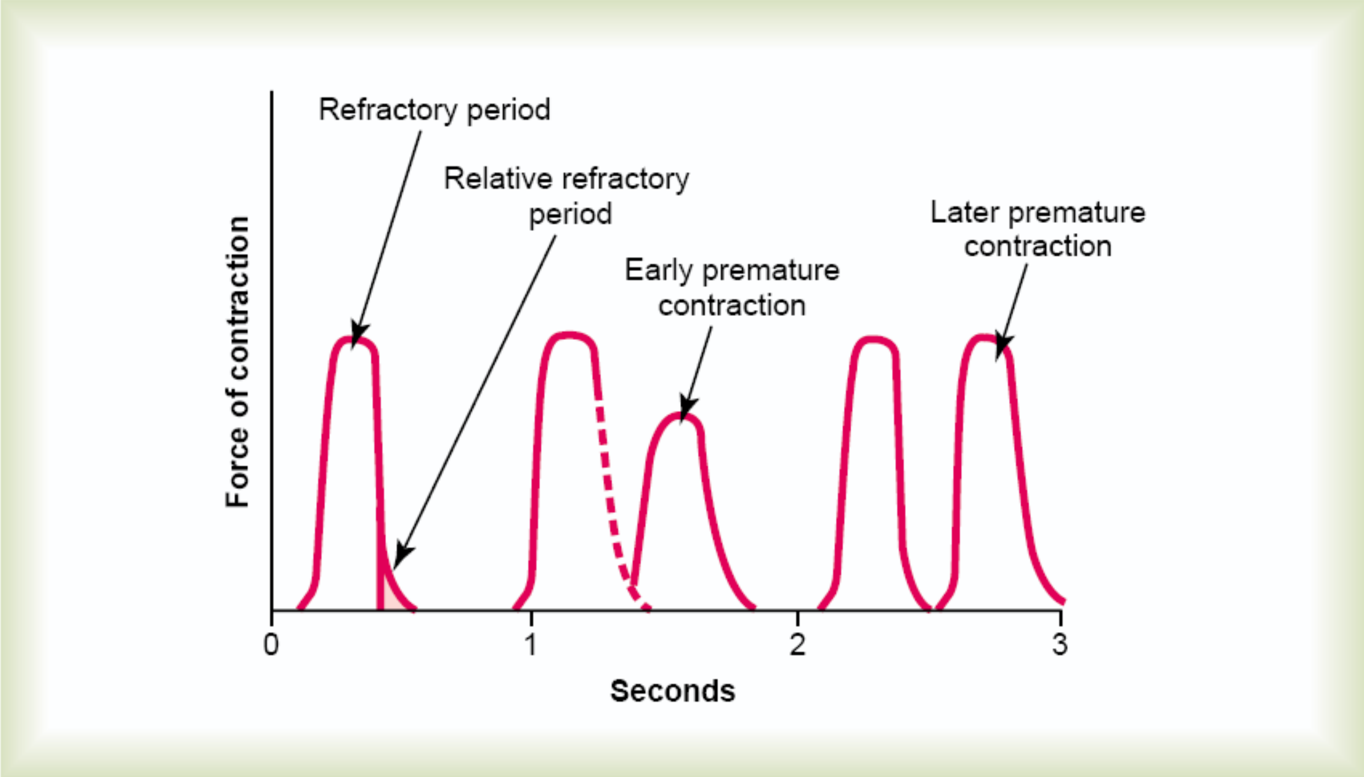
Events of the cardiac cycle for left ventricular function, showing changes in left atrial pressure, left ventricular pressure, aortic pressure, ventricular volume, the electrocardiogram, and the phonocardiogram.

Guyton et Hall Medical Physiology

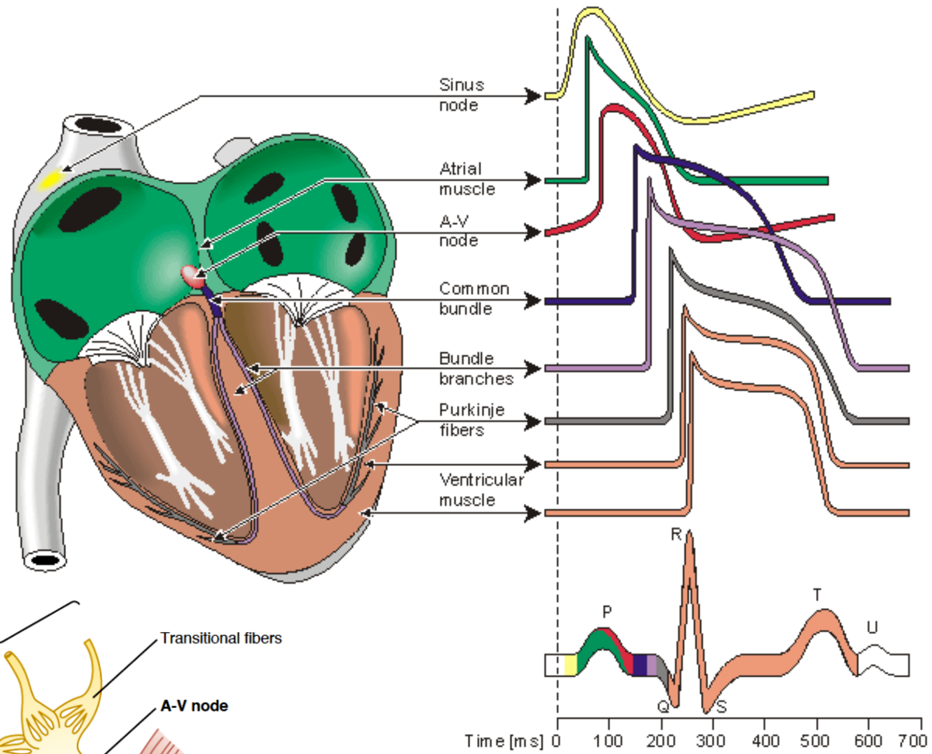
Coeur: excitation cardiaque et périodes réfractaires

Figure 9–4

Force of ventricular heart muscle contraction, showing also duration of the refractory period and relative refractory period, plus the effect of premature contraction. Note that premature contractions do not cause wave summation, as occurs in skeletal muscle.



Coeur: excitation cardiaque et séquence de dépolarisation du coeur



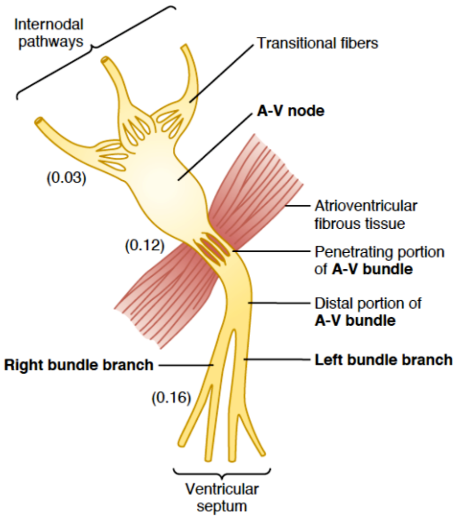


Figure 10–3

Organization of the A-V node. The numbers represent the interval of time from the origin of the impulse in the sinus node. The values have been extrapolated to human beings.

Electrophysiology of the heart. The different waveforms for each of the specialized cells found in the heart are shown. The latency shown approximates that normally found in the healthy heart

http://www.bem.fi/book/06/06.html

Respective speed of conduction in cardiac tissues

Purkinje fibers	1.5-4.0 m/sec
AV node	15-20 cm/sec
Cardiac cells	30-50 cm/sec

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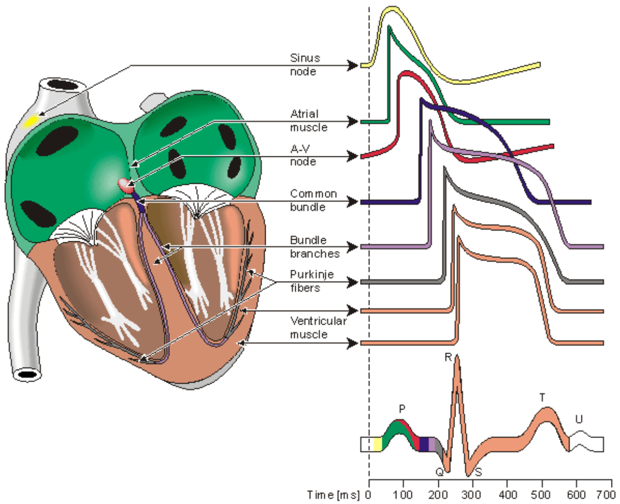
Coeur: excitation cardiaque et séquence de dépolarisation du cœur

La source du rythme cardiaque à 3 niveaux



Electric events in the heart

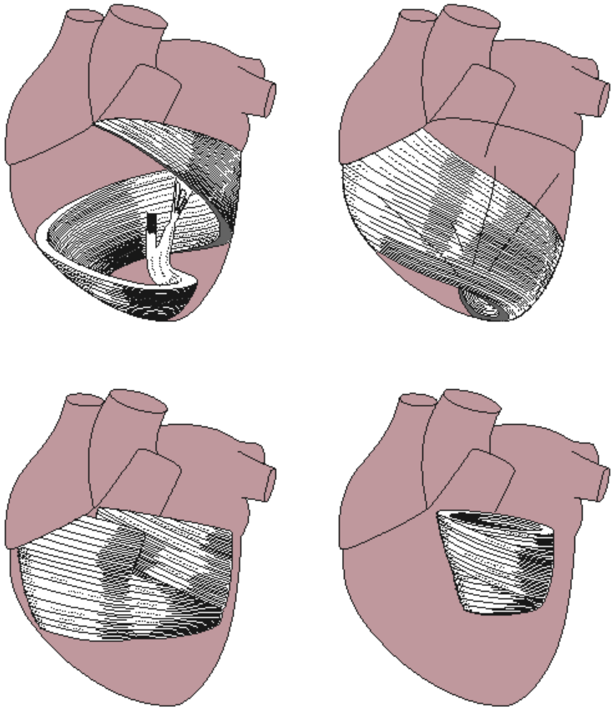
Location in the heart	Event	Time [ms]	ECG-terminology	Conduction velocity [m/s]	Intrinsic frequency [1/min]
SA node	impulse generated	0		0.05	70-80
atrium, Right	depolarization *)	5	P	0.8-1.0	50-60
Left	depolarization	85	P	0.8-1.0	
AV node	arrival of impulse	50	P-Q	0.02-0.05	
	departure of impulse	125	interval		
bundle of His	activated	130		1.0-1.5	
bundle branches	activated	145		1.0-1.5	
Purkinje fibers	activated	150		3.0-3.5	
endocardium					
Septum	depolarization	175		0.3 (axial)	20-40
Left ventricle	depolarization	190		-	
			QRS	0.8	
epicardium	depolarization	225		(transverse)	
Left ventricle	depolarization	250			
Right ventricle					
epicardium					
Left ventricle	repolarization	400			
Right ventricle	repolarization				
			T	0.5	
endocardium					
Left ventricle	repolarization	600			

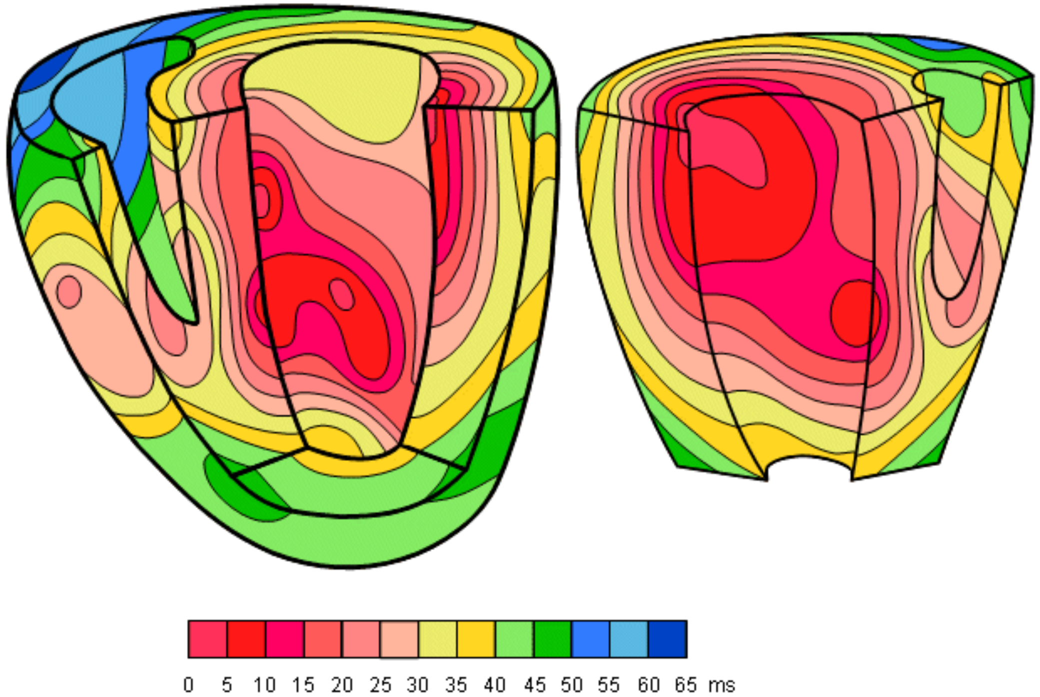
*) Atrial repolarization occurs during the ventricular depolarization; therefore, it is not normally seen in the electrocardiogram.

http://www.bem.fi/book/06/06.html

Coeur: excitation cardiaque et séquence de dépolarisation du cœur

Orientation des fibres et distribution de la dépolarisation

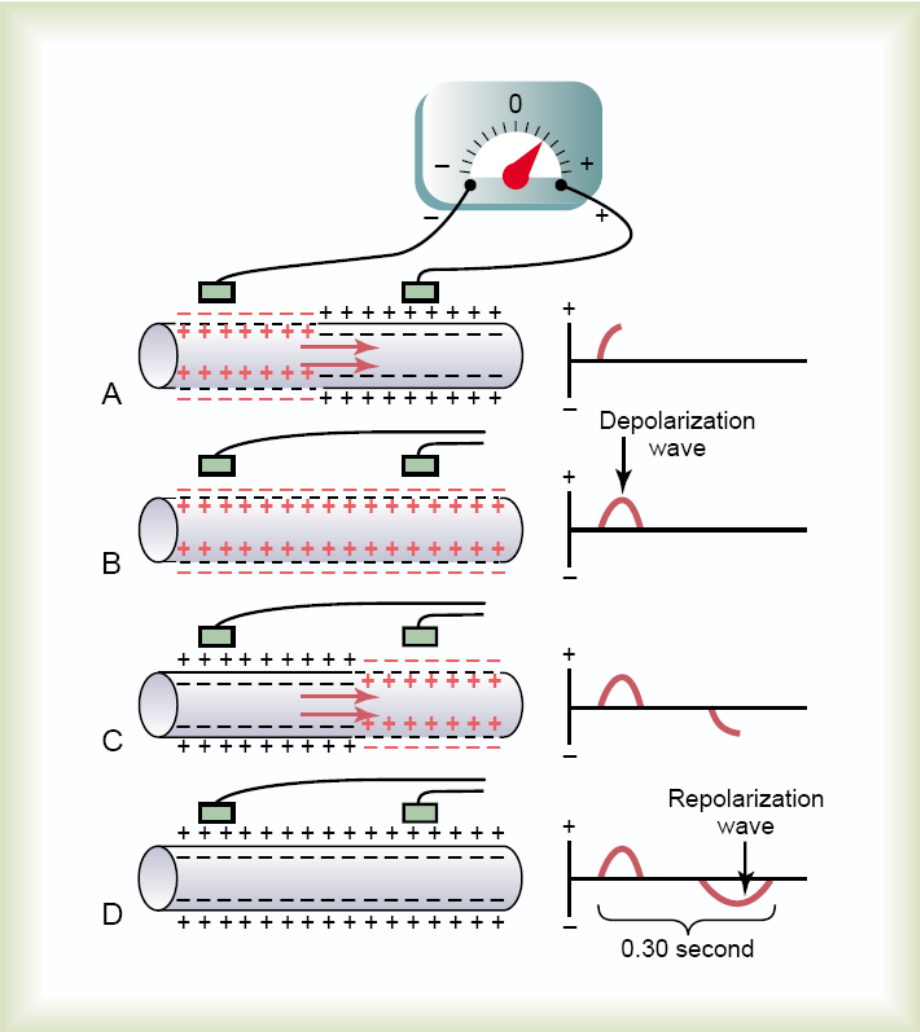




This figure is redrawn from experimental data. The ventricles are shown with the anterior wall of the left and partly that of the right ventricle opened. The isochronic surfaces clearly show that ventricular activation starts from the inner wall of the left ventricle and proceeds radially toward the epicardium. In the terminal part of ventricular activation, the excitation wavefront proceeds more tangentially.

http://www.bem.fi/book/06/06.html

Coeur: électrocardiogramme enregistrement de l'activité électrique du coeur



Recording the *depolarization wave* (*A* and *B*) and the *repolarization wave* (*C* and *D*) from a cardiac muscle fiber.

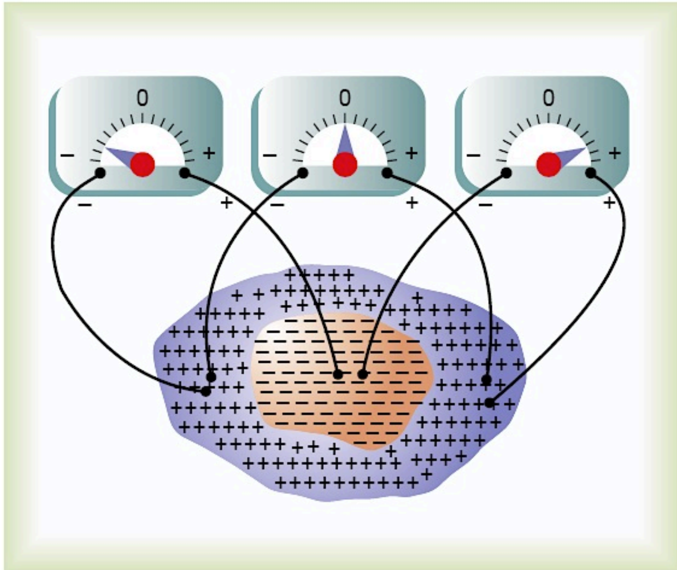


Figure 11–4

Instantaneous potentials develop on the surface of a cardiac muscle mass that has been depolarized in its center.

Coeur: électrocardiogramme enregistrement de l'activité électrique du cœur

Exemple d'un tracé ECG normal

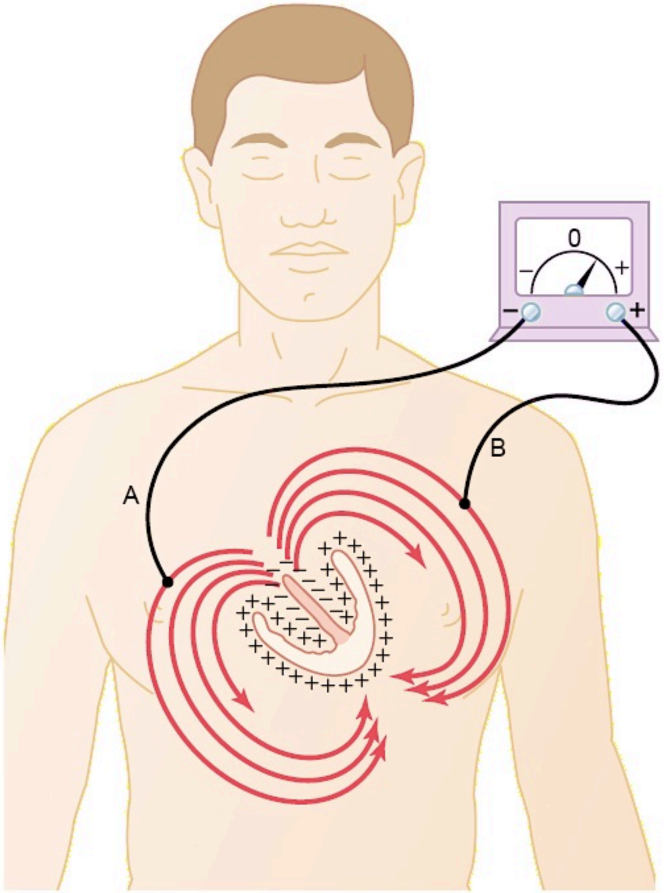


Figure 11–5

Flow of current in the chest around partially depolarized ventricles.

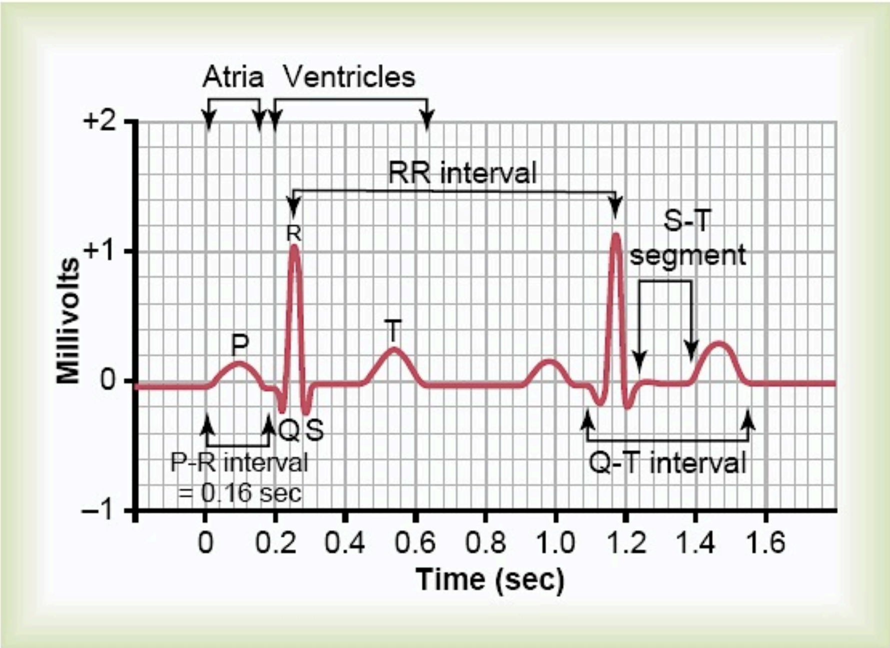


Figure 11–1

Normal electrocardiogram.

Coeur: électrocardiogramme enregistrement de l'activité électrique du cœur

Exemple de dérivations standards de l'ECG

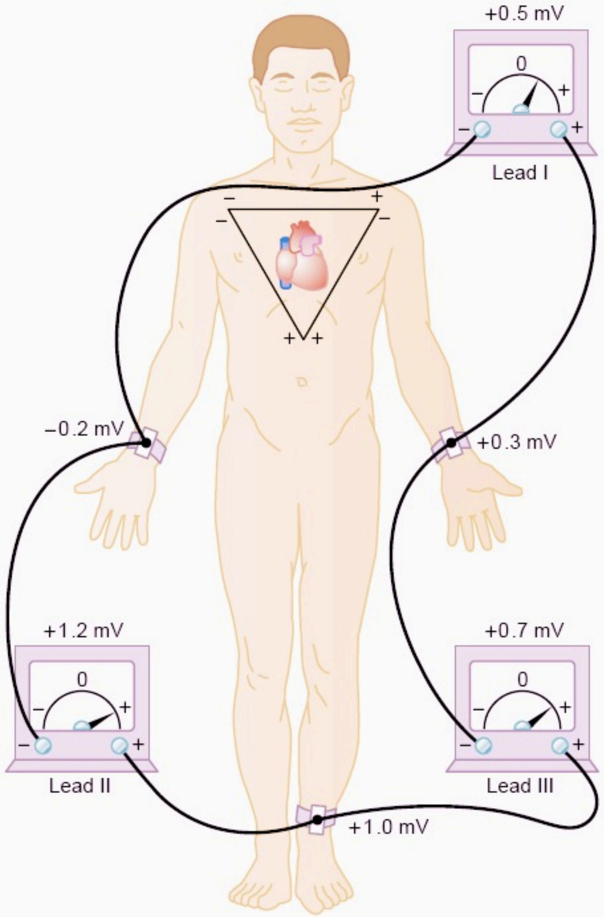


Figure 11–6

Conventional arrangement of electrodes for recording the standard electrocardiographic leads. Einthoven's triangle is superimposed on the chest.

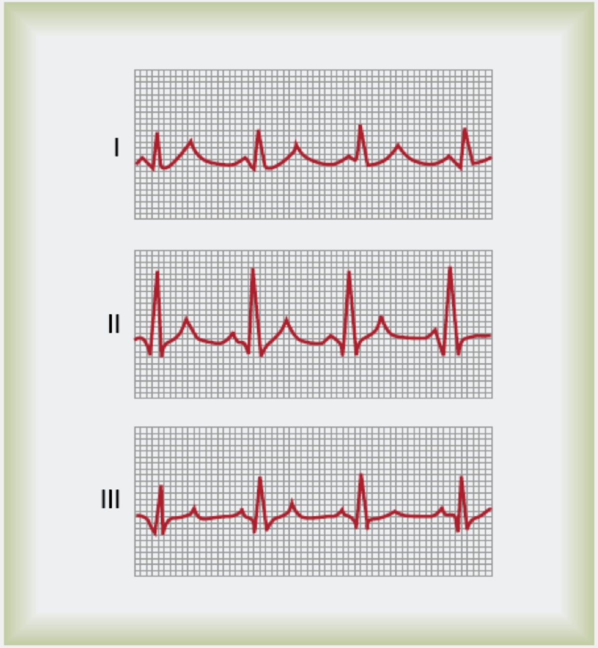


Figure 11–7

Normal electrocardiograms recorded from the three *standard* electrocardiographic leads.

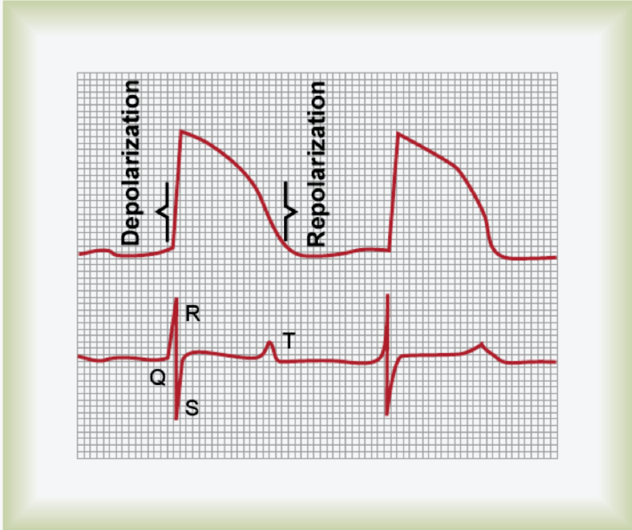


Figure 11–3

Above, Monophasic action potential from a ventricular muscle fiber during normal cardiac function, showing rapid depolarization and then repolarization occurring slowly during the plateau stage but rapidly toward the end. *Below,* Electrocardiogram recorded simultaneously.

Coeur: Résumé

The electrical activity of the heart is automatic and rhythmic and precedes the mechanical activity

The electrical activity of the heart is generated in the pacemaker (nodal) cells and spreads along preferential pathways: conducting apparatus

The propagation of cardiac action potentials takes place along the cell membranes and through the GAP

The ventricular depolarization propagates from the subendocardial to subepicardial muscular layers (from interior to exterior)

The ventricular repolarization propagates from the subepicardial to subendocardial muscular layers (from exterior to interior) this results from subepicardial action potentials being of shorter duration

At every instant the electrical fields of each individual cardiac fibre sum into a resulting vector that can be recorded from the body surface with respect to time: ECG

The vector summation of QRS complexes allows to determine the electrical axis of the heart

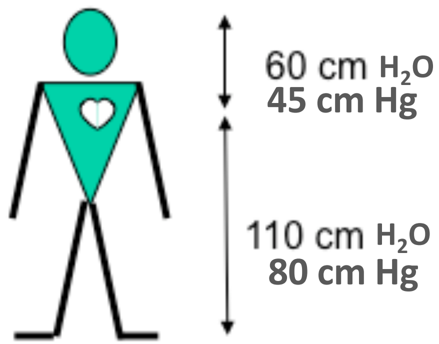
The spatial image of the heart electrical activity may be obtained directly by vectocardiography

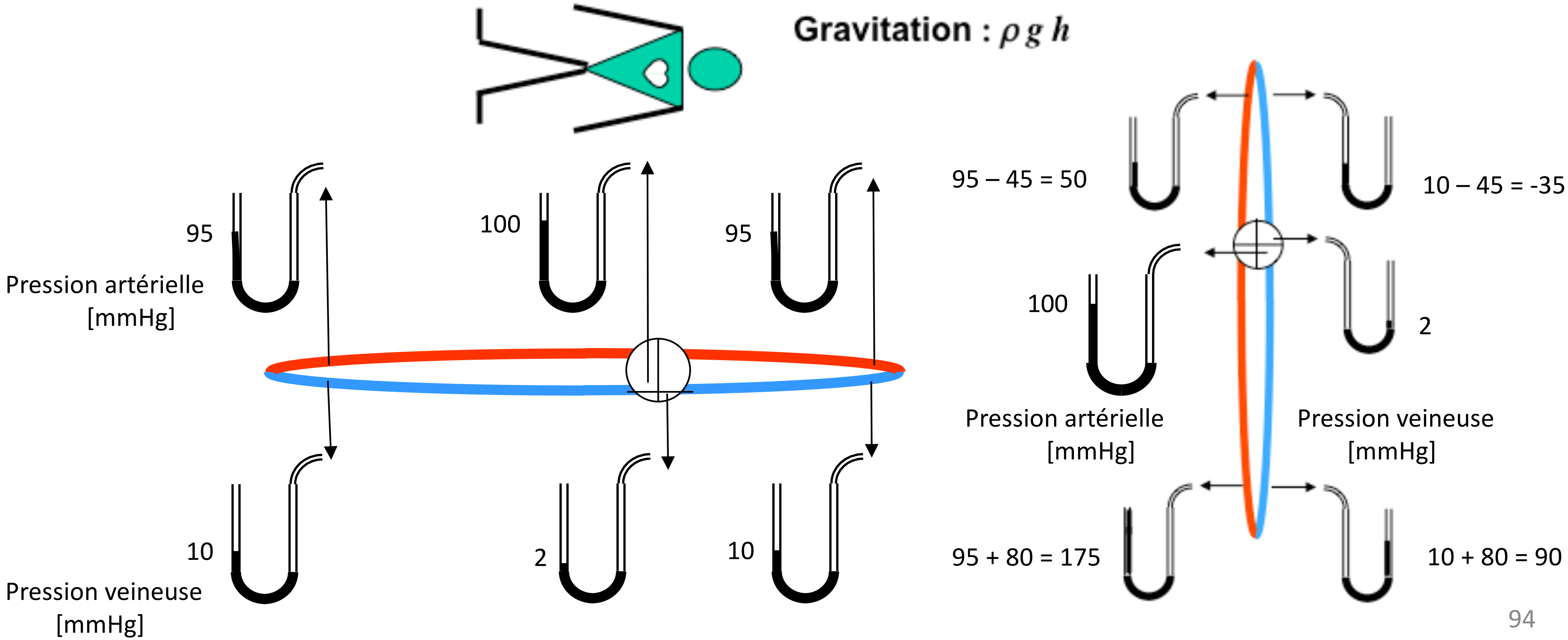
The entry of calcium into the cardiac cell activates the actin-myosin interaction: **cardiac contraction**

Vaisseaux (Veines)

Veines: larges avec des parois très fines (grande compliance)
➔ les veines sont les réservoirs du sang

En position debout, la pression veineuse devient:
infra-atmosphérique dans la tête et le cou (-*mgh*)
élevée dans l'abdomen et les jambes (+*mgh*): *risque d'oedème*





Vaisseaux (Veines)

Débit veineux = $\frac{\text{(P veineuse périphérique – P veineuse centrale)}}{\text{Résistance veineuse}}$

~ 5-10 mm Hg

très basse

comme le Q_c

Les veines sont larges et ont des parois très minces (grande compliance -> les veines sont les réservoirs du sang)

De part la confluence vasculaire, la vitesse du sang augmente, mais le flux est moins pulsé.

Aux extrémités (mais pas dans le crâne ou le thorax) , les veines ont des valves

Le retour veineux est augmenté par:
- la position couchée (choc: élévation des extrémités)
- contraction veineuse (mobilisation des réserves de sang)
- inspirations profondes
- compression des veines par les muscles squelettiques