

Fondamenti di bioingegneria

***Laurea in
Ingegneria Informatica, Biomedica e delle
Telecomunicazioni***

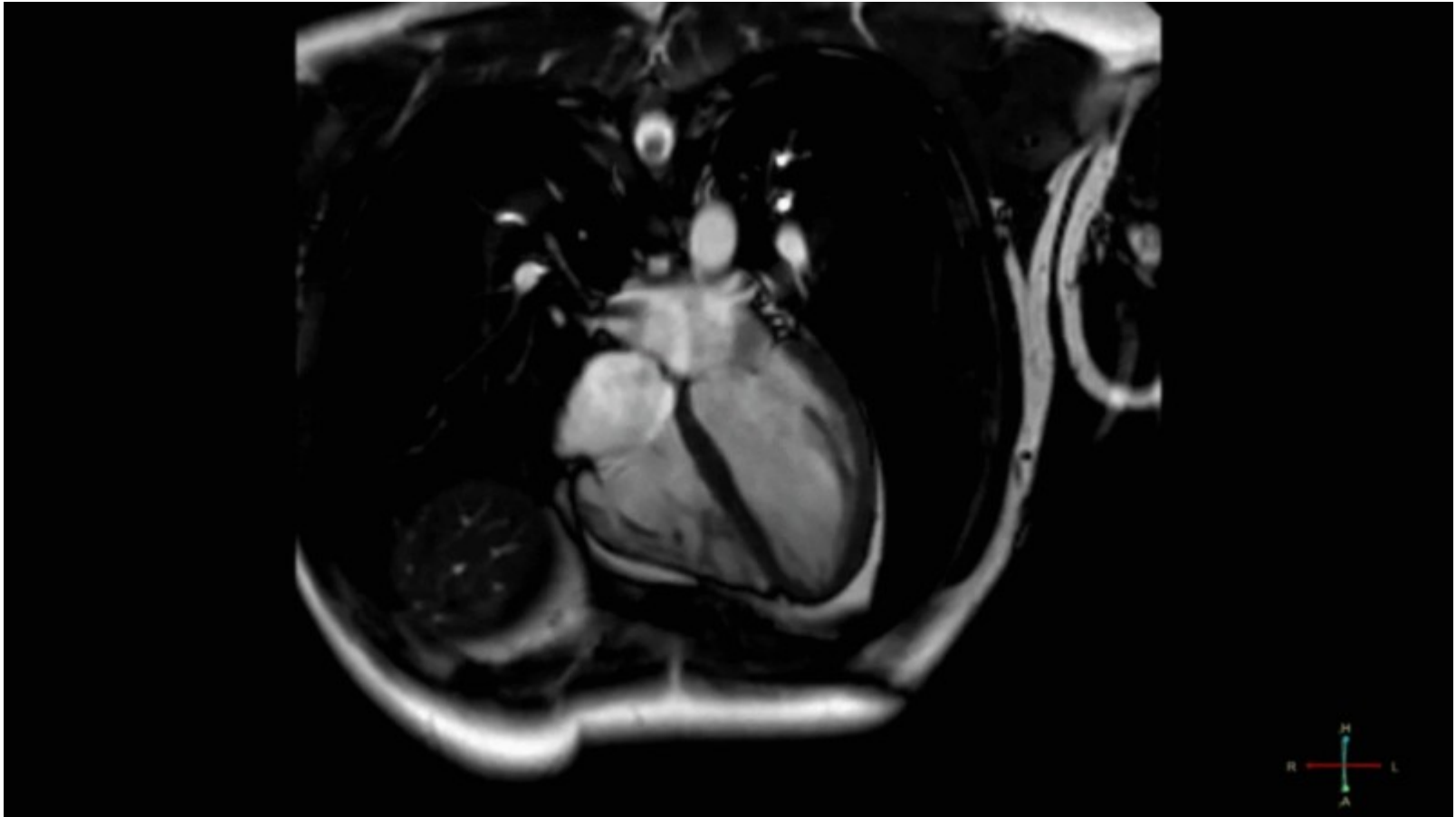
Fabio Baselice



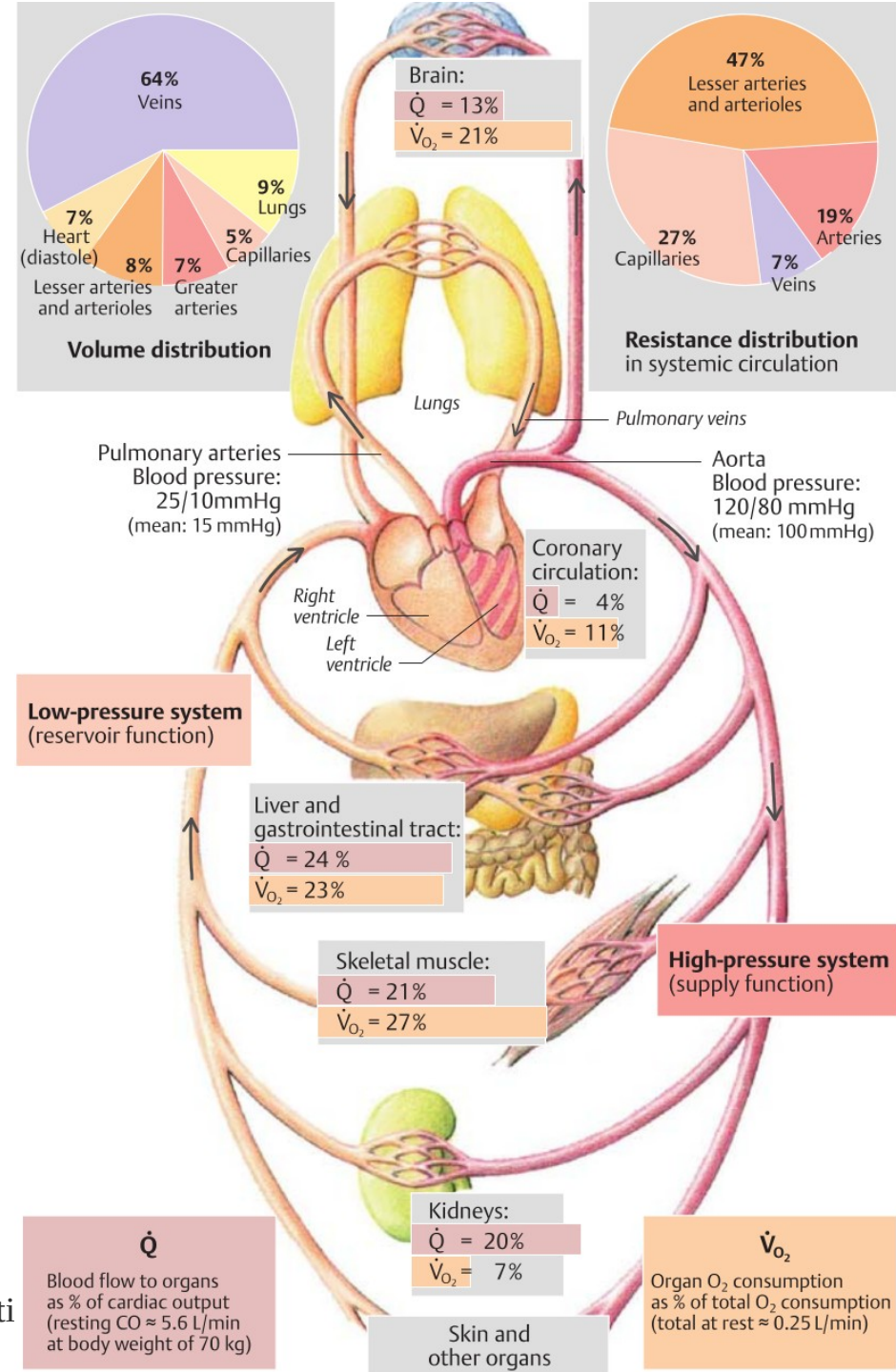
Argomenti

- Elettrocardiogramma (ECG)

L'attività cardiaca



L'attività cardiaca



Il sistema cardiovascolare.

L'attività cardiaca

I vasi sanguigni.

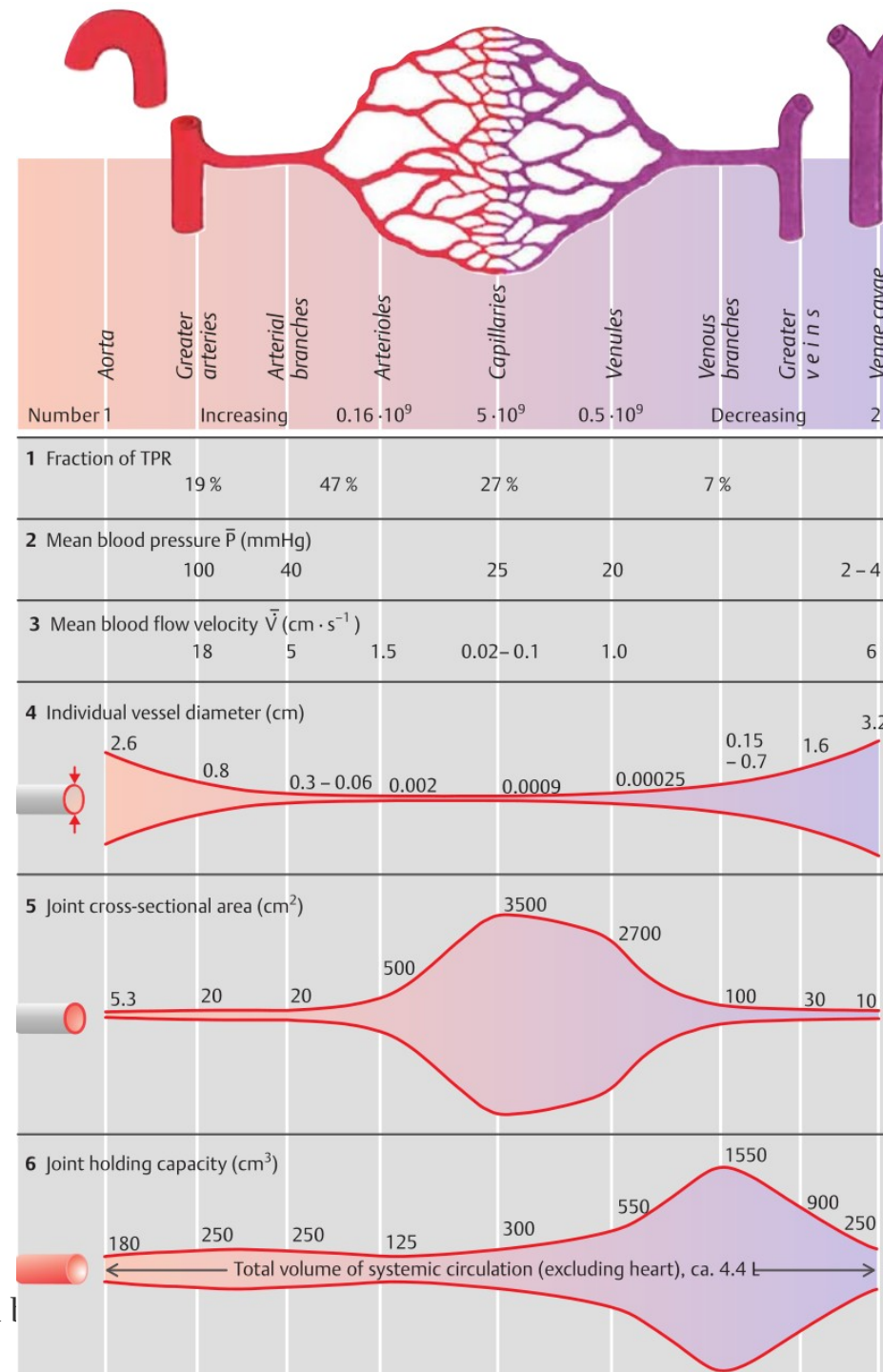
Vale la legge di Ohm:

$$\Delta P = \dot{Q} \cdot R$$

ΔP differenza di pressione

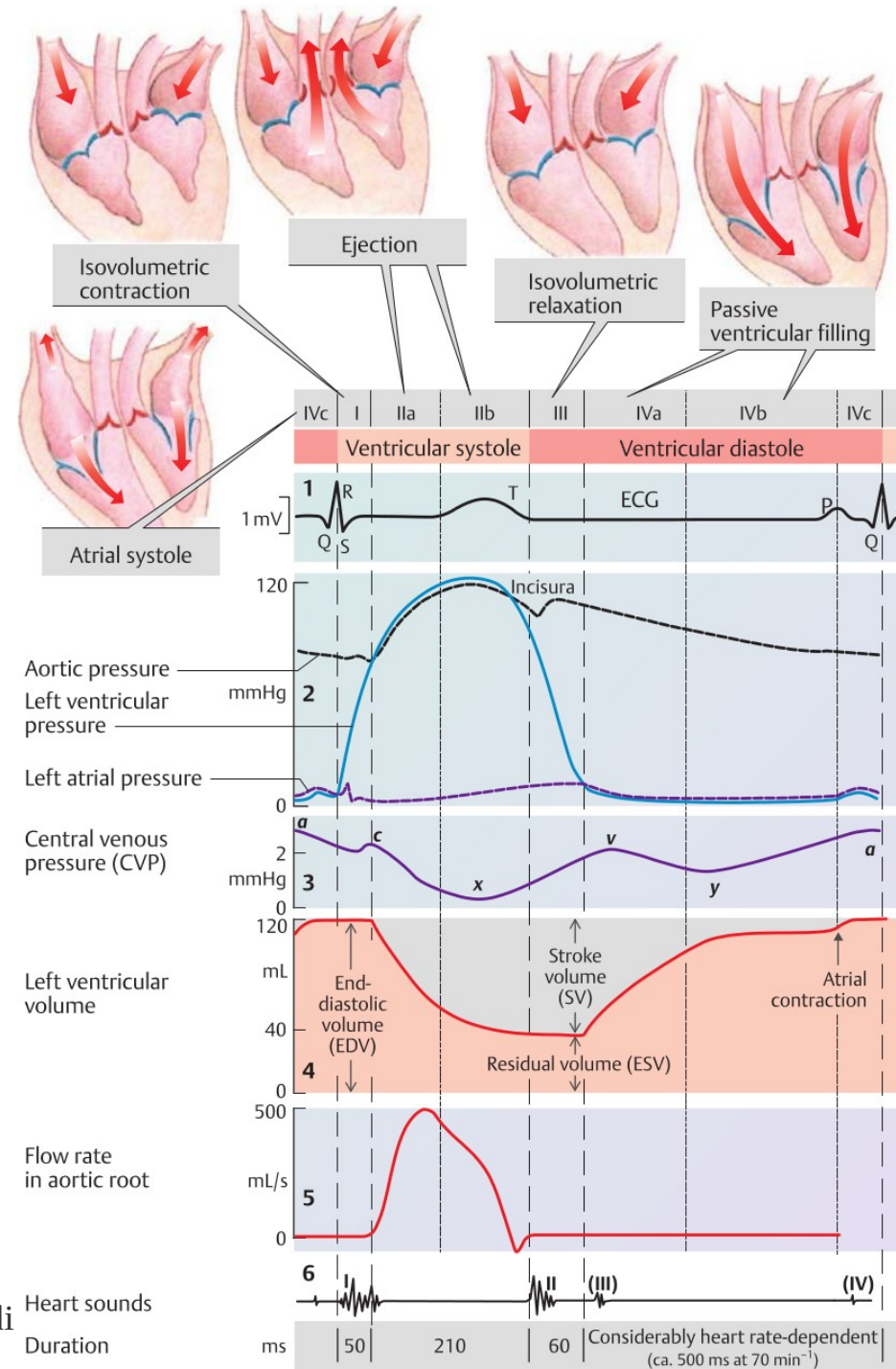
$\dot{Q}$ flusso sanguigno

R resistenza al flusso

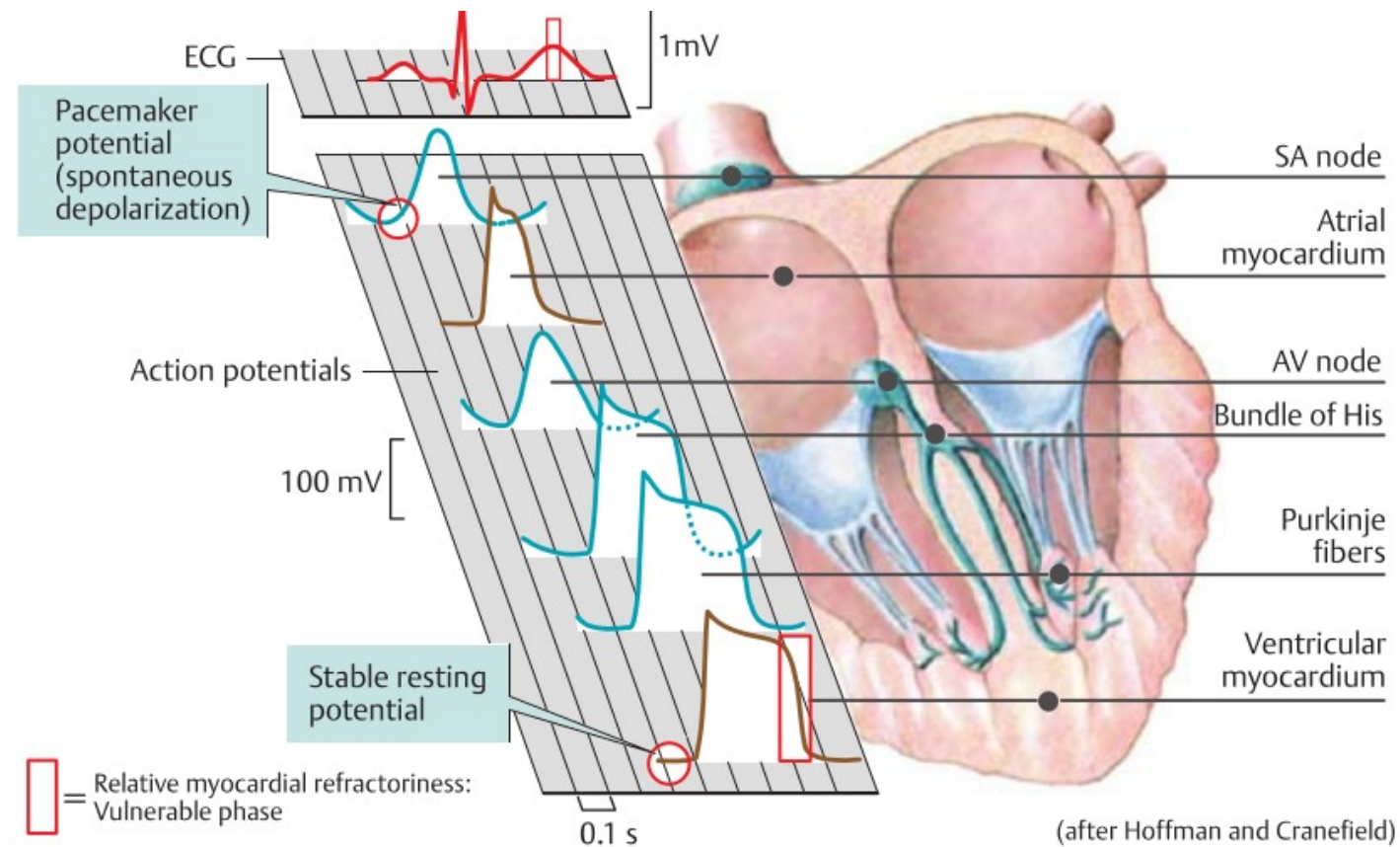


L'attività cardiaca

Il ciclo cardiaco.

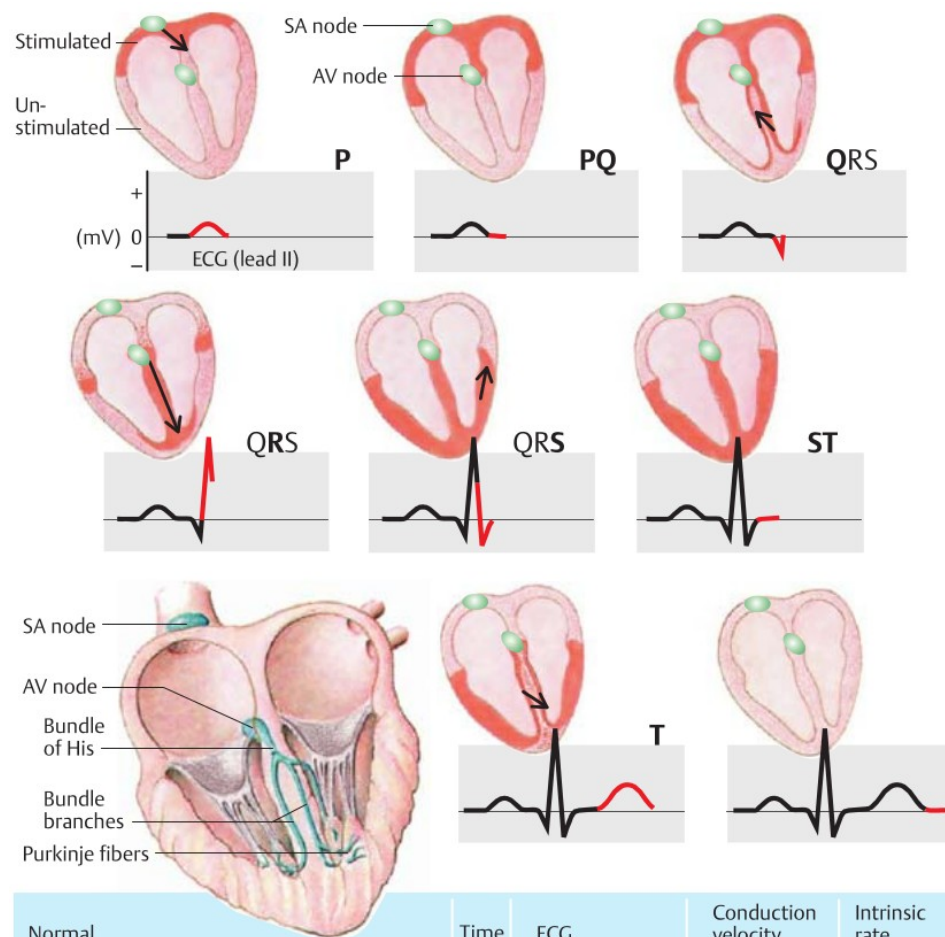


L'attività cardiaca



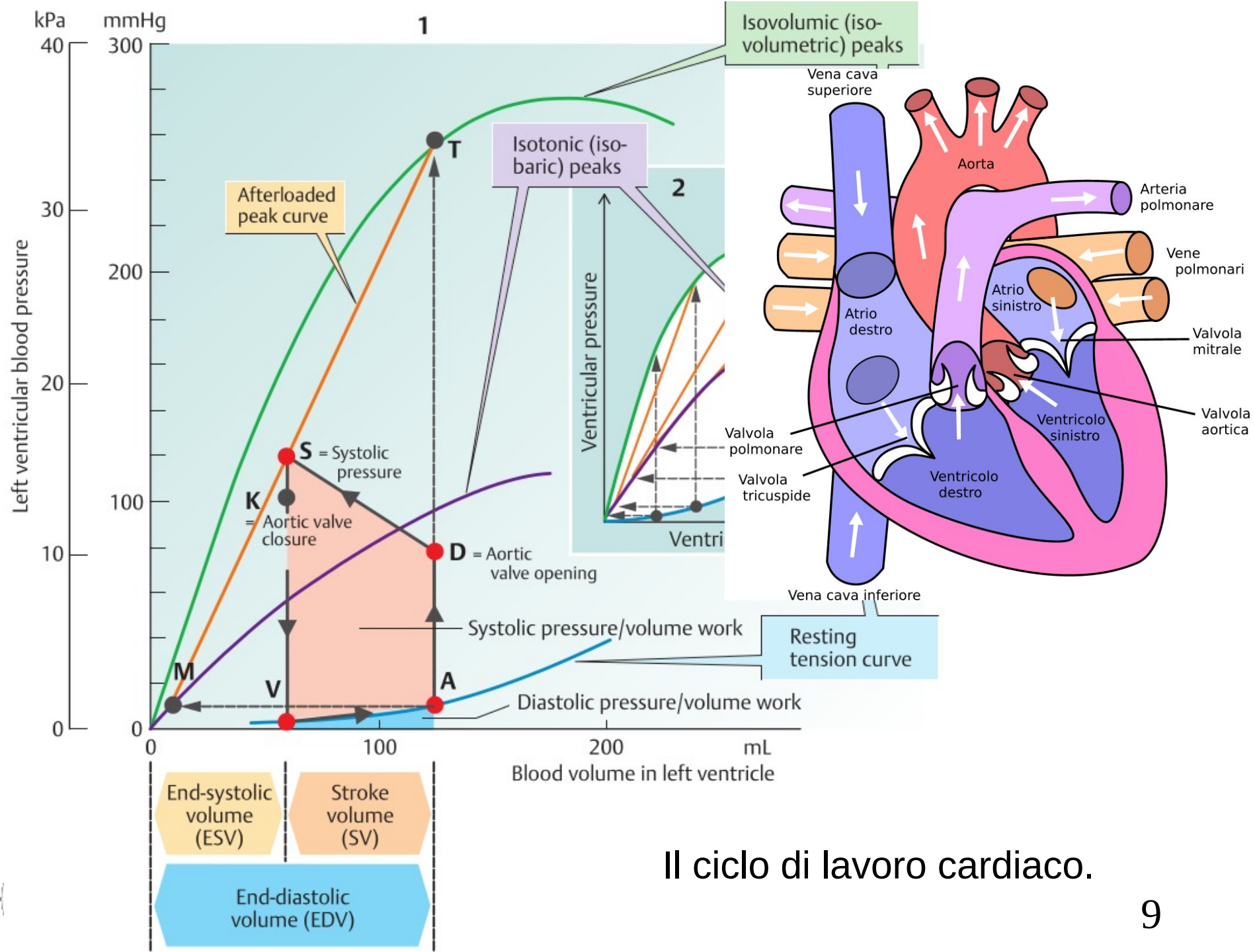
Eccitazione cardiaca: nodo seno-atriale → nodo atrio-ventricolare → fascio di His → fibre del Purkinje

L'attività cardiaca

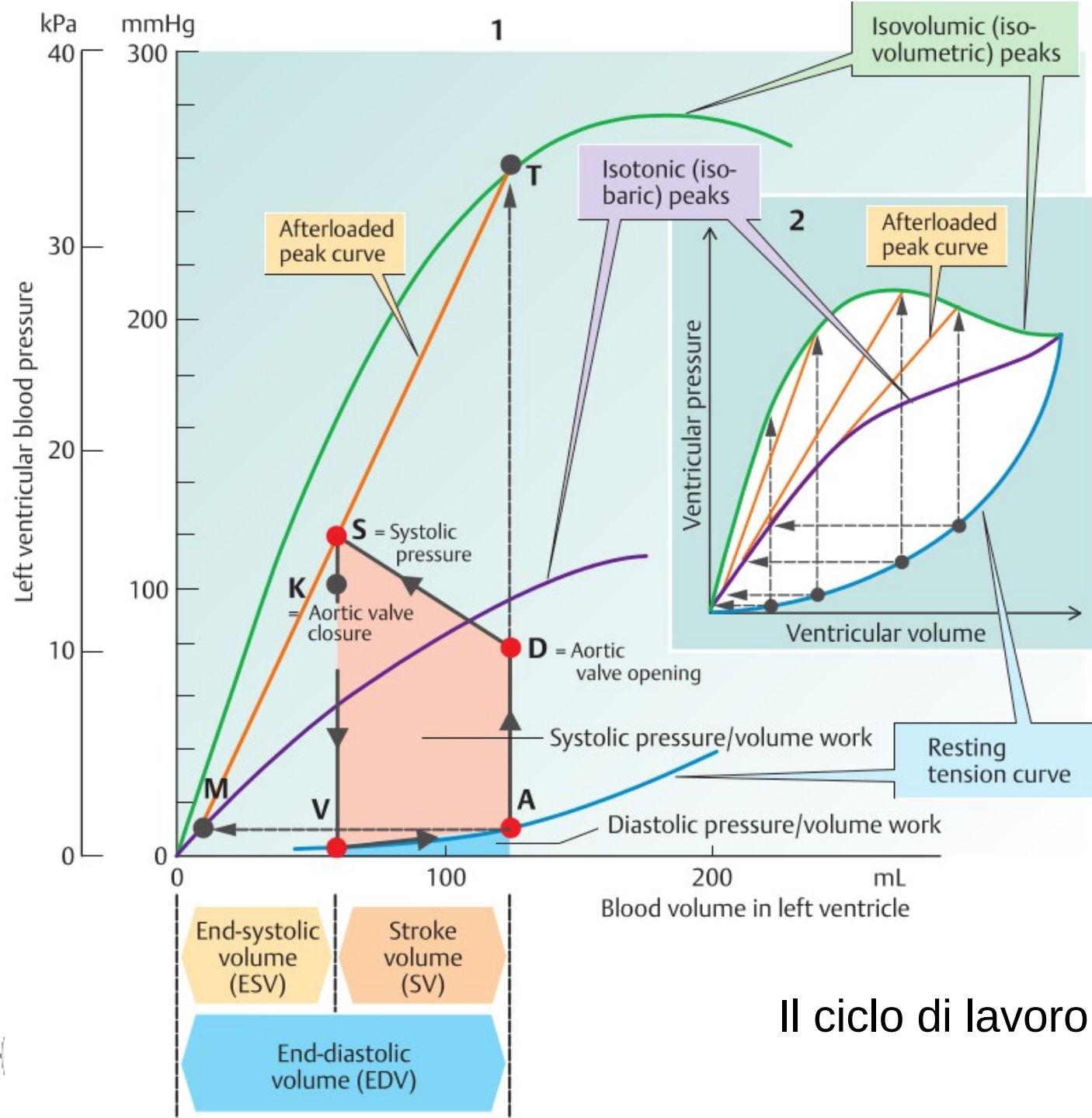


Propagazione dell'impulso cardiaco.

Normal activation sequence	Time (ms)	ECG	Conduction velocity ($\text{m} \cdot \text{s}^{-1}$)	Intrinsic rate (min^{-1})
SA node Impulse generation Arrival of impulse in distal parts of atrium	0 50 85	P wave	0.05	 60–100
AV node Arrival of impulse Relaying of impulse	50 125	P-Q segment (delayed conduction)	0.8–1.0 in atrium	 40–55
His bundle activated	130		0.05	
End of bundle branches activated	145		1.0–1.5	
Purkinje fibers activated	150	QRS complex	1.0–1.5	 25–40
Inner myocardium { Right ventricle completely activated Left ventricle	175 190		3.0–3.5	
Outer myocardium { Right ventricle completely activated Left ventricle	205 225		1.0 in myocardium	
				None



Il ciclo di lavoro cardiaco.



Il ciclo di lavoro cardiaco.

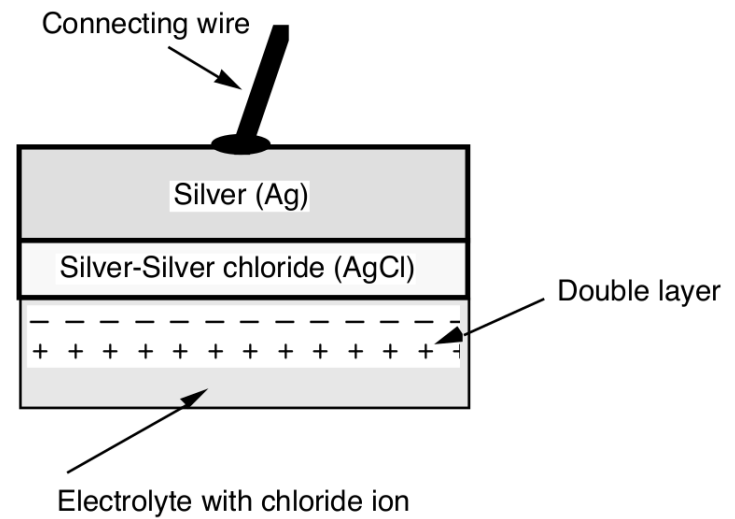
Elettrocardiogramma

L'elettrocardiogramma consente di dedurre difetti elettrici o meccanici del cuore tramite l'analisi di potenziali elettrici misurati sulla superficie del corpo.

Vi sono 3 tecniche di base usate in elettrocardiografia clinica:

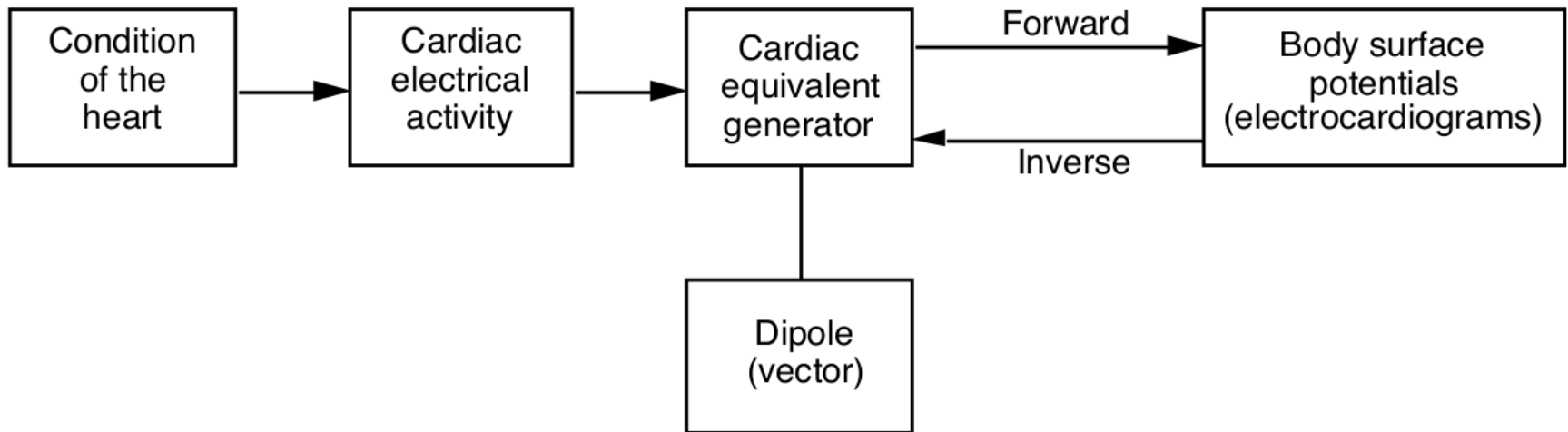
- ECG clinico standard - 12 leads
- Vettocardiogramma (VCG) - 3 leads ortogonali
- Monitoraggio ECG - 1 o 2 leads

Elettrocardiogramma

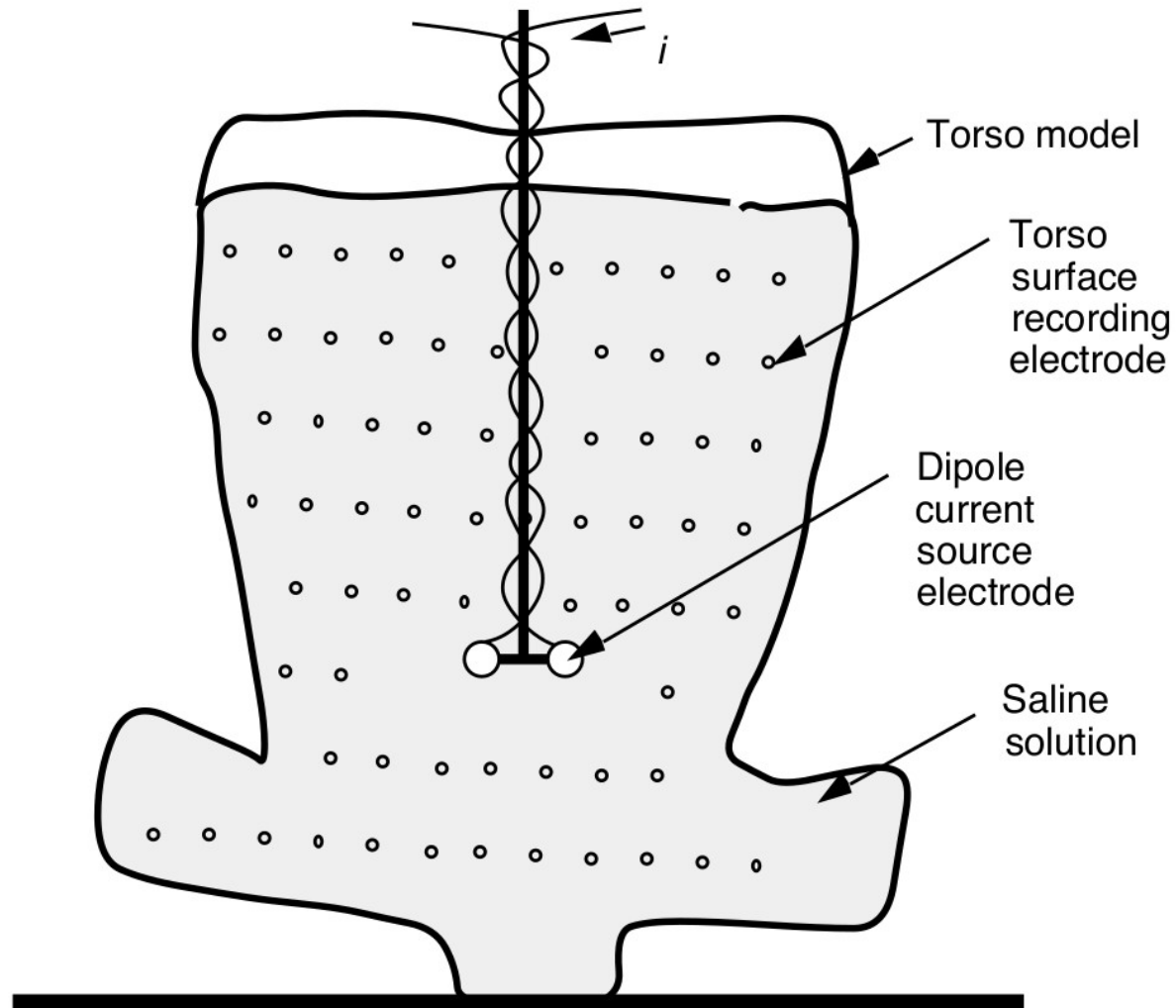


Elettrodi

Generatore Equivalente Cardiaco



Modello elettrico del torace di Frank



Modello del torace di Frank

Il potenziale misurato in ciascun punto n sulla superficie del corpo è dato dalla somma del prodotto di un insieme di coefficienti di trasferimento per le componenti dei vettori dei dipoli corrispondenti, ovvero:

$$v_n(t) = t_{nx} p_x(t) + t_{ny} p_y(t) + t_{nz} p_z(t)$$

Considerando k leads perveniamo alla formulazione vettoriale:

$$\mathbf{V}_{k \times 1} = \mathbf{T}_{k \times 3} \times \mathbf{P}_{3 \times 1}$$

dove $\mathbf{V}$ contiene le misure e $\mathbf{P}$ descrive il vettore cardiaco.



Modello del torace di Frank

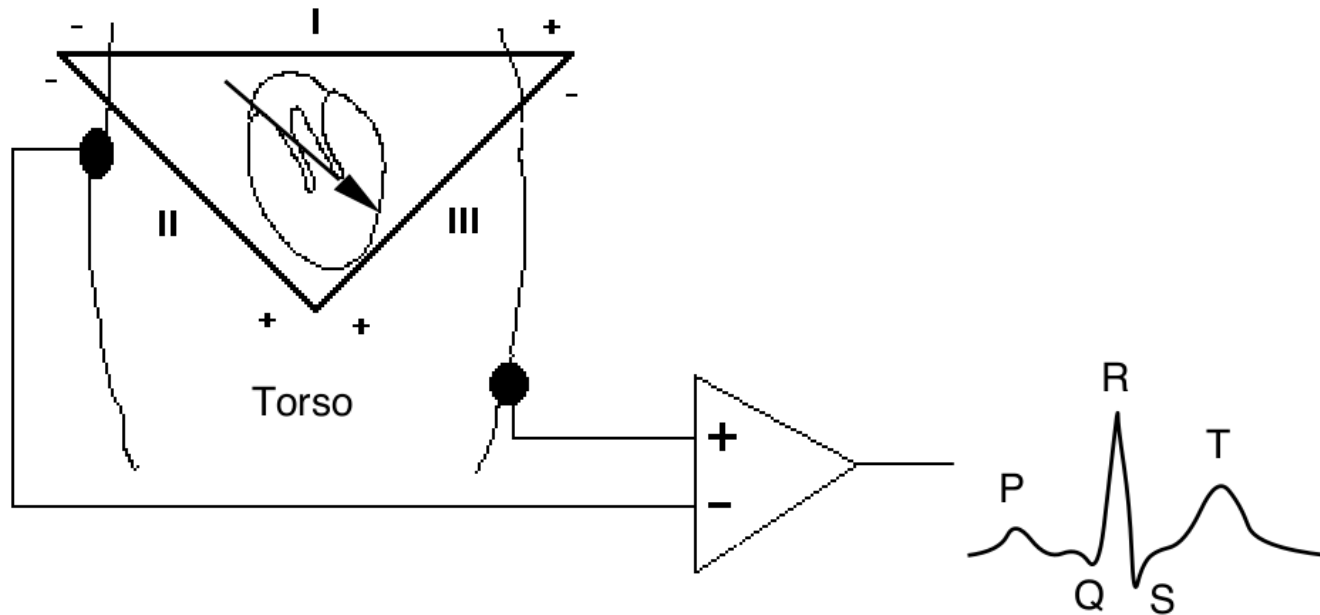
La matrice di trasformazione T varia da persona a persona, ma può essere standardizzata tramite un modello fisico del torso. A questo punto a partire dalle misure possiamo calcolare il vettore di dipolo cardiaco:

$$\mathbf{P} = \mathbf{B} \times \mathbf{V}$$

dove $\mathbf{B}$ è una matrice $3 \times k$ ottenuta dall'inversione di T . Pertanto le componenti di $\mathbf{P}$ sono calcolate come:

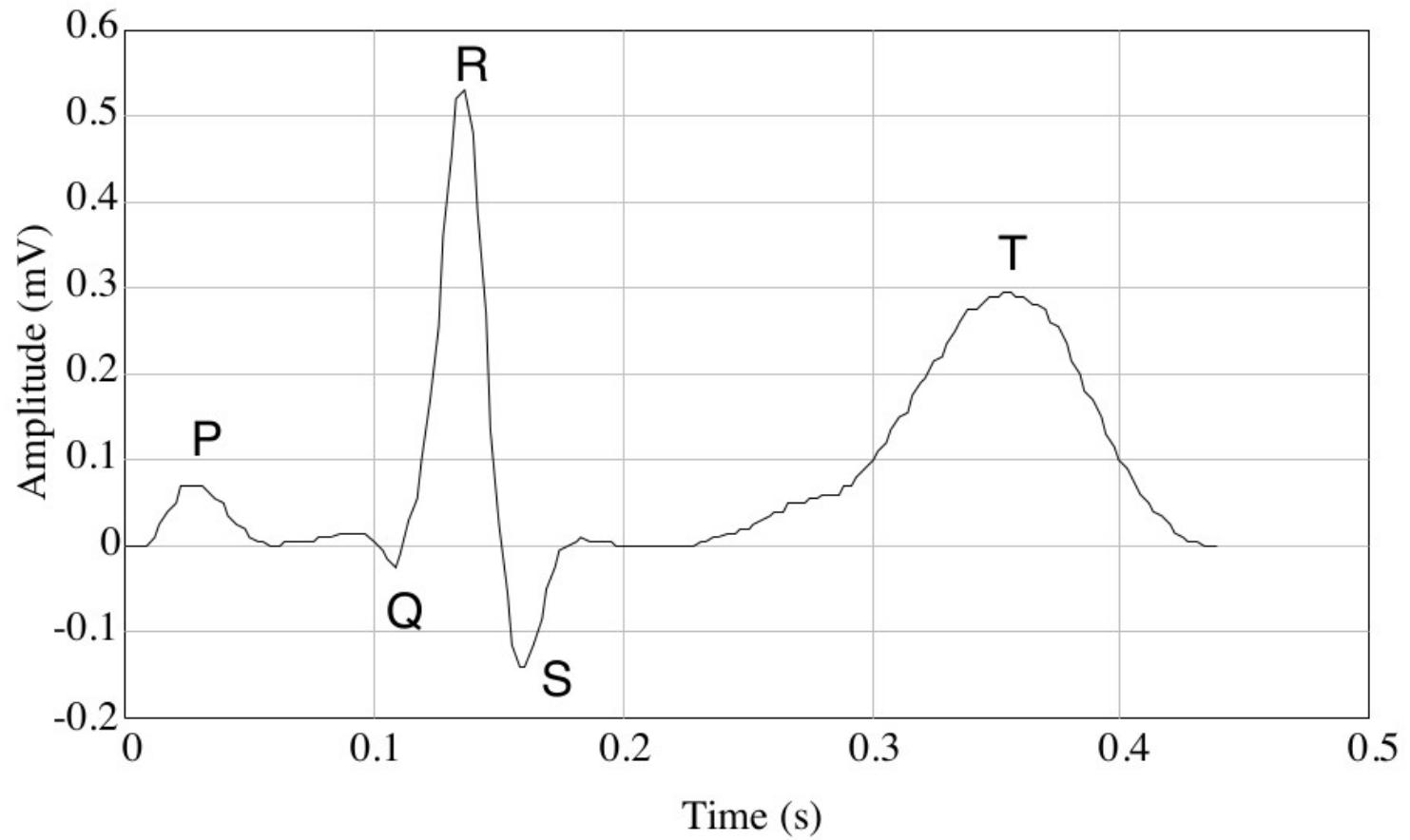
$$\begin{aligned} p_x(t) &= b_{x1} v_1(t) + b_{x2} v_2(t) + \dots + b_{xk} v_k(t) \\ p_y(t) &= b_{y1} v_1(t) + b_{y2} v_2(t) + \dots + b_{yk} v_k(t) \\ p_z(t) &= b_{z1} v_1(t) + b_{z2} v_2(t) + \dots + b_{zk} v_k(t) \end{aligned}$$

ECG

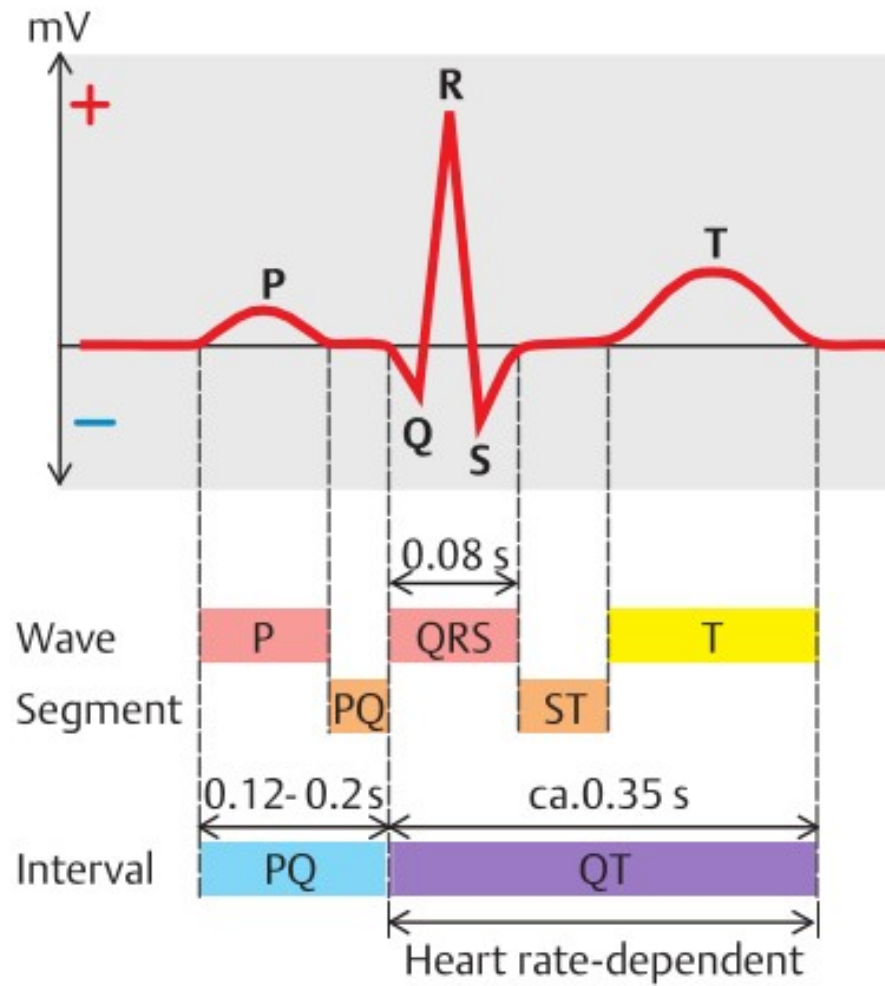


Esempio di un ECG. In base ai terminali dell'amplificatore cambia il segno del segnale registrato. Un tipico segnale ECG relativo ad un battito viene decomposto in 5 onde: P, Q, R, S, T.

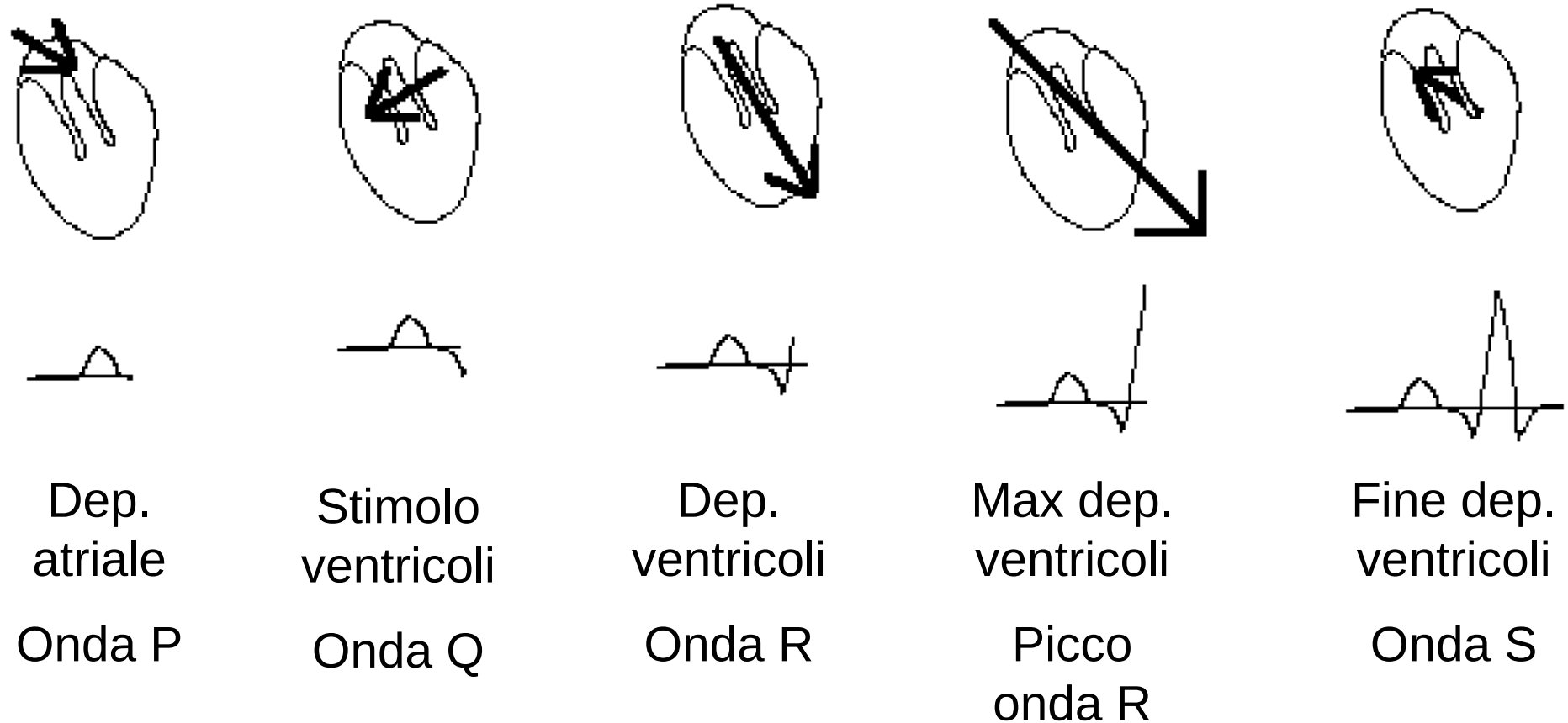
ECG



ECG

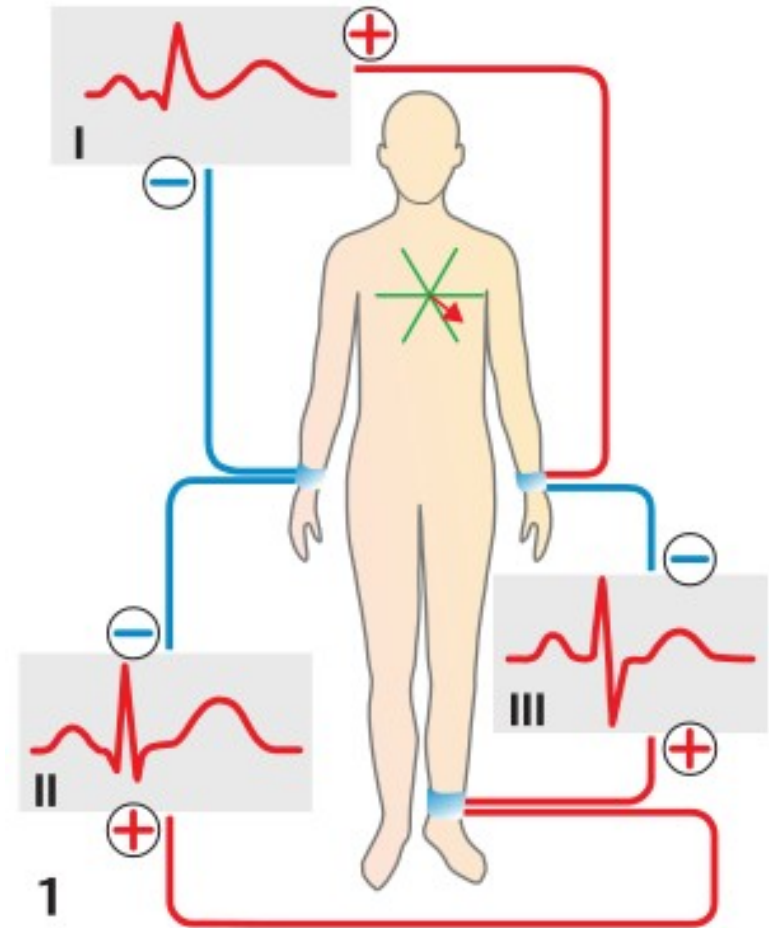


ECG



Vettore di eccitazione cardiaca e complesso PQRS.

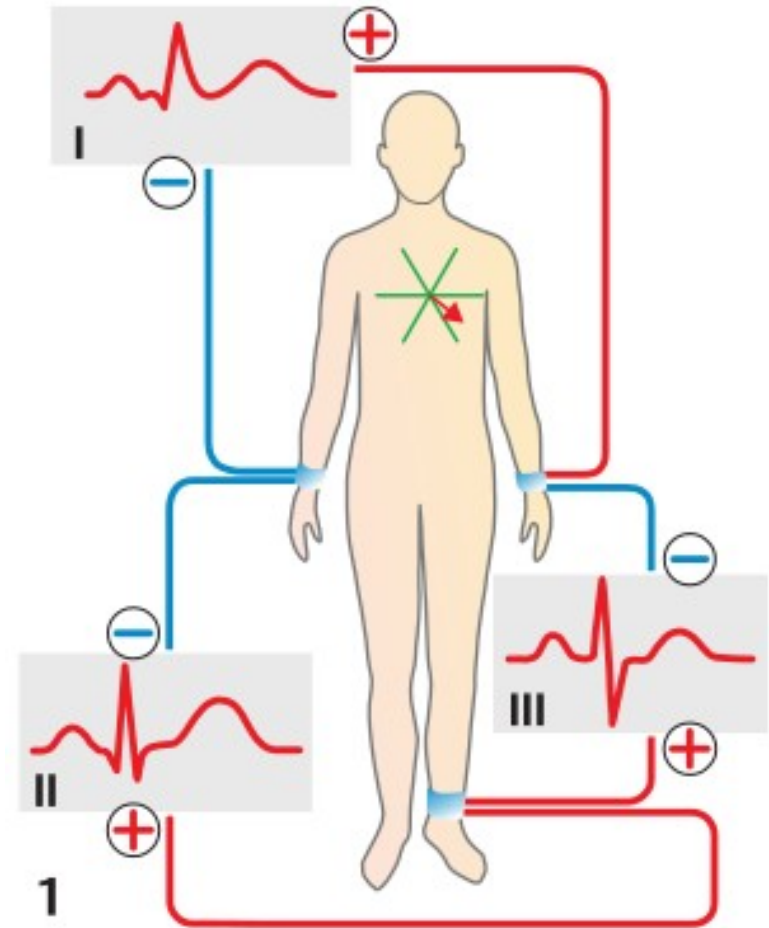
Triangolo equilatero di Einthoven



Triangolo equilatero di Einthoven

Einthoven ha postulato che l'eccitazione elettrica cardiaca può essere descritta da un vettore.

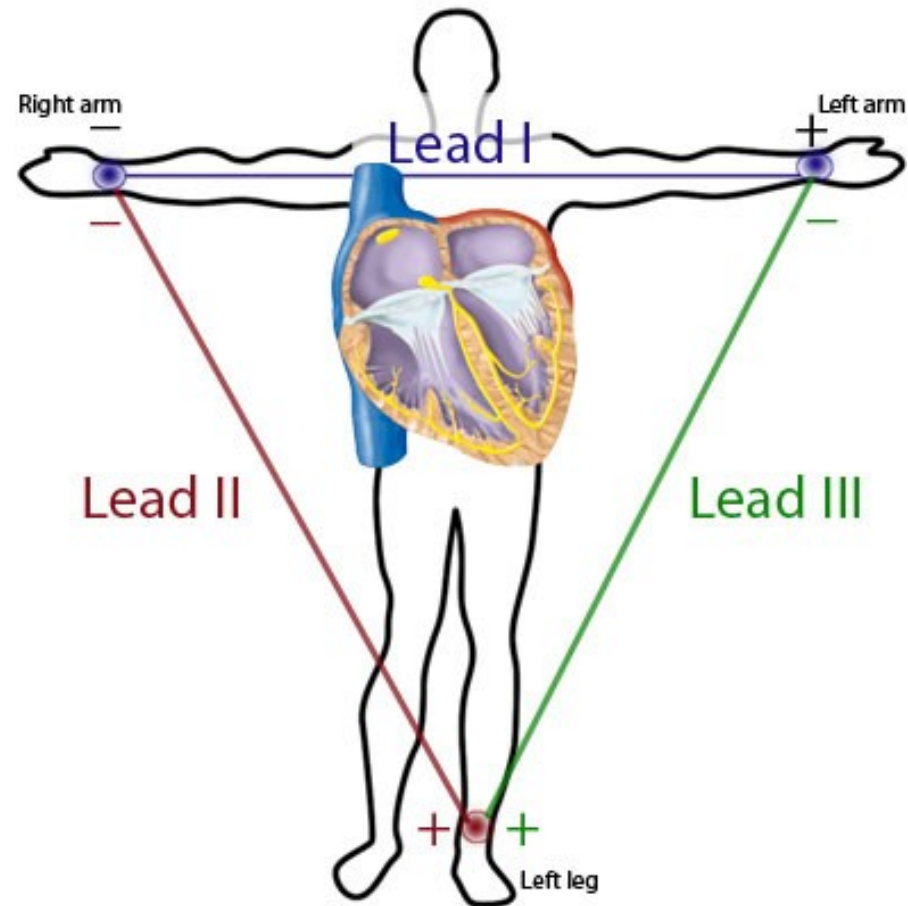
Ciascun lato del suo triangolo descrive una componente del vettore cardiaco, ed è registrato come differenza di potenziale fra una coppia di arti.



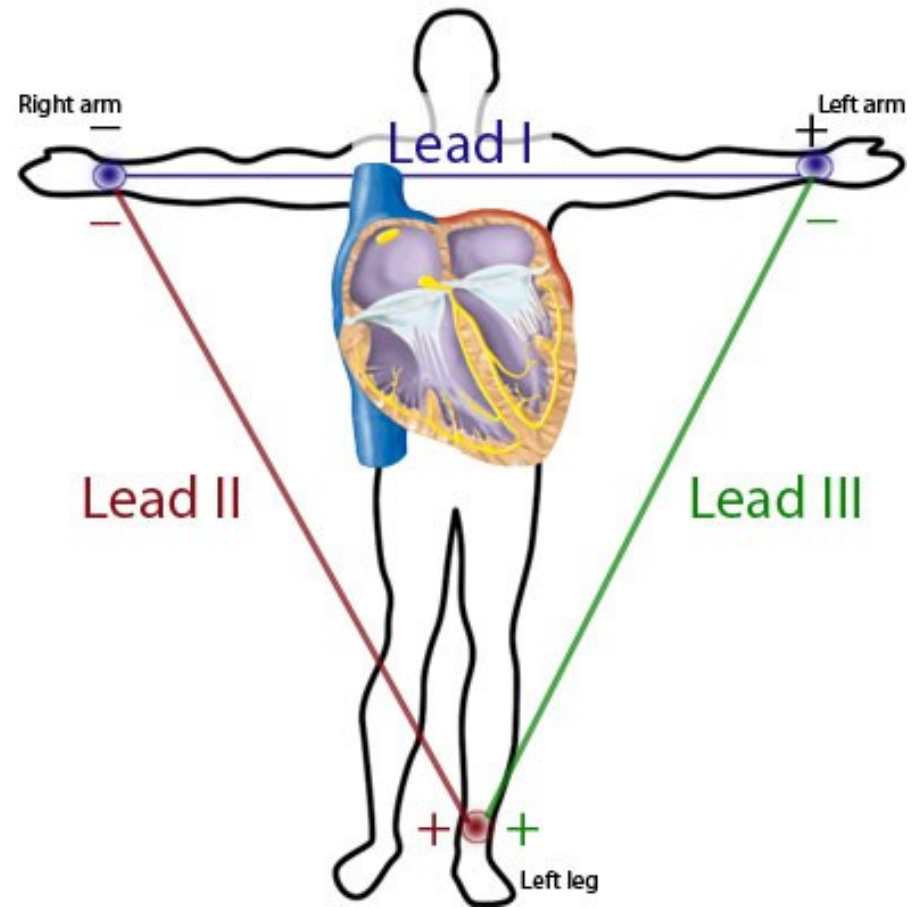
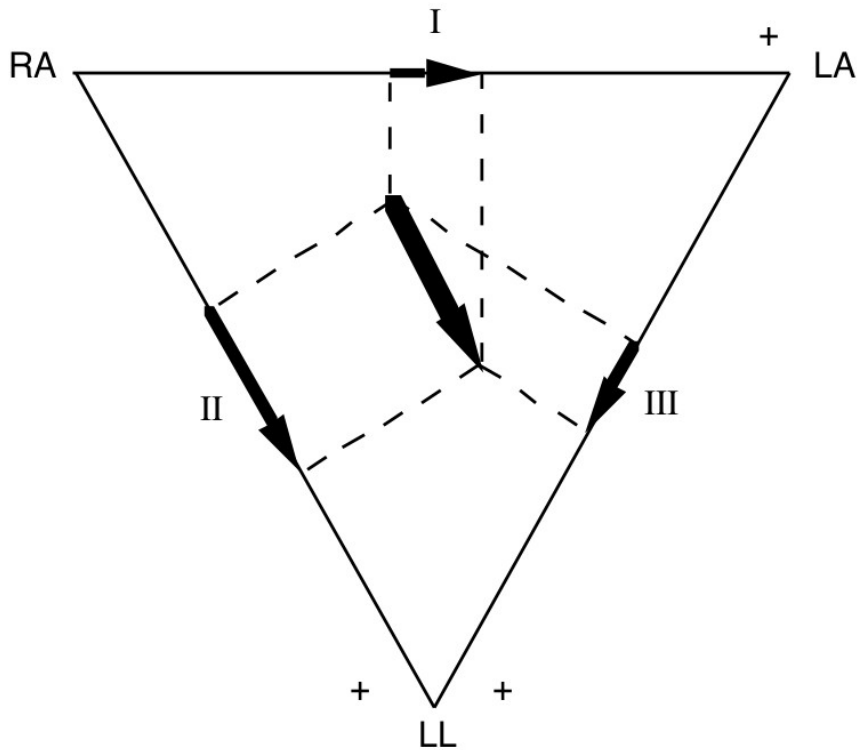
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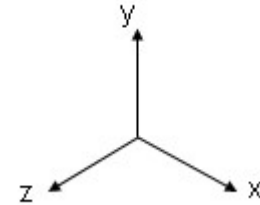
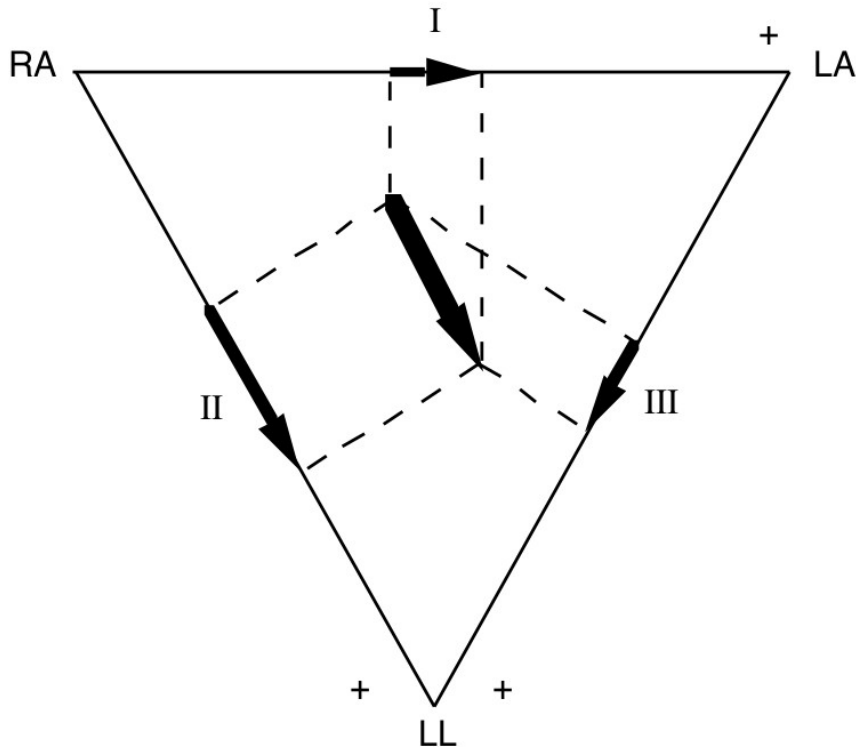
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Triangolo equilatero di Einthoven



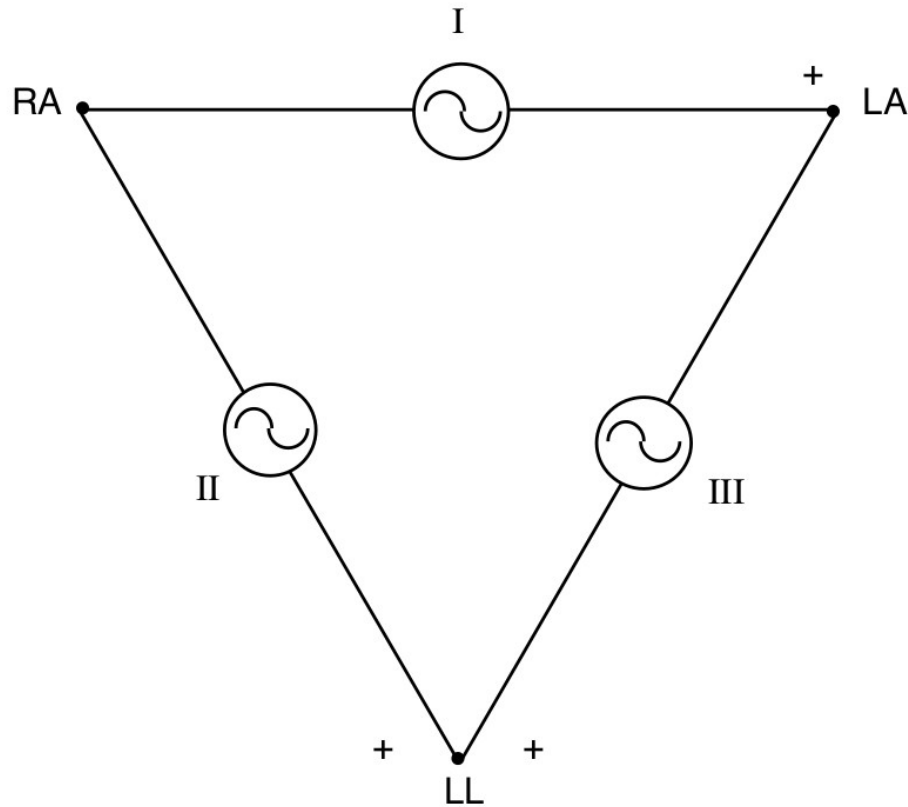
Triangolo equilatero di Einthoven



$$\mathbf{p}(t) = p_x(t)\hat{\mathbf{x}} + p_y(t)\hat{\mathbf{y}} + p_z(t)\hat{\mathbf{z}}$$

Il vettore cardiaco (tempo variante) può essere decomposto in componenti ortogonali.

Standard limb leads



Per la legge di Kirchhoff:

$$II - I - III = 0$$

da cui:

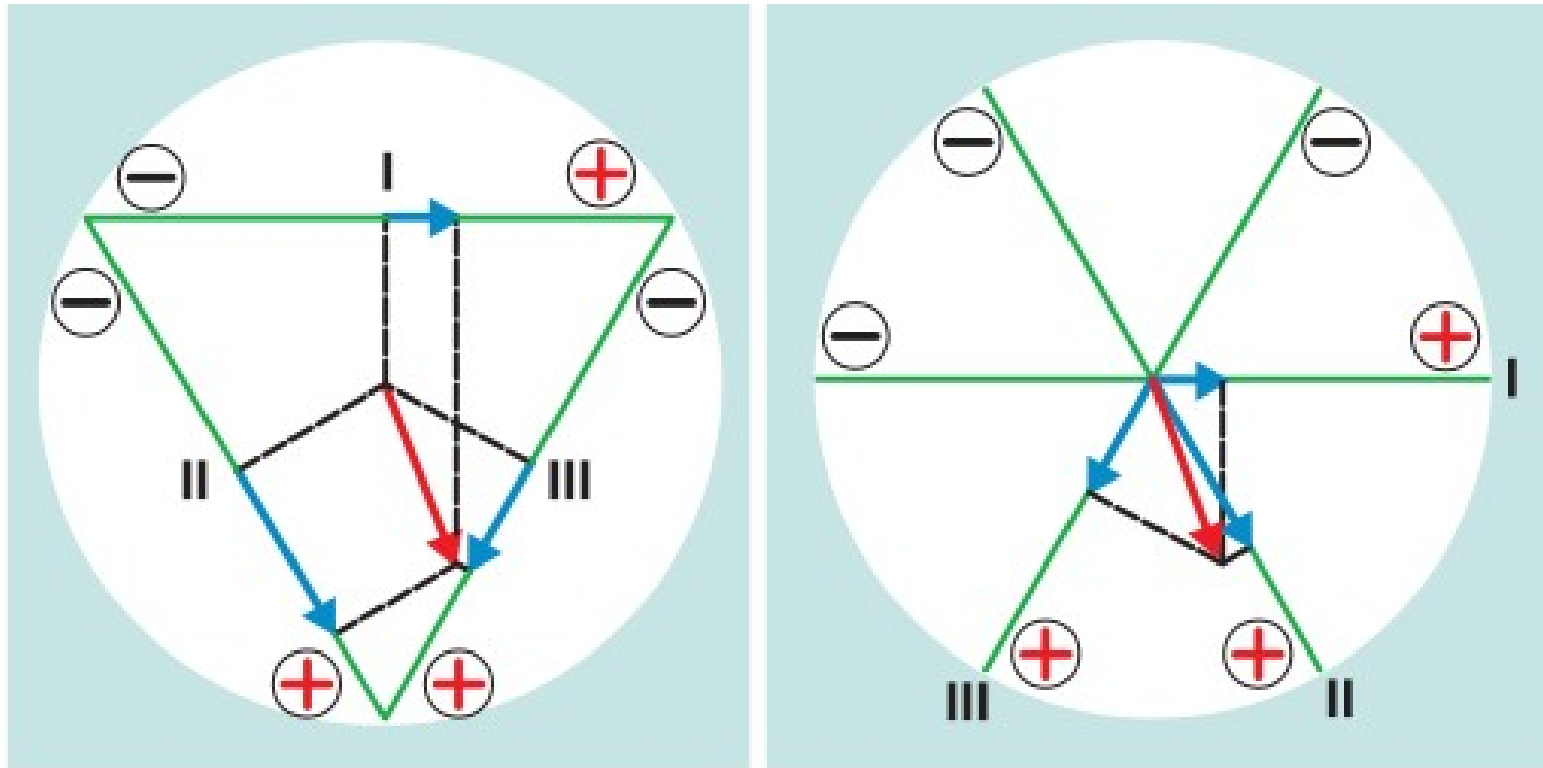
$$II = I + III$$

$$I = II - III$$

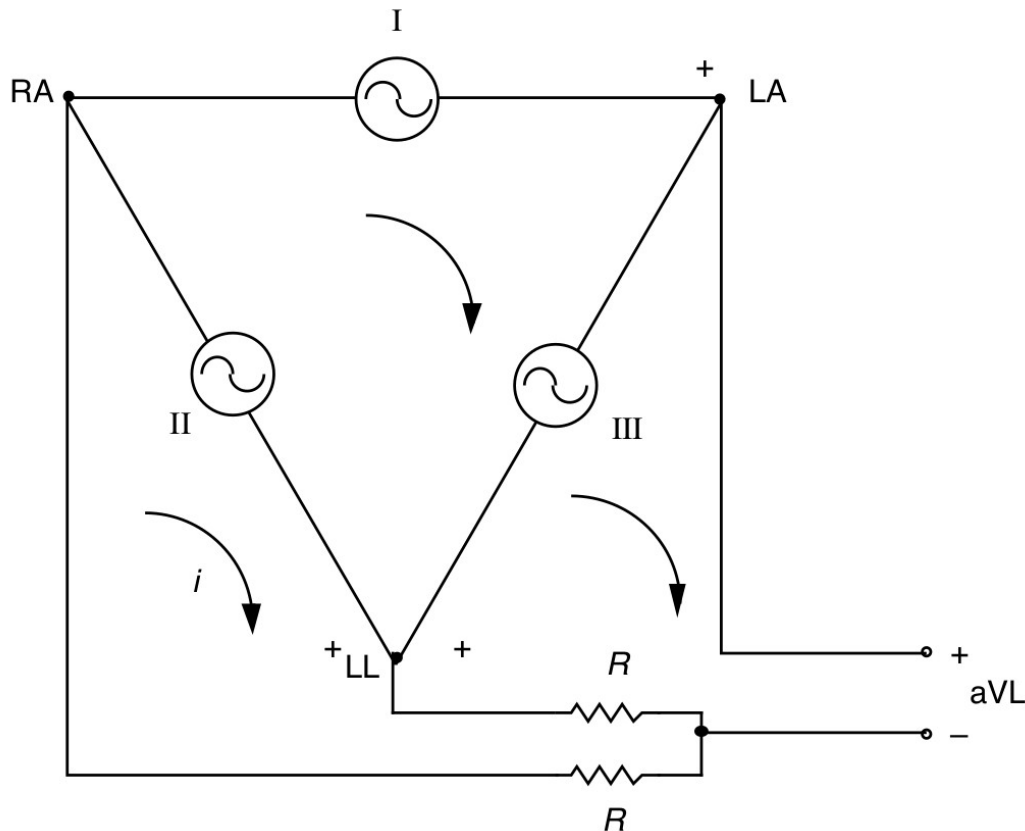
$$III = II - I$$

Non è necessario registrare tutti i leads, uno è ridondante.

Triangolo equilatero di Einthoven



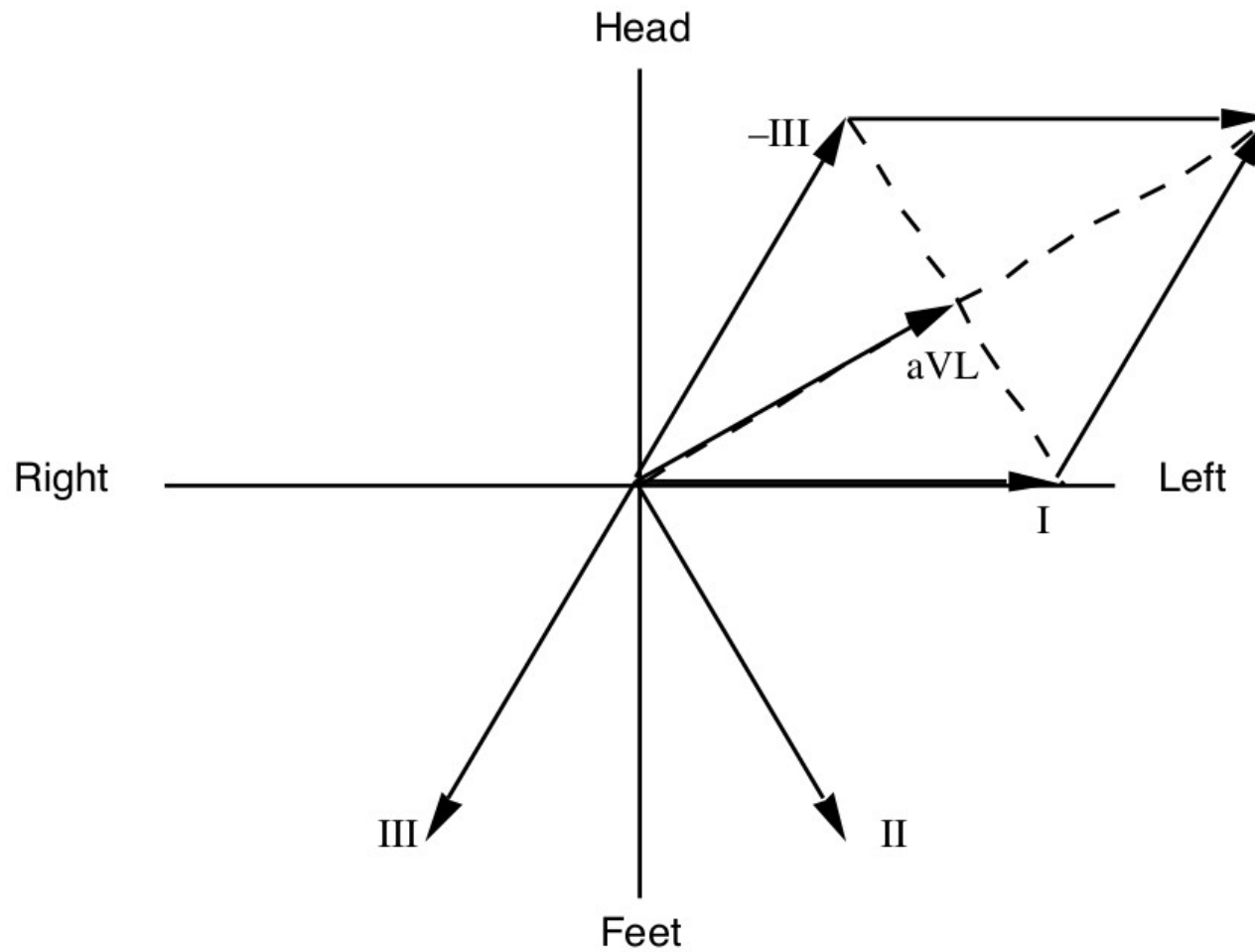
Augmented limb leads



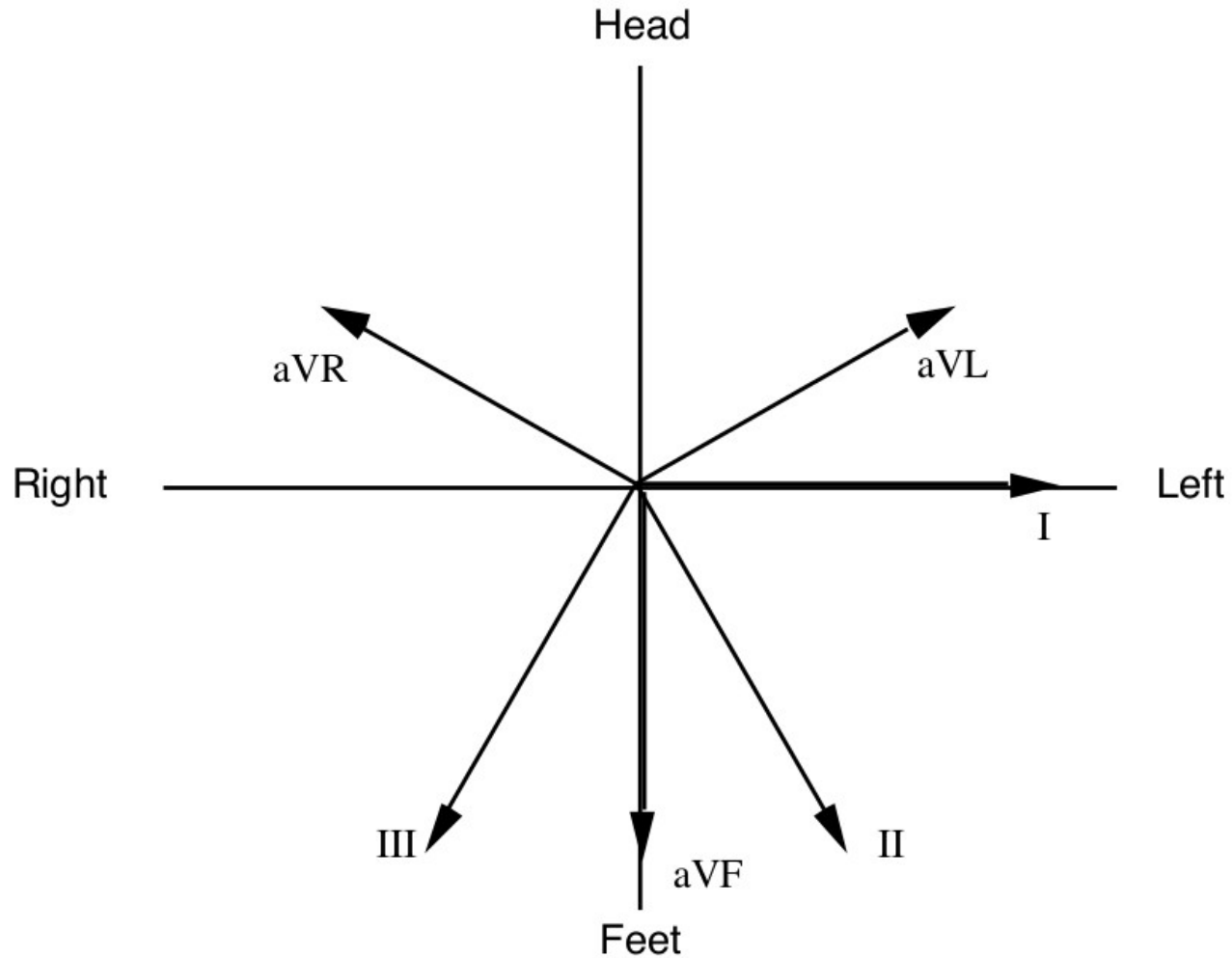
I limb lead classici producono un segnale di modesta ampiezza, non ottimale per amplificatori di modesto guadagno.

Lo schema in figura garantisce un segnale più intenso.

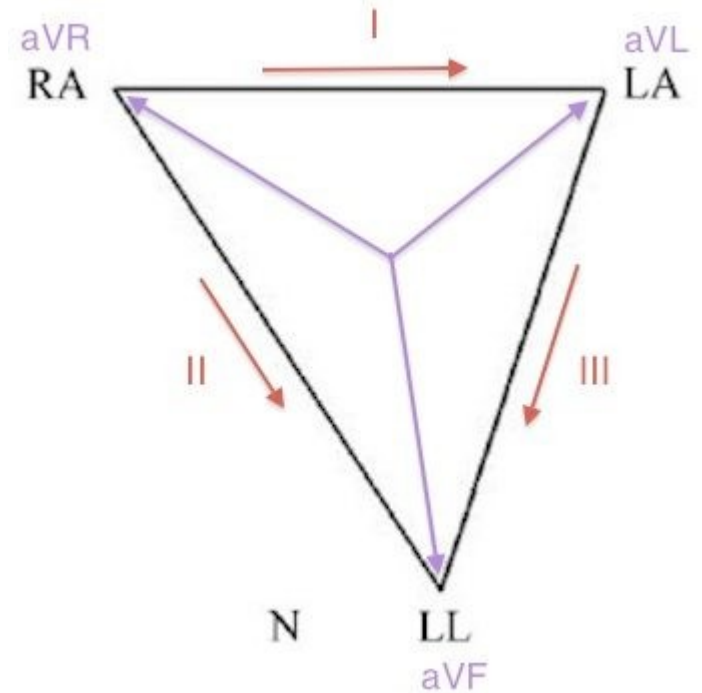
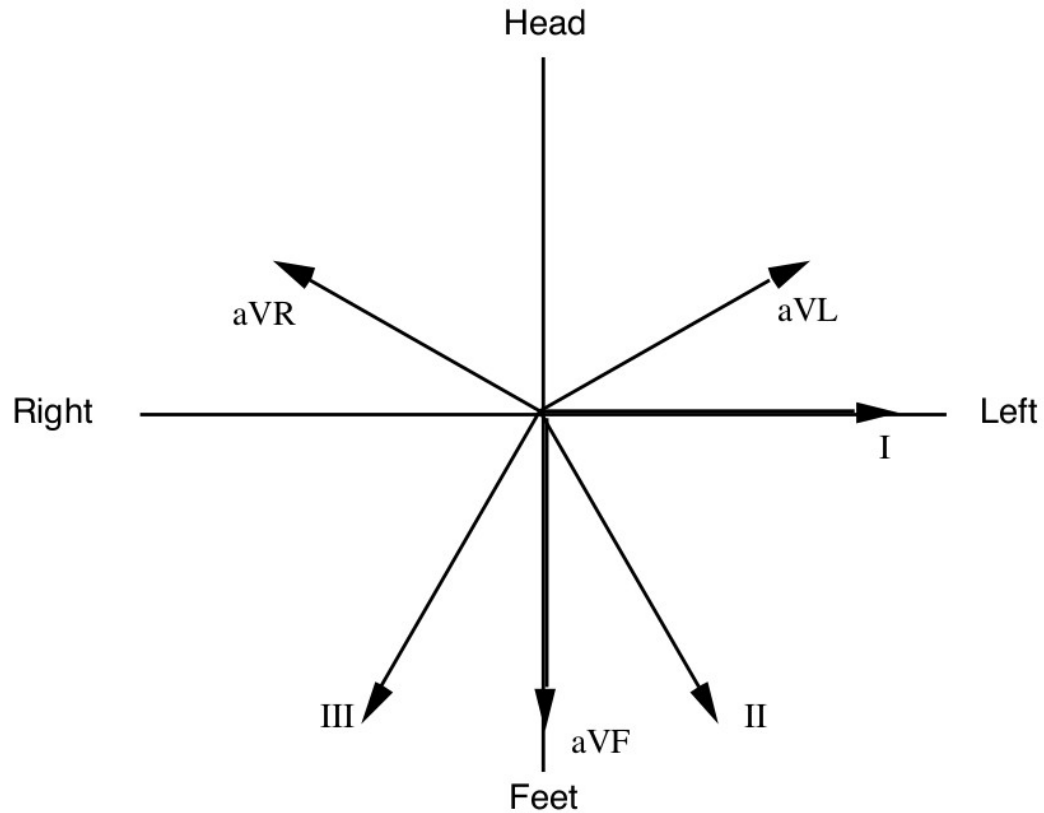
Augmented limb leads



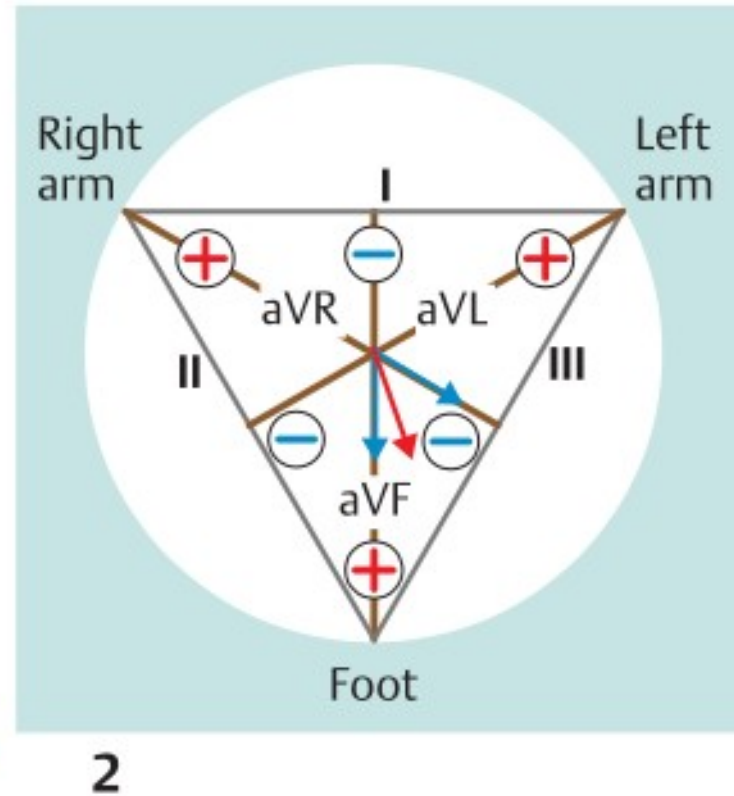
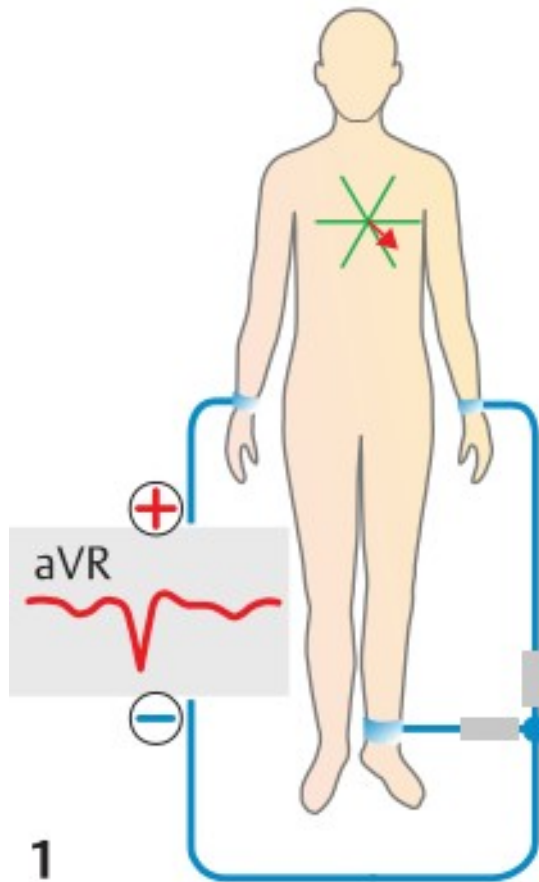
Augmented limb leads



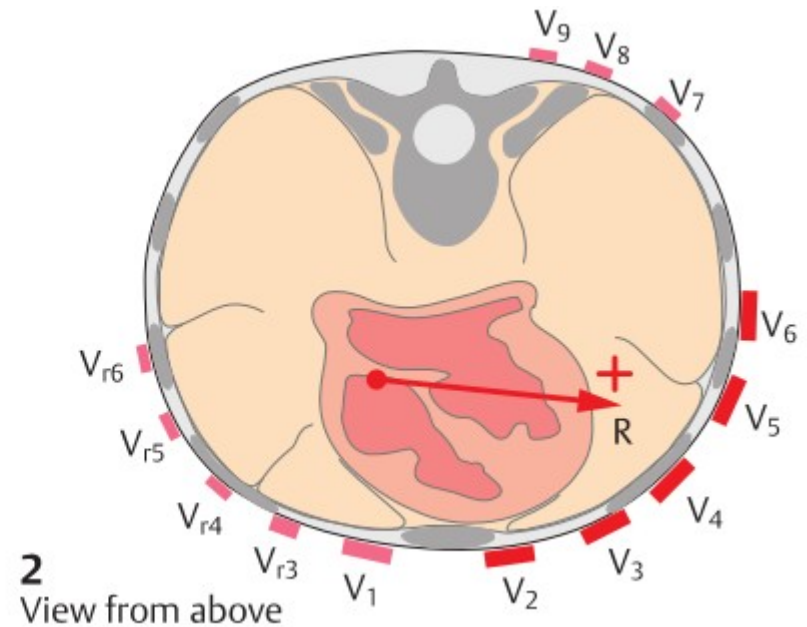
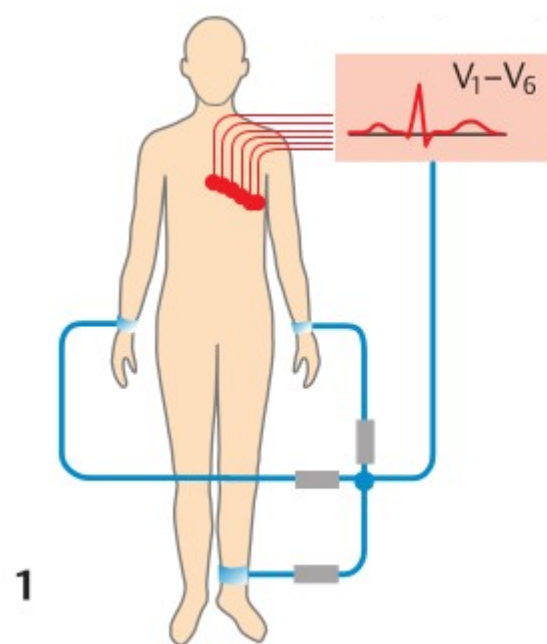
Augmented limb leads



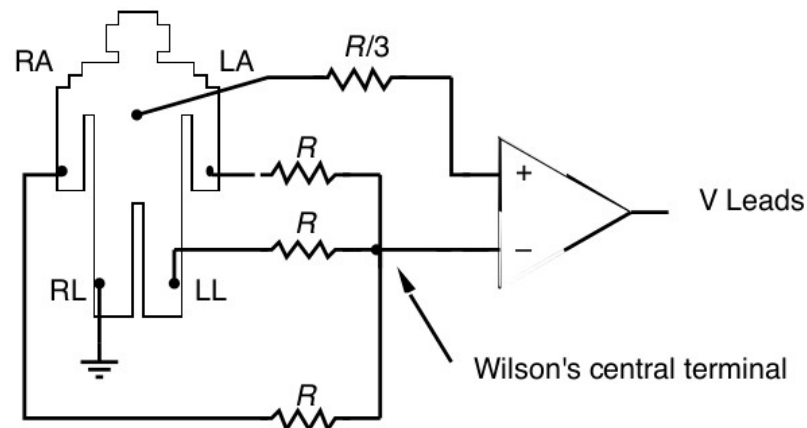
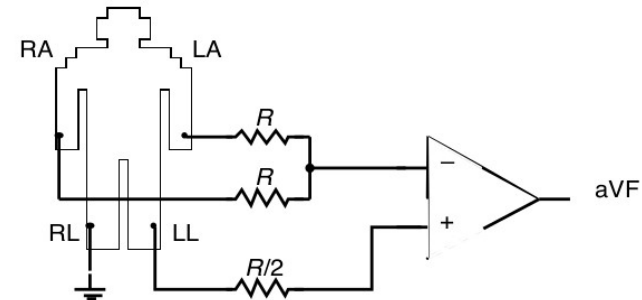
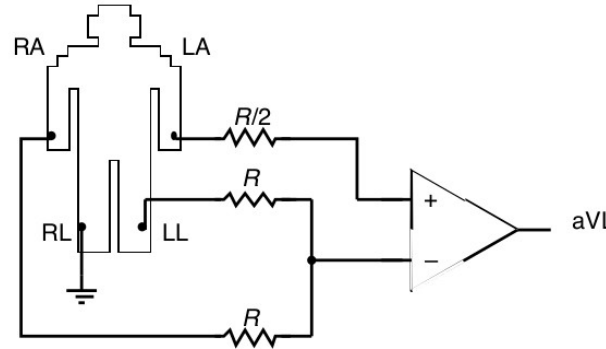
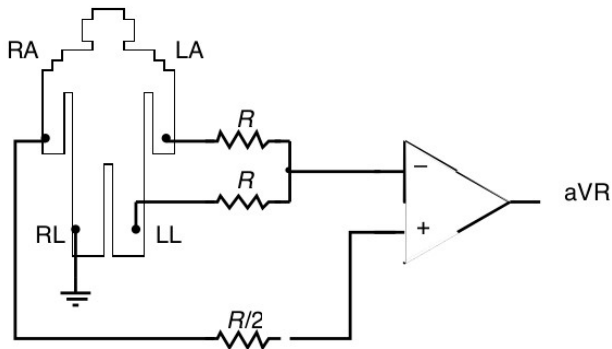
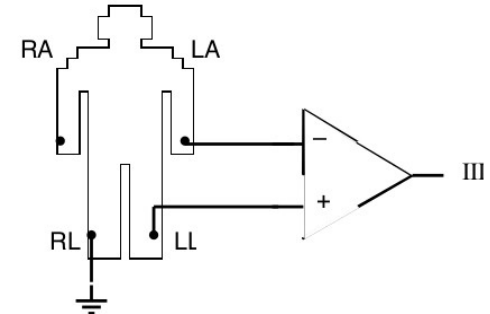
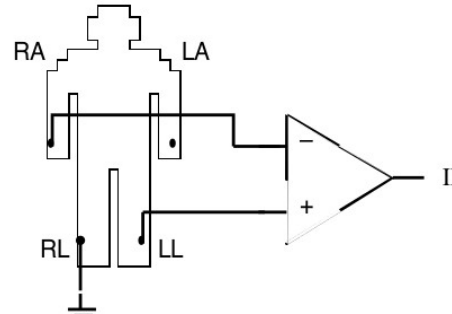
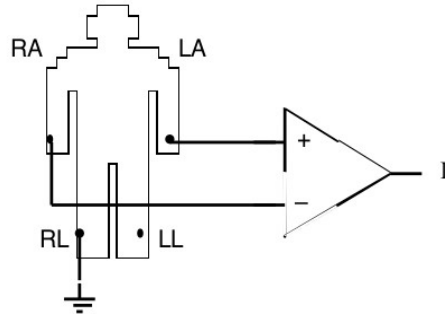
Schema Goldberger



Schema Wilson

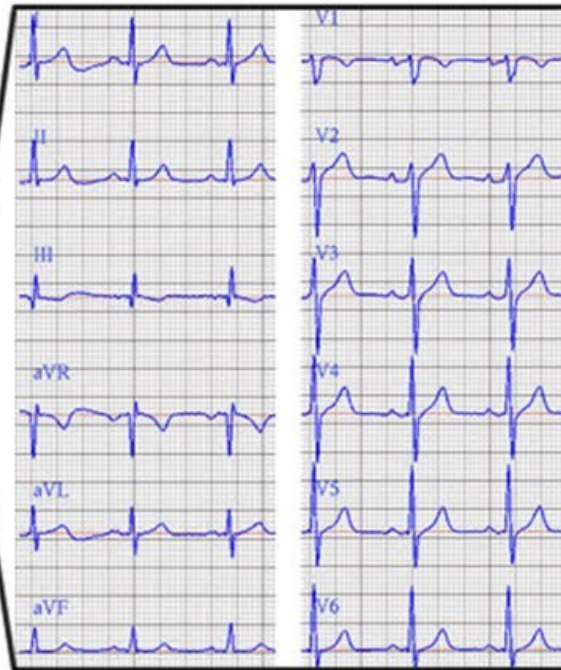
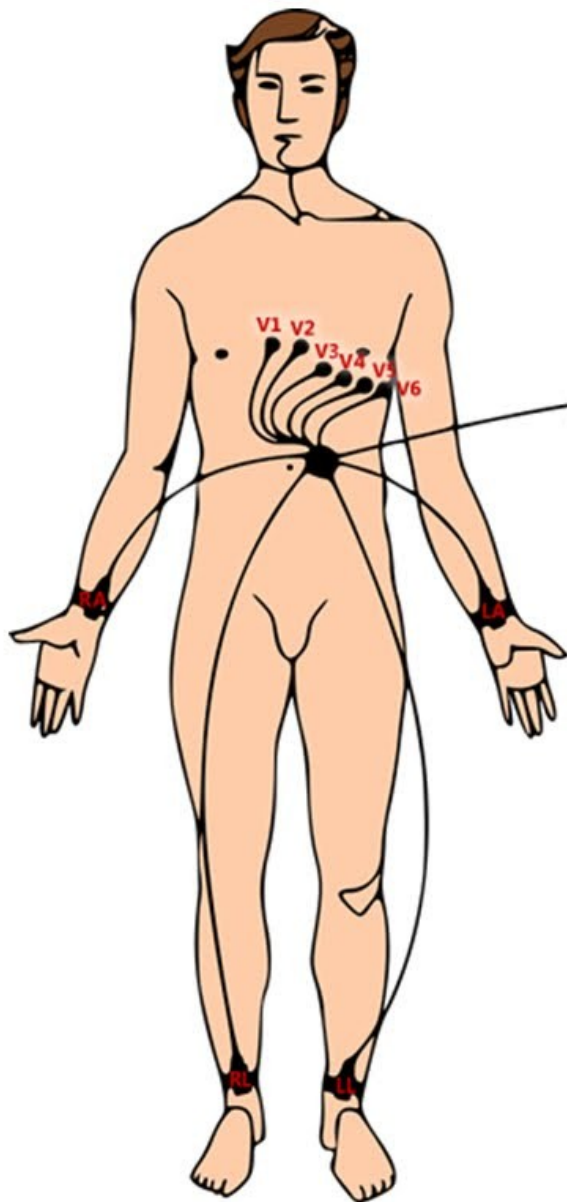


Augmented limb leads



Vi sono 6 “V leads”, relative a posizioni diverse sul torace

12 leads ECG



V1 - 4th intercostal space
R sternal border

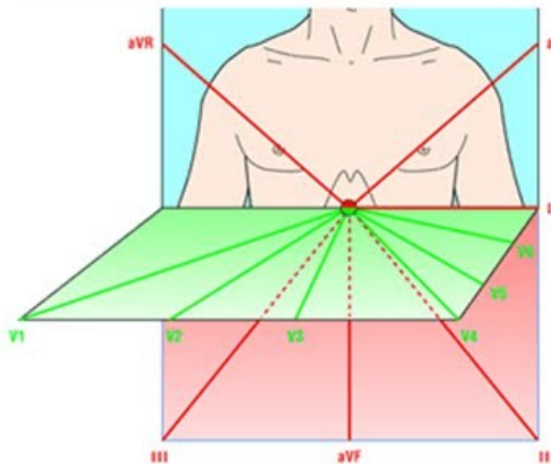
V2 - 4th intercostal space
L sternal border

V3 - Between leads V2 and V4.

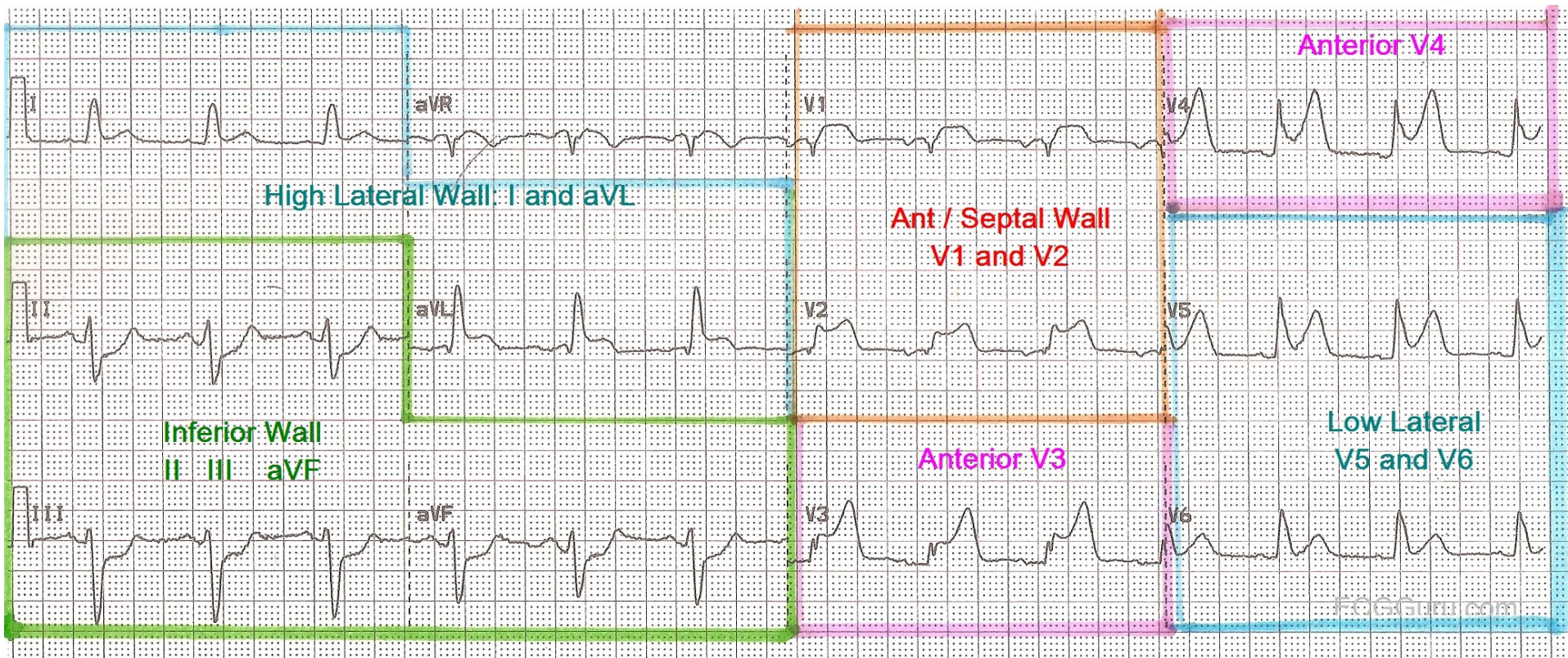
V4 - 5th L intercostal space in
midclavicular line

V5 - Horizontally even with V4,
but in the anterior axillary line.

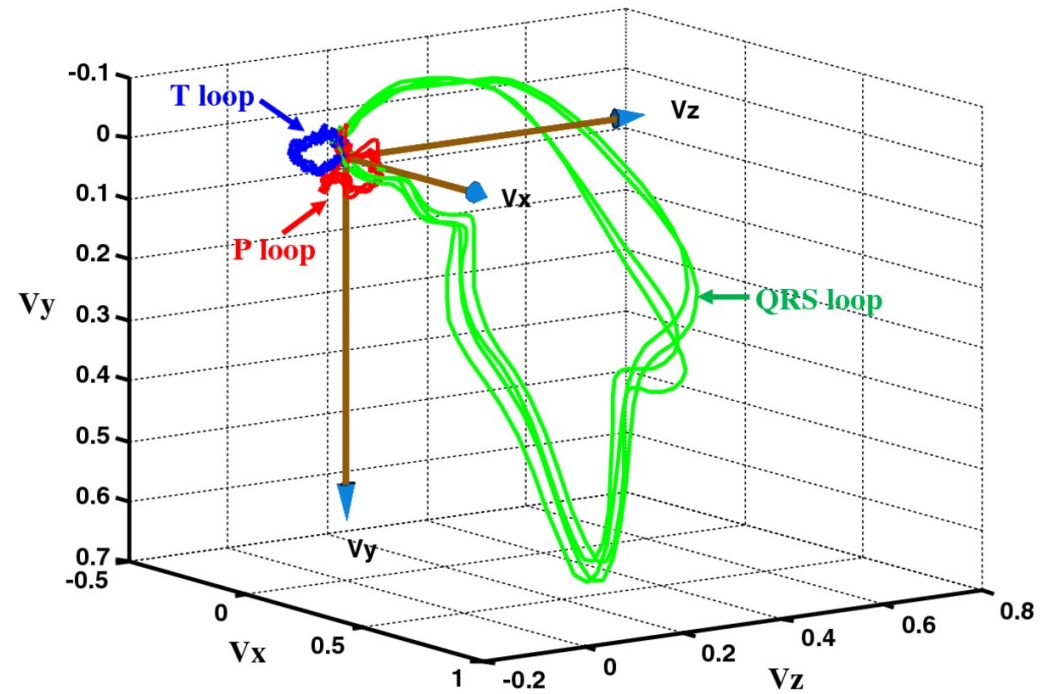
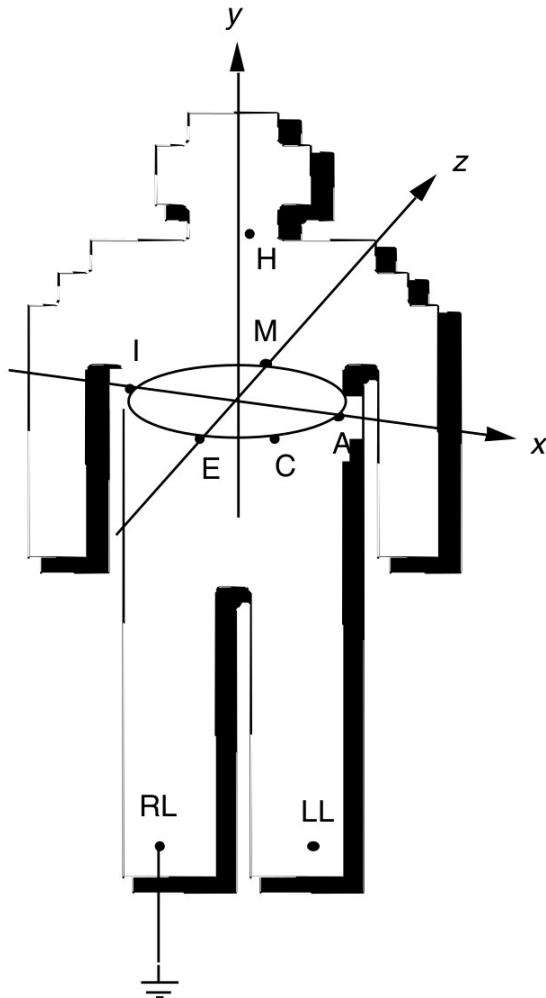
V6 - Horizontally even with V4
and V5 in the midaxillary line.
(The midaxillary line is the
imaginary line that extends
down from the middle of the
patient's armpit.)



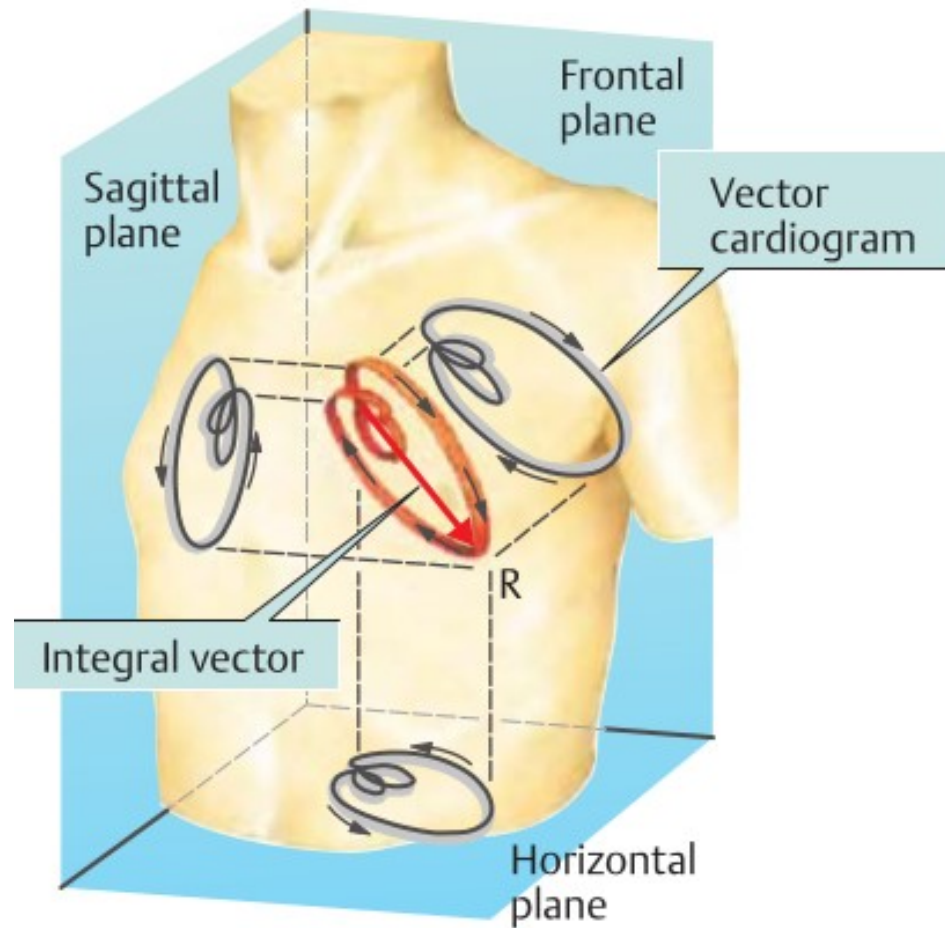
12 leads ECG



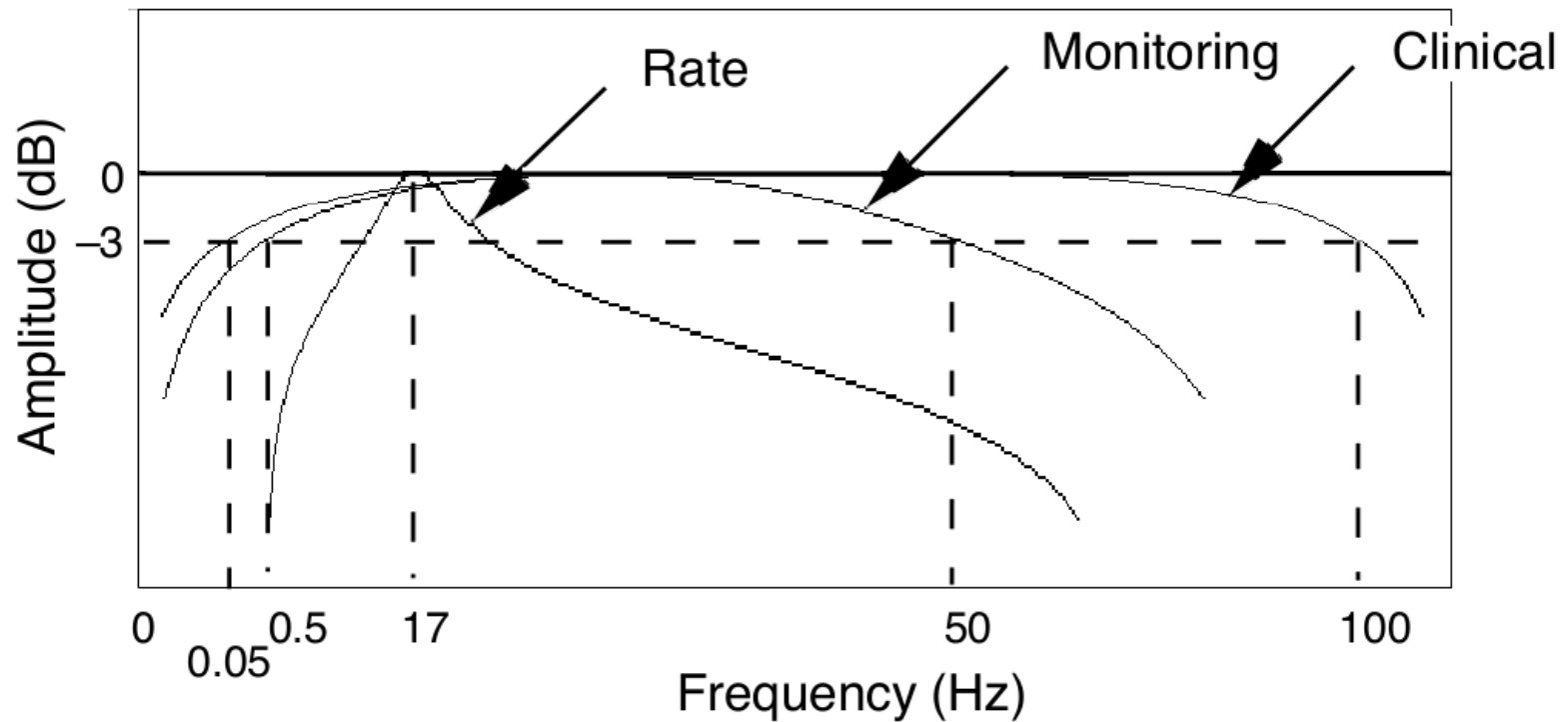
Vectorcardiogram



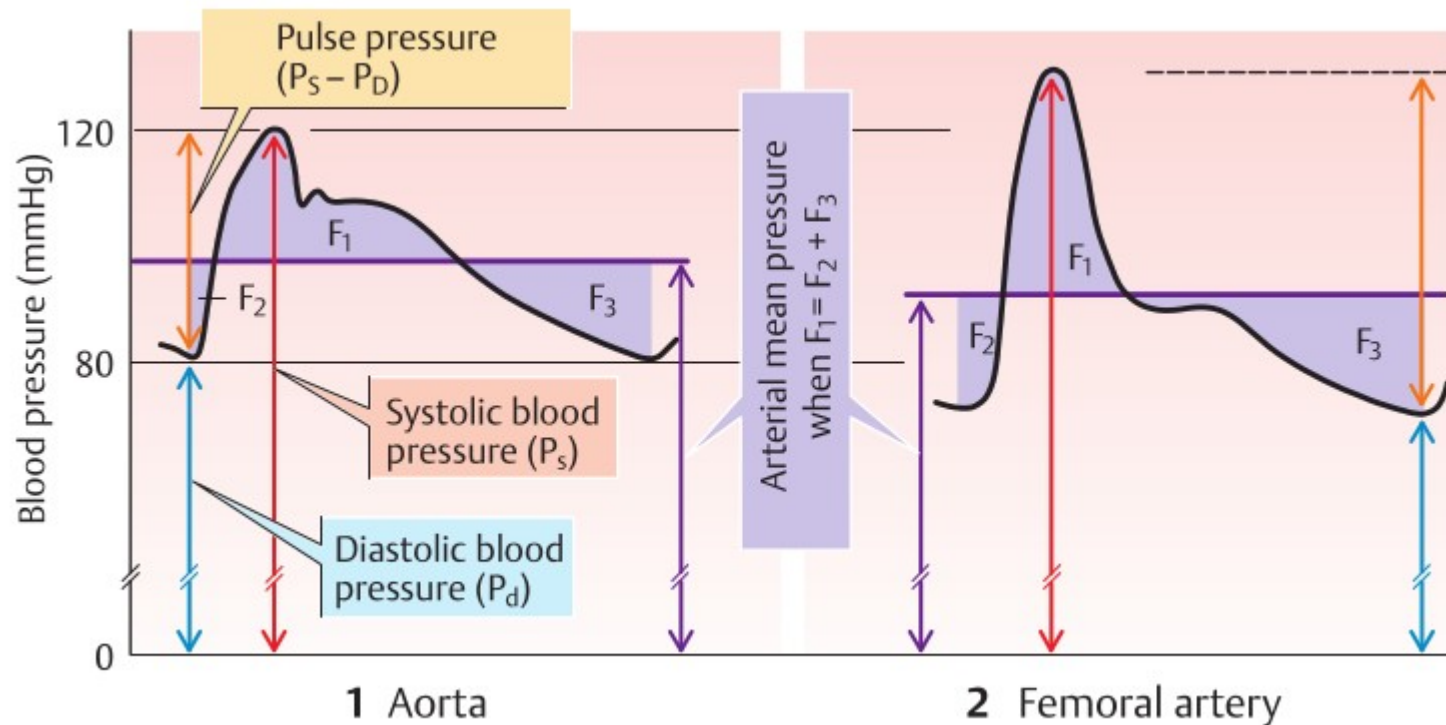
Vectorcardiogram



Bande di interesse

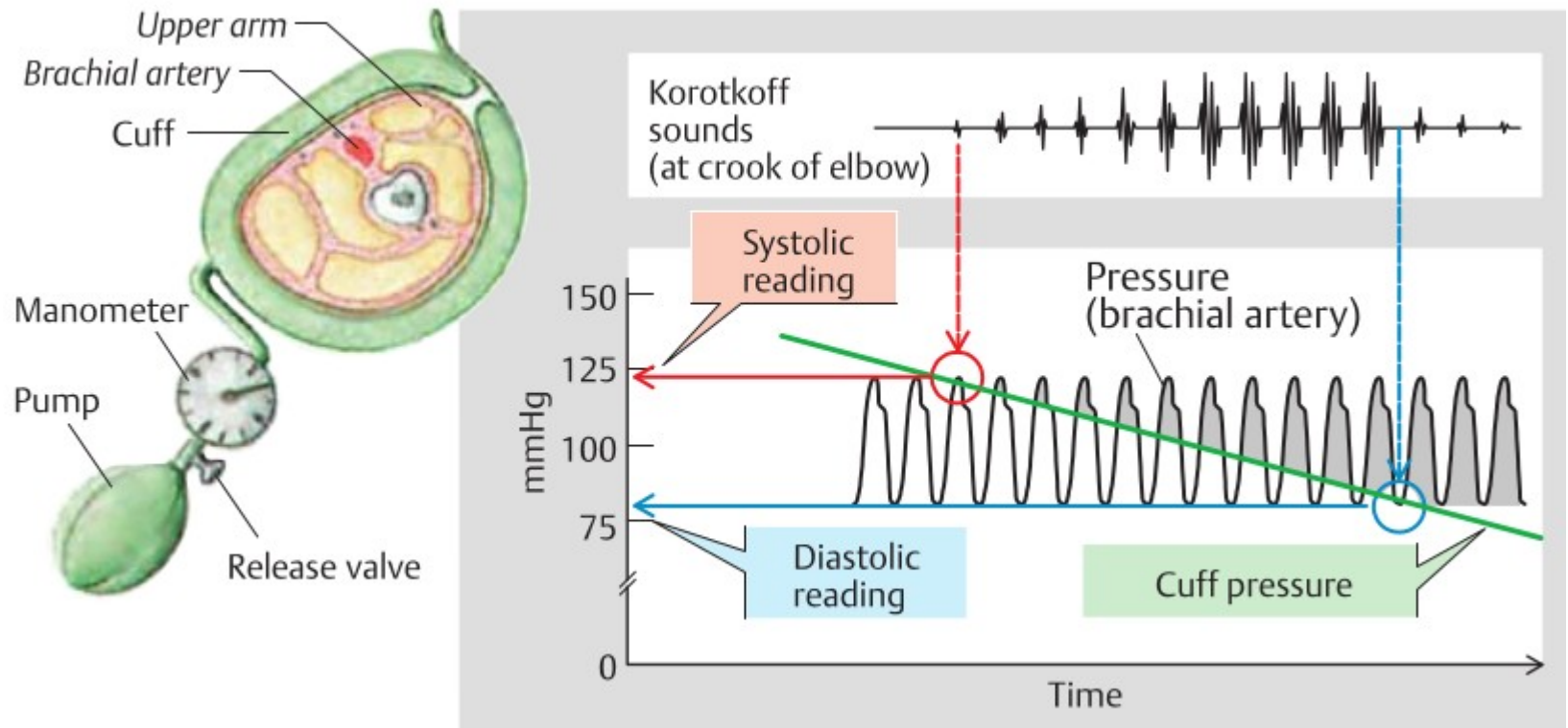


Pressione sanguigna



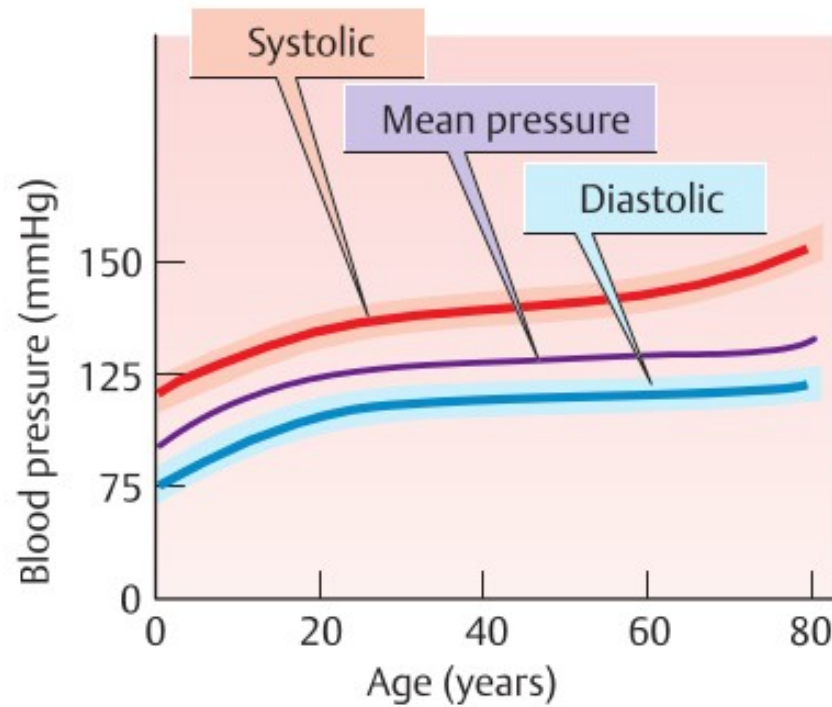
Andamento della pressione arteriosa.

Pressione sanguigna



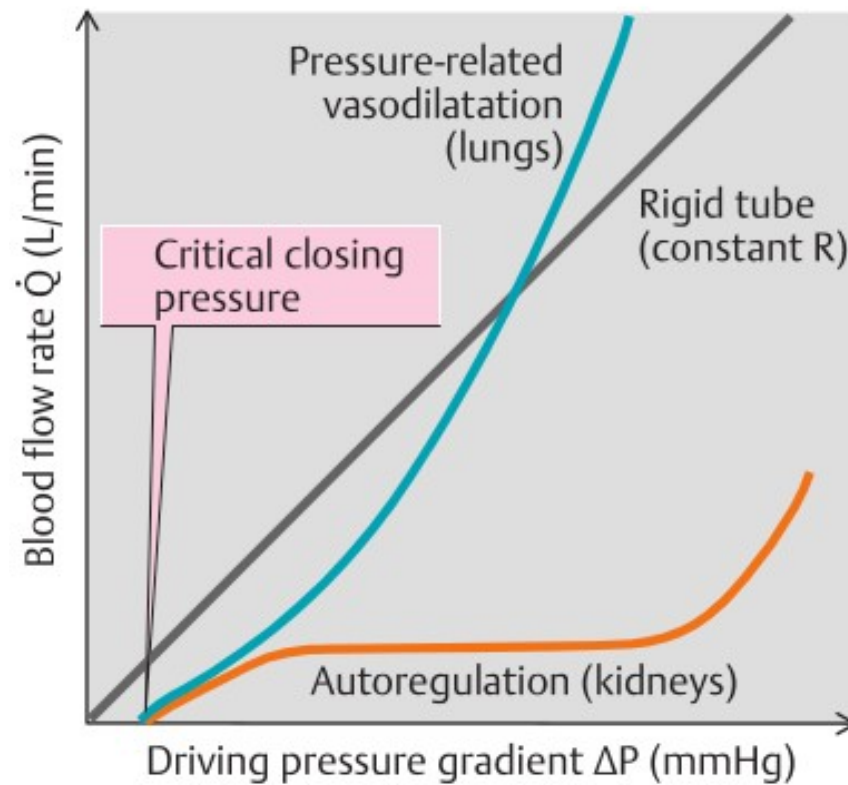
Misurazione della pressione tramite sfigmomanometro.

Pressione sanguigna



Dipendenza della pressione dall'età.

Pressione sanguigna



Pressione e flusso sanguigno.