Università degli Studi Di Milano - Laurea in Scienze Infermieristiche
Polo Didattico "Ospedale Civile Legnano" - AA 2010-2011
Corso di Fisiologia Umana

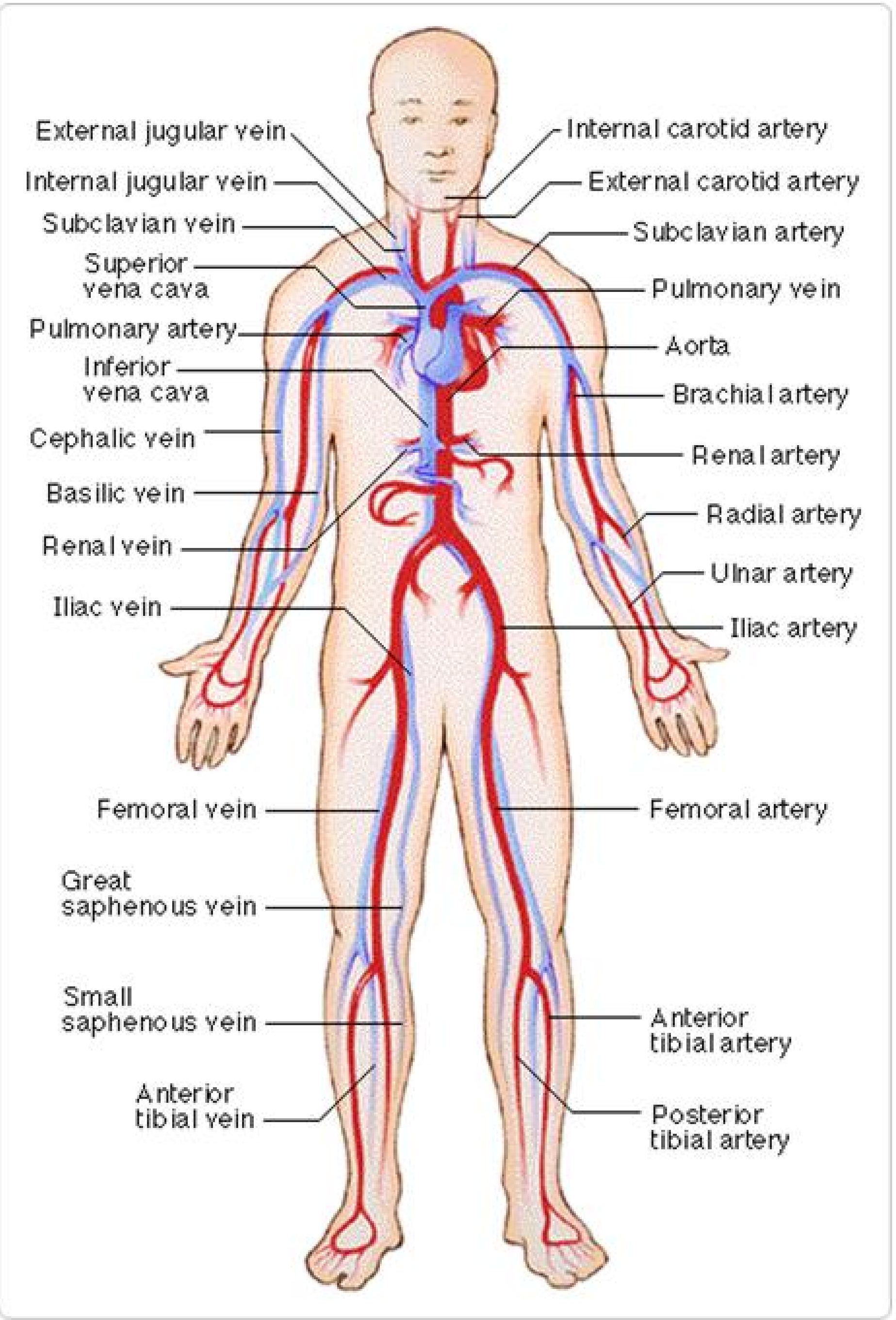
APPARATO CARDIOCIRCOLATORIO

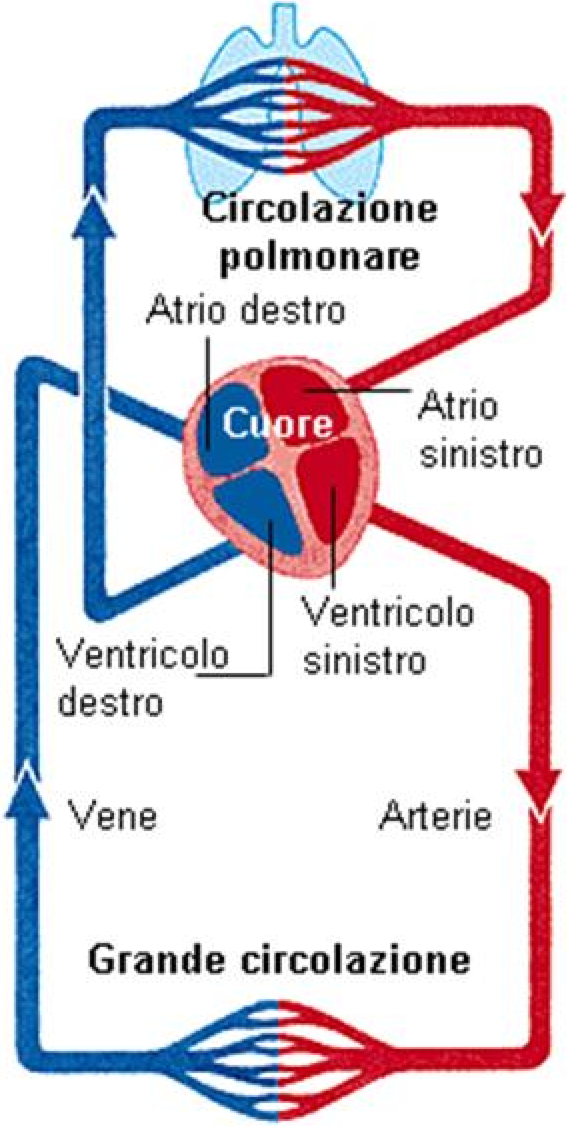
PARTE PRIMA

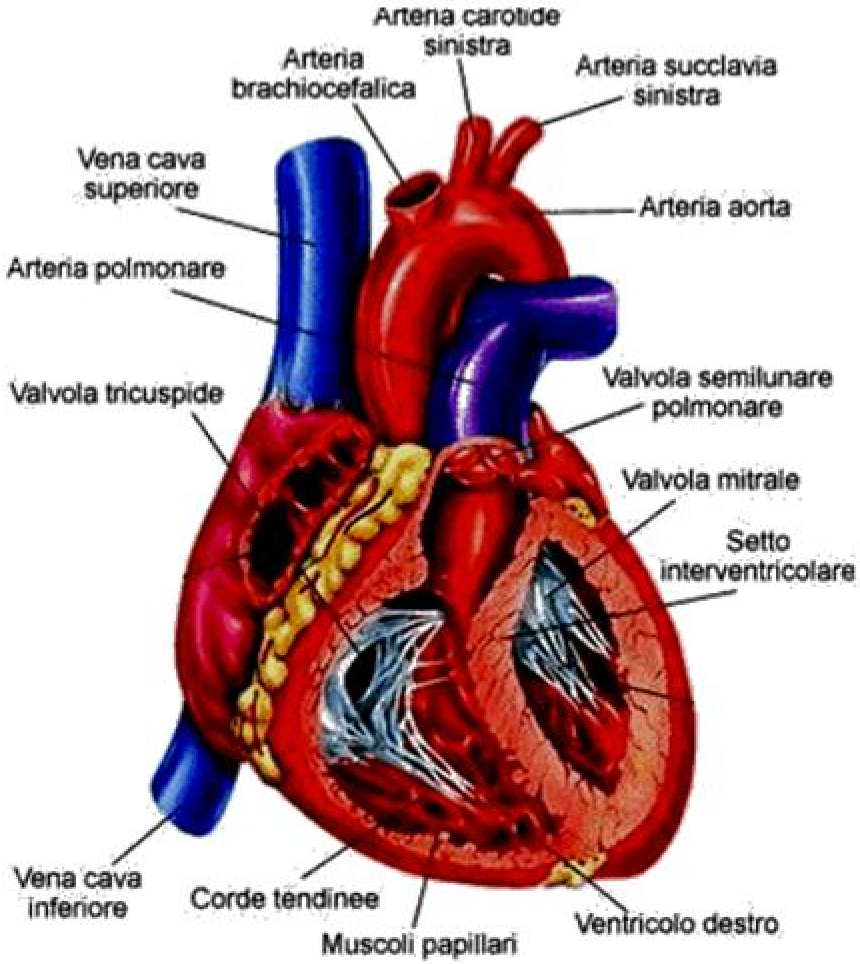
Dr. ALBERTO VIGNATI
Medicina Nucleare Legnano

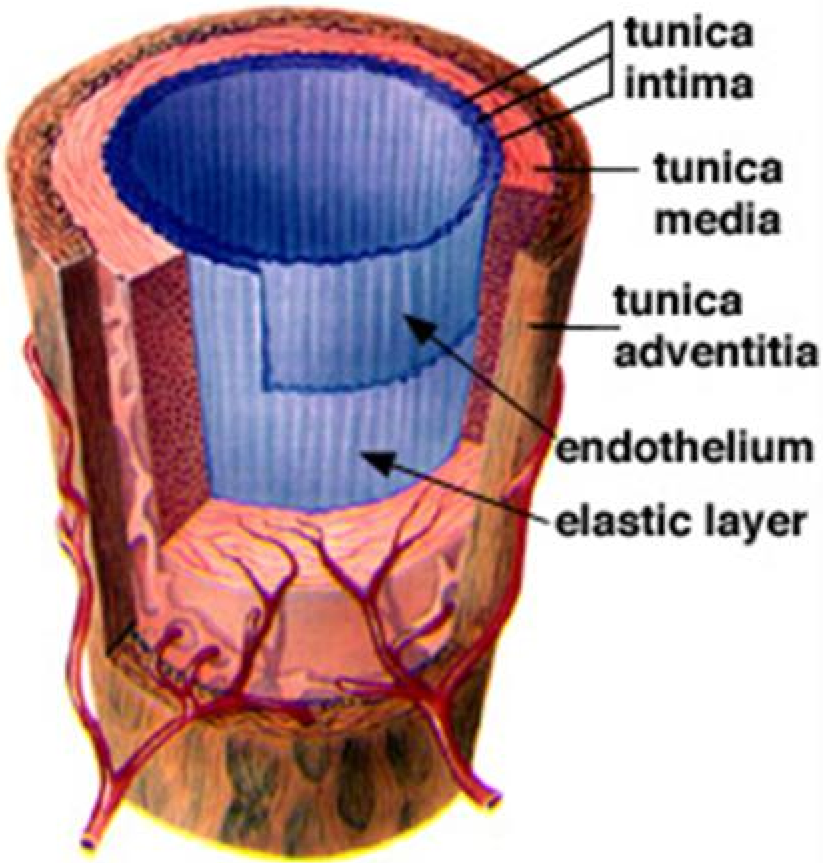
SISTEMA CIRCOLATORIO:

GENERALITA’

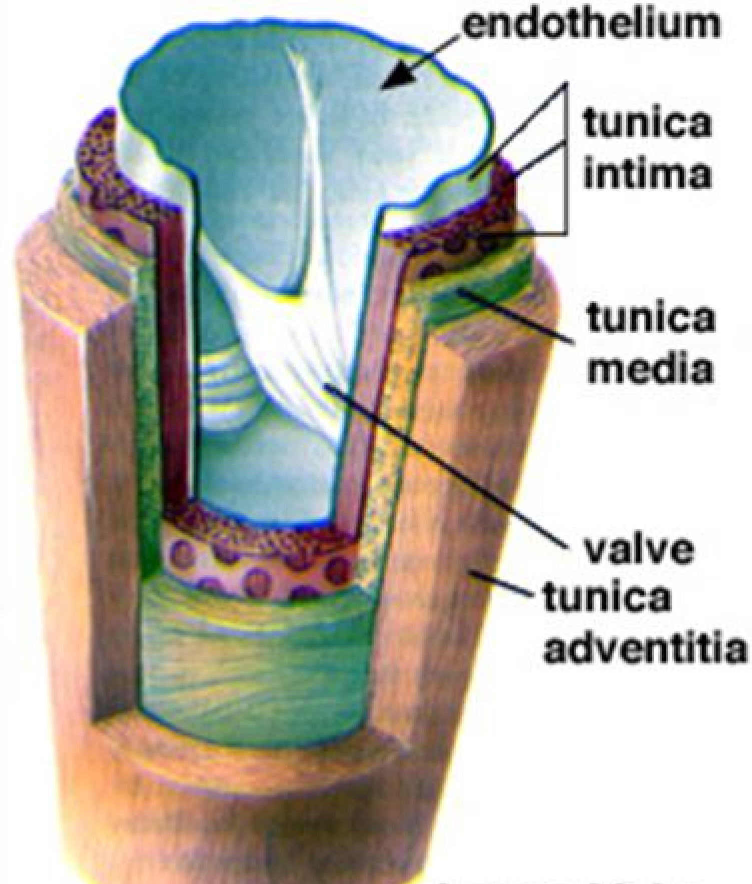

External jugular vein
Internal jugular vein
Subclavian vein
Superior vena cava
Pulmonary artery
Inferior vena cava
Cephalic vein
Basilic vein
Renal vein
Iliac vein
Femoral vein
Great saphenous vein
Small saphenous vein
Anterior tibial vein
Internal carotid artery
External carotid artery
Subclavian artery
Pulmonary vein
Aorta
Brachial artery
Renal artery
Radial artery
Ulnar artery
Iliac artery
Femoral artery
Anterior tibial artery
Posterior tibial artery


Circolazione polmonare
Atrio destro
Cuore
Atrio sinistro
Ventricolo destro
Ventricolo sinistro
Vene
Arterie
Grande circolazione

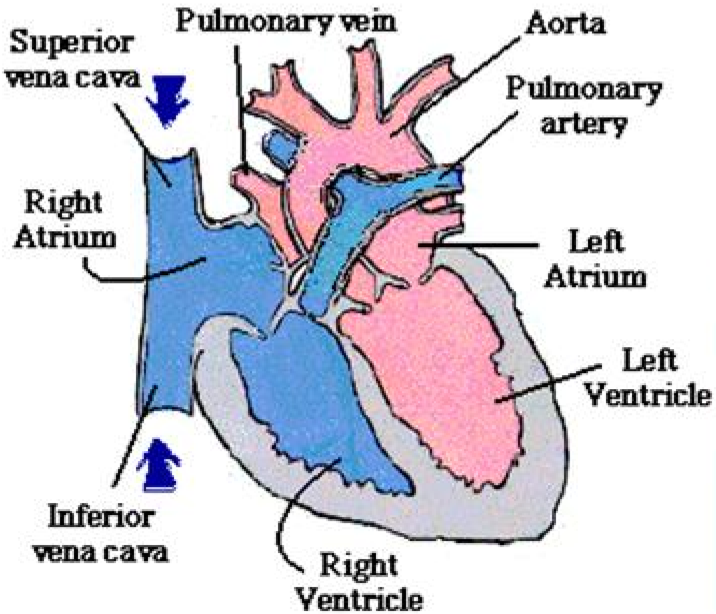

Arteria carotide sinistra
Arteria brachiocefalica
Arteria succlavia sinistra
Vena cava superiore
Arteria aorta
Arteria polmonare
Valvola tricuspide
Valvola semilunare polmonare
Valvola mitrale
Setto interventricolare
Vena cava inferiore
Corde tendinee
Muscoli papillari
Ventricolo destro

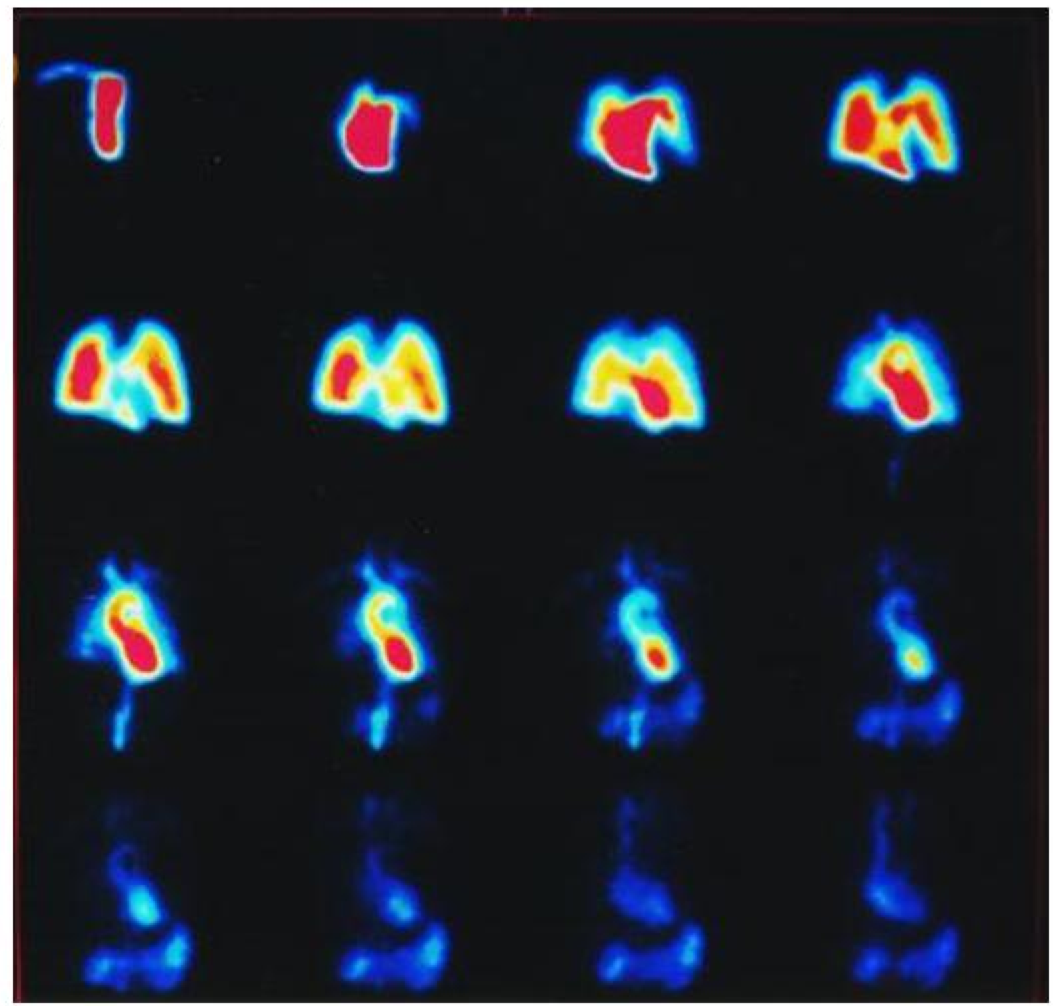


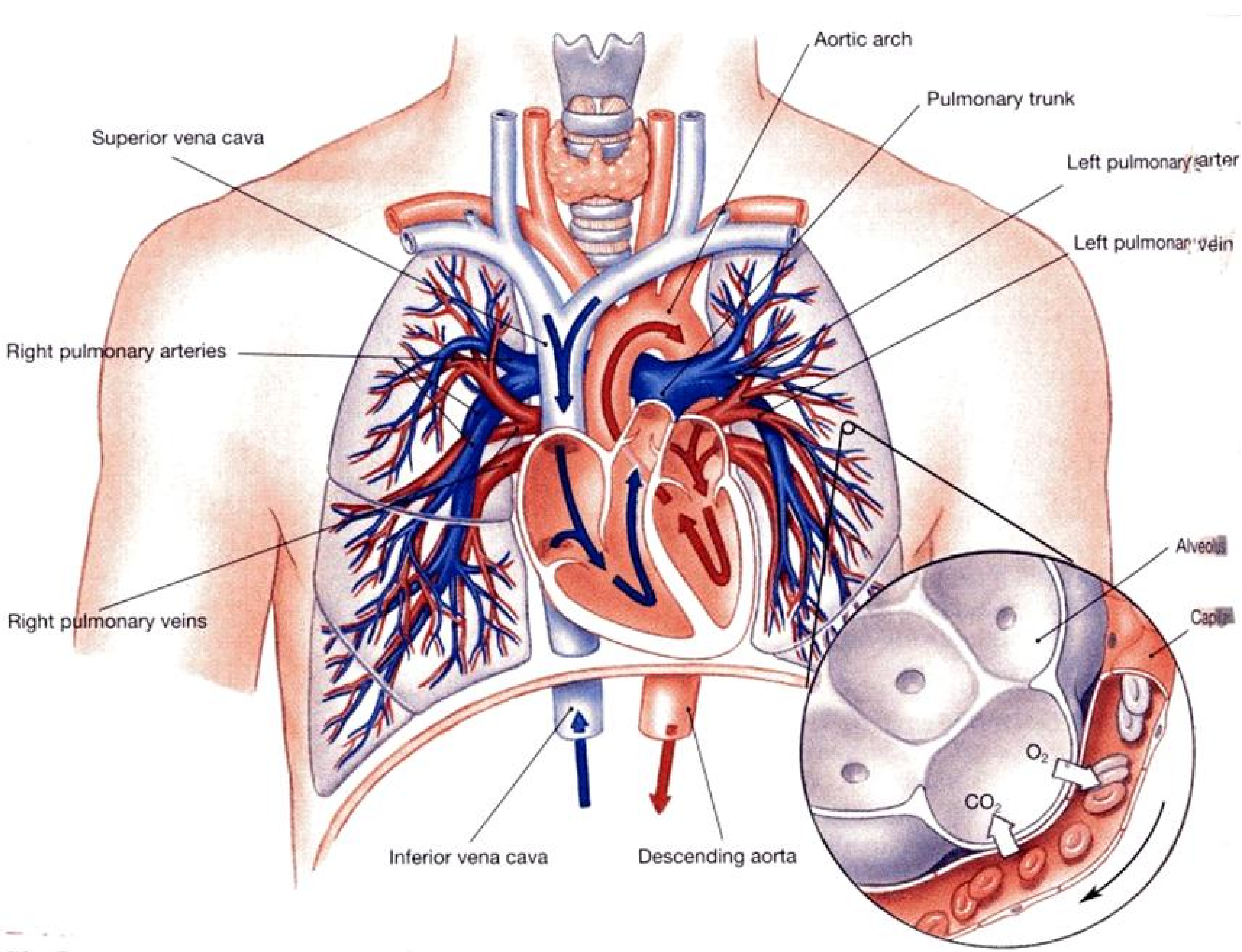
Muscular Artery



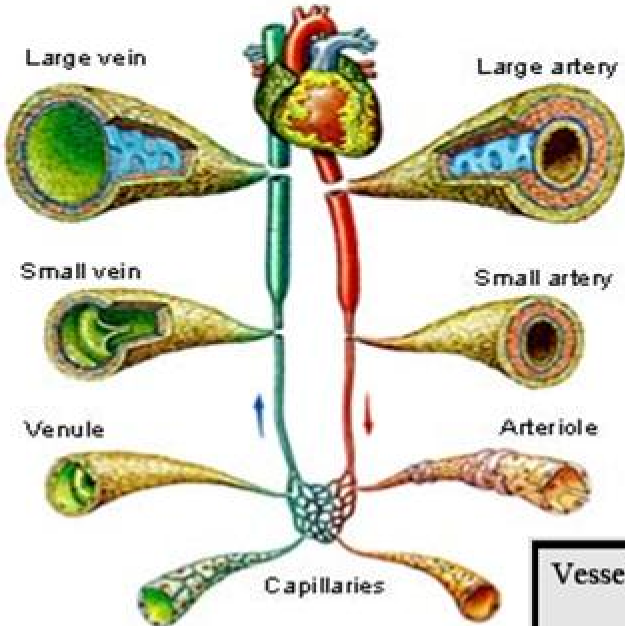
Large Vein


Superior vena cava
Pulmonary vein
Aorta
Pulmonary artery
Right Atrium
Left Atrium
Left Ventricle
Inferior vena cava
Right Ventricle

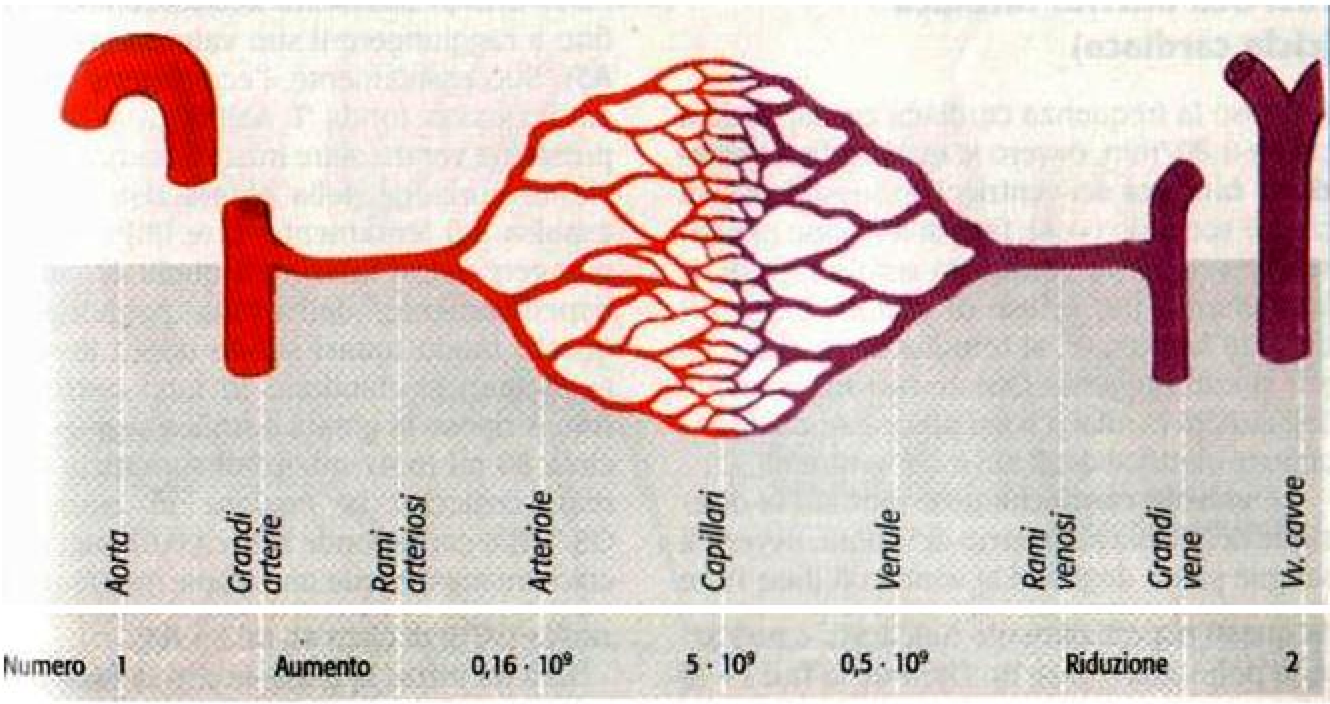




Aortic arch
Pulmonary trunk
Superior vena cava
Left pulmonary arter
Left pulmonar vein
Right pulmonary arteries
Right pulmonary veins
O_2
CO_2
Inferior vena cava
Descending aorta



Vessel	D (cm)	A (cm^2)	P (mm Hg)	V (cm/s)
Aorta	2.5	2.5	100	33
Small Arteries	0.5	20	100	30
Arterioles	3×10^{-3}	40	85	15
Capillaries	6×10^{-4}	2500	30	0.03
Venules	2×10^{-3}	250	10	0.5
Small Veins	0.5	80	5	2
Venae cavae	3.0	8	2	20



-CIRCOLO SISTEMICO: VARI “SETTORI” DI VASI UGUALI

-NUMERO VASI PER SETTORE: DA 1 A 5.10^9 A 2

-I VARI “SETTORI” DI VASI SONO IN SERIE TRA LORO

-ENTRO OGNI SETTORE I SINGOLI VASI SONO IN PARALLELO TRA LORO

8.3.2 Legge di Poiseulle (o perdita di carico)

Quando un fluido si muove in un condotto di sezione piccola, la portata è data da:

$$Q = \frac{\pi R^4}{8\eta} \cdot \frac{\Delta P}{l}$$

Q= ΔP / Resis

dove:

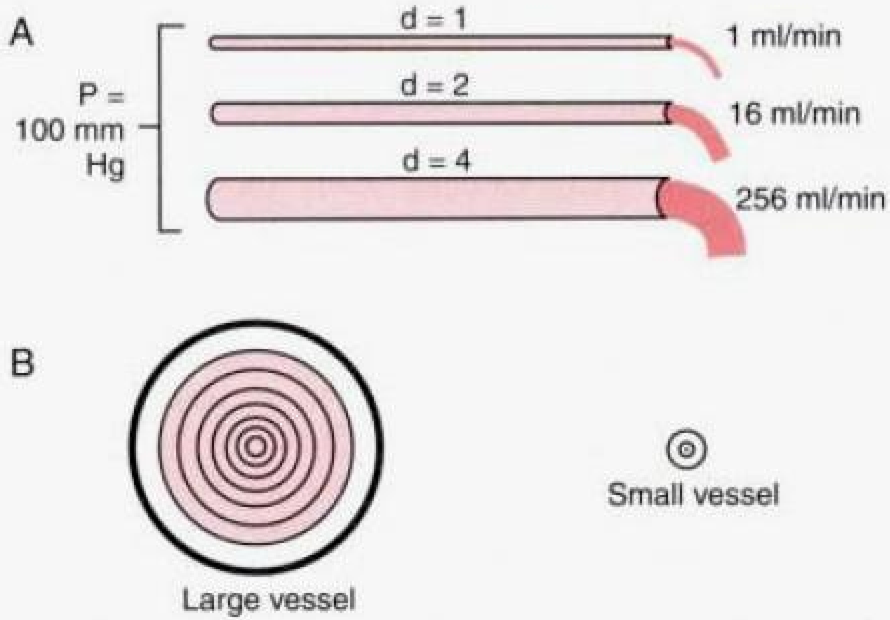
- R è il raggio del condotto;
- l è la lunghezza del condotto;
- ΔP è la differenza di pressione agli estremi del condotto.

Dalla formula di Poiseulle si ricava:

$$\eta = \frac{\pi R^4}{8Q} \cdot \frac{\Delta P}{l}$$

Resistenze= 8 l η /π r ^{4}

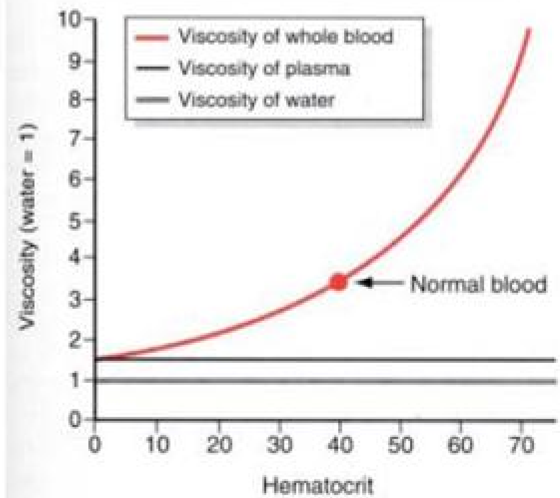
Conductance = 1 / Resistance ∝ diameter^4

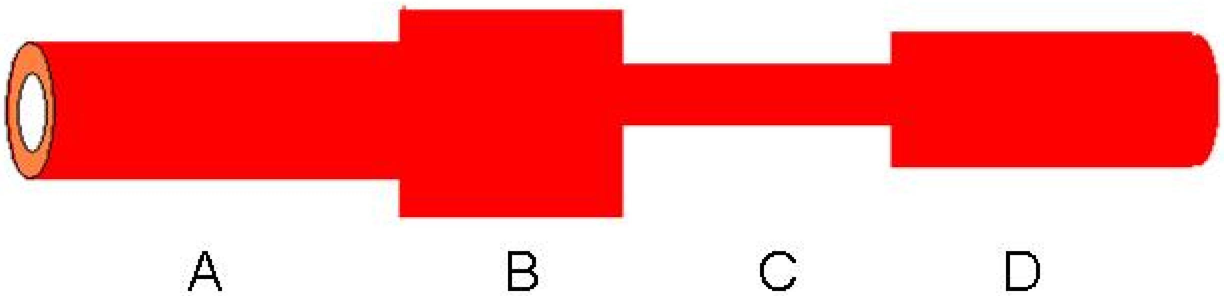


The Poiseuille's law:

$$Q = \frac{\pi \Delta P r^4}{8 \eta l}$$

Q – rate of blood flow
ΔP - pressure difference
r – radius of the vessel
L – length of the vessel
η - viscosity of the blood



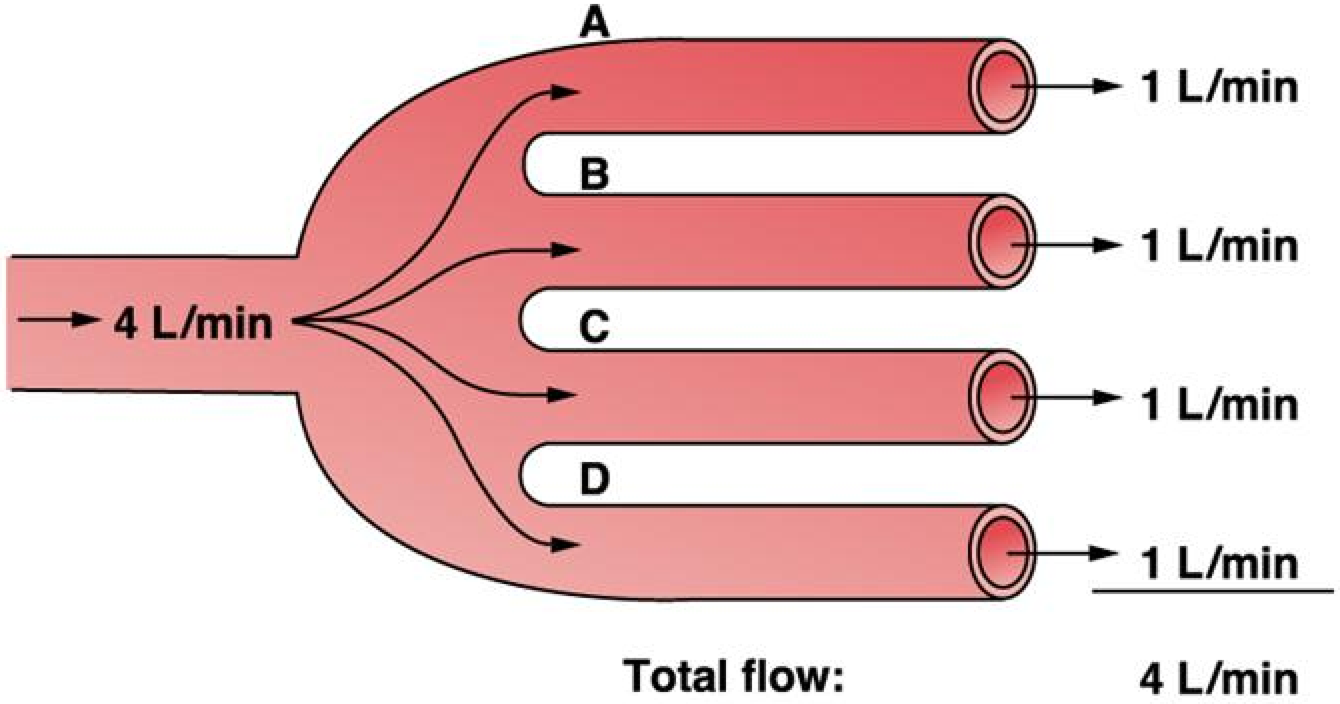


CONDOTTI IN SERIE

FLUSSO COSTANTE: $F_A = F_B = F_C = F_D = F$

LA CADUTA DI PRESSIONE COMPLESSIVA SI DISTRIBUISCE NEI VARI TRATTI:
$\Delta P = \Delta P_A + \Delta P_B + \Delta P_C + \Delta P_D$

LA RESISTENZA TOTALE E' LA SOMMA DI QUELLA DI OGNI TRATTO:
$R = R_A + R_B + R_C + R_D$.



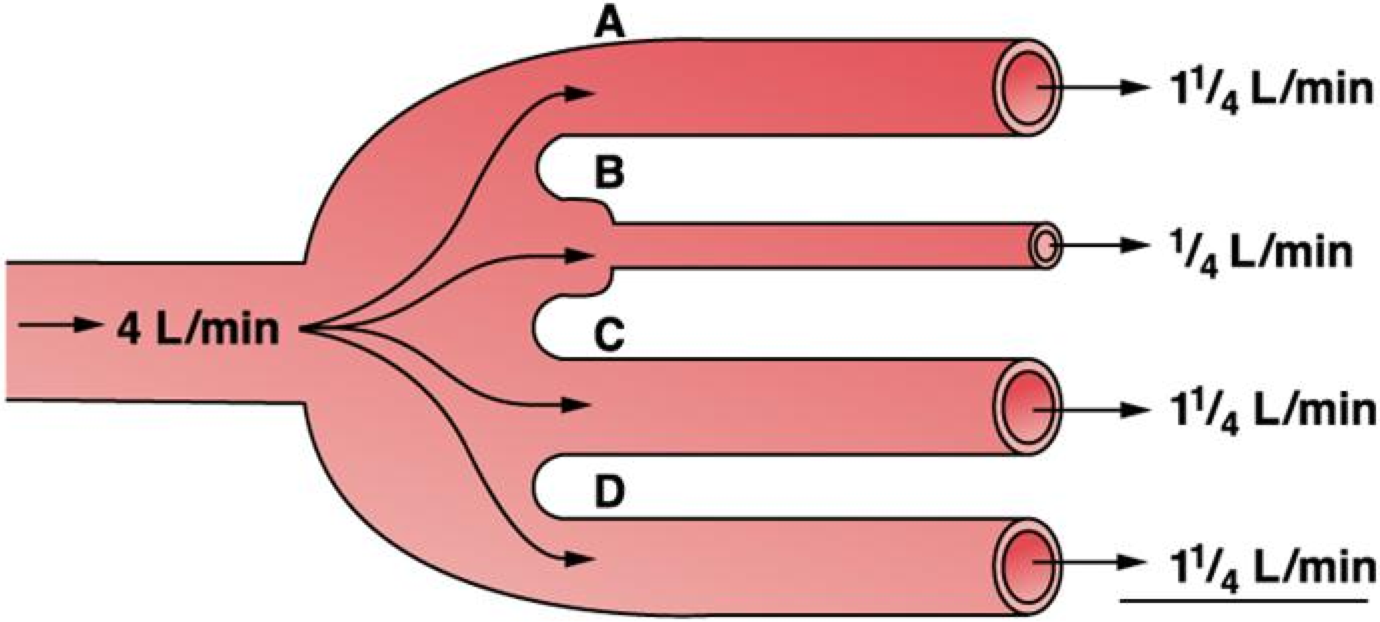
CONDOTTI IN PARALLELO

LA CADUTA DI PRESSIONE E' LA STESSA IN OGNI TRATTO:

$\Delta P = \Delta P_A = \Delta P_B = \Delta P_C = \Delta P_D$

IL FLUSSO COMPLESSIVO SI DISTRIBUISCE NEI VARI TRATTI:

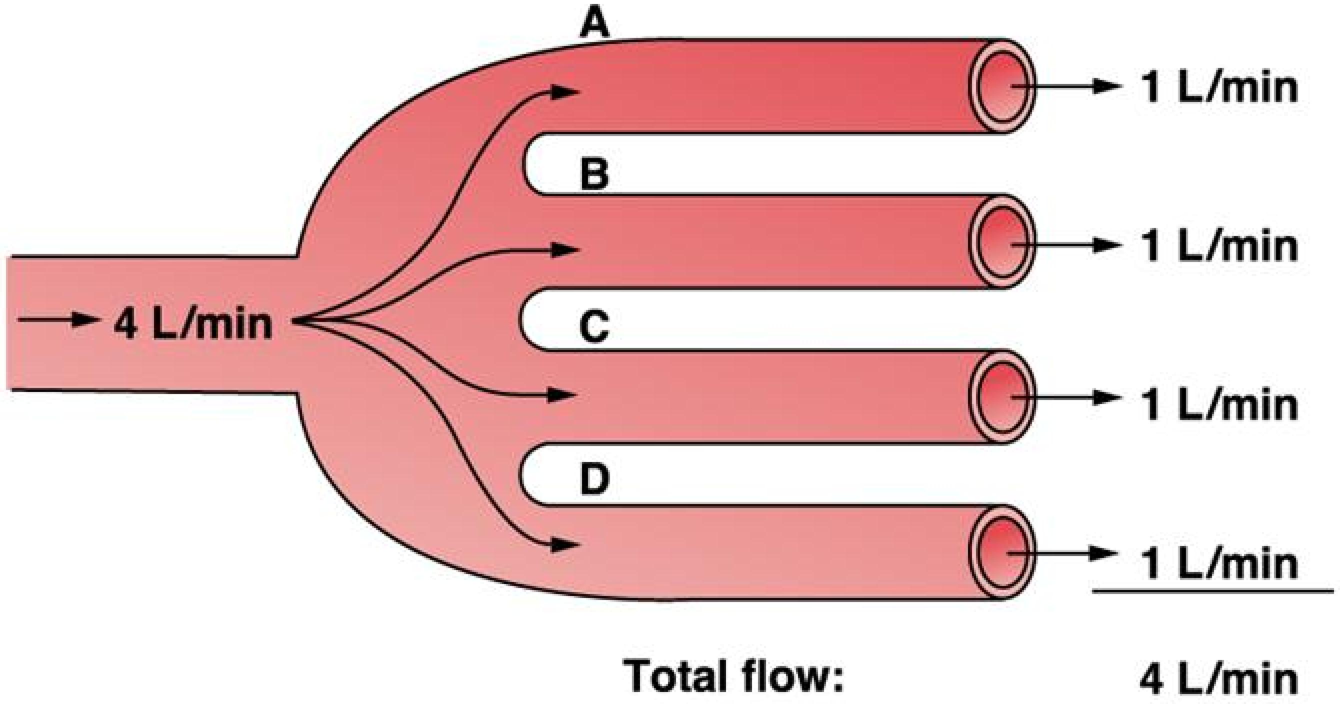
$F = F_A + F_B + F_C + F_D$



CONDOTTI IN PARALLELO

Essendo $F = F_A + F_B + F_C + F_D$
E poiché $R = \Delta P / F$ e $F = \Delta P / R$
$F = \Delta P/R = \Delta P/R_A + \Delta P/R_B + \Delta P/R_C + \Delta P/R_D$
Cioè: $1/R = 1/R_A + 1/R_B + 1/R_C + 1/R_D$

LA RESISTENZA TOTALE è il reciproco della somma dei reciproci delle resistenze dei vari tratti



CONDOTTI IN PARALLELO

LA RESISTENZA TOTALE è il reciproco della somma dei reciproci delle resistenze dei vari tratti

Se $R_A = R_B = R_C = R_D = R_U$ per N tubi uguali

$1/R=1/R_A+1/R_B+1/R_C+1/R_D$ diventa

$1/R= N/R_U$

$R = R_U / N$ ovvero resistenza unitaria diviso numero condotti

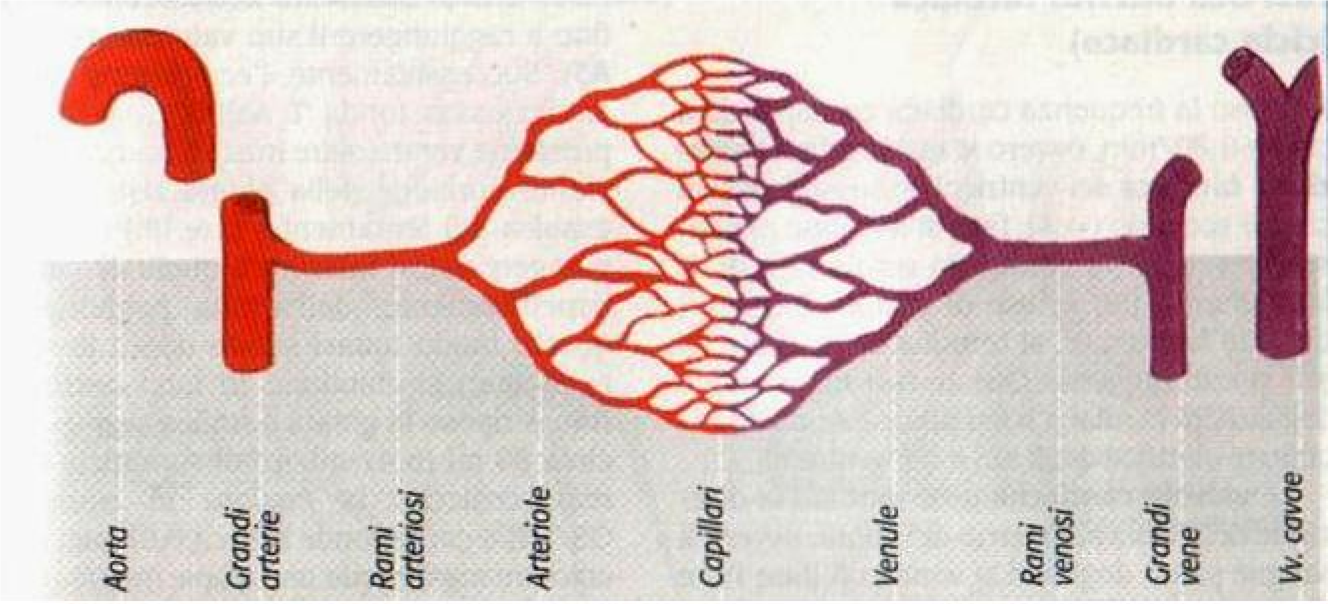
EQUAZIONE DI CONTINUITA'

FLUSSO = V / t = costante

V=S.x   *V/t = S. x/t = S.v*

FLUSSO = S . v = costante

S e *v* sono quindi inversamente proporzionali.



Numero	1	Aumento	$0,16 \cdot 10^9$	$5 \cdot 10^9$	$0,5 \cdot 10^9$	Riduzione	2
Percentuale al RPT		19%	47%	27%	7%		

$$R = 8\, l\, \eta / \pi\, r^4$$

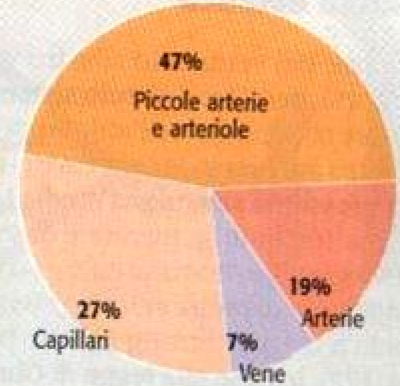
$$R = Ru / N$$

RESISTENZE VASCOLARI PERIFERICHE:

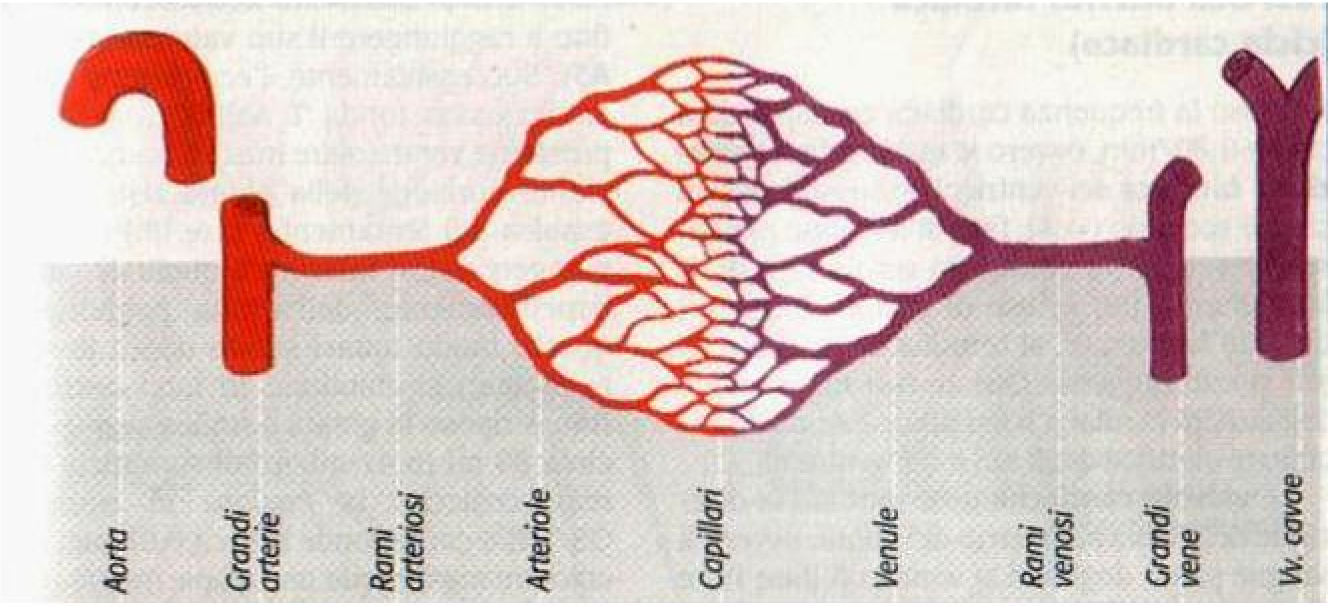
-PER OGNI VASO DIPENDONO DA 1/ raggio^4

-PER OGNI SETTORE DIPENDONO DA 1/Nvasi

-SONO MASSIME NELLE ARTERIOLE



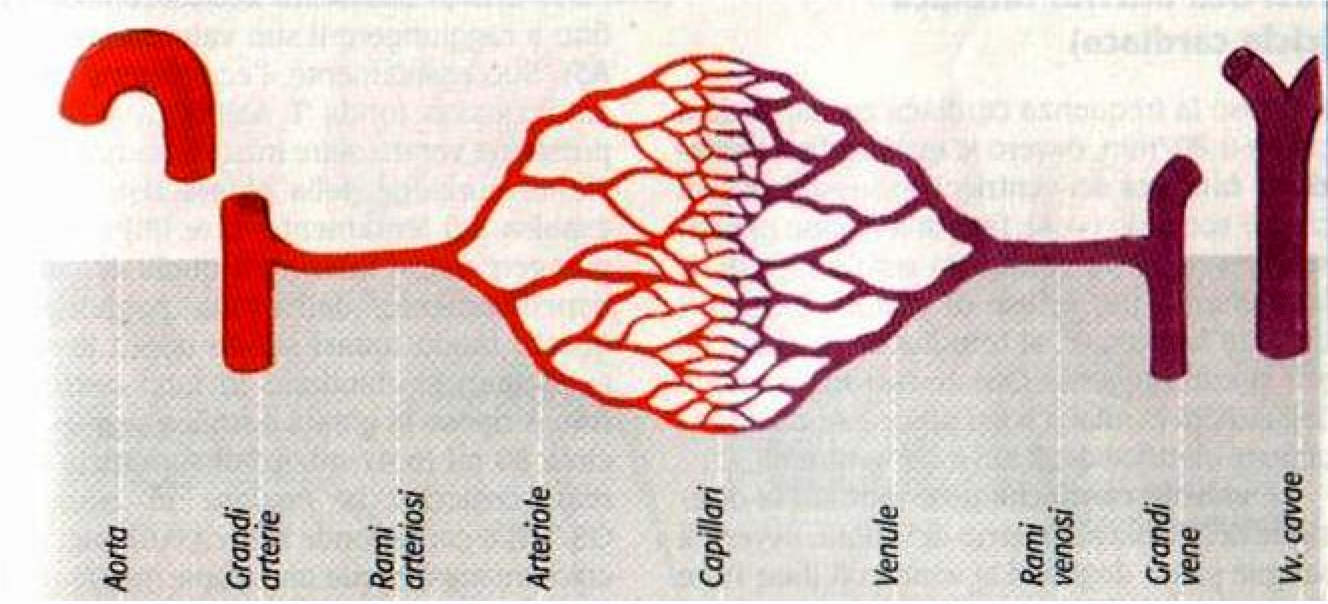
Distribuzione delle resistenze nel circolo sistemico



Numero	1	Aumento	$0,16 \cdot 10^9$	$5 \cdot 10^9$	$0,5 \cdot 10^9$	Riduzione	2
1 Percentuale al RPT	19%	47%	27%		7%		

$Q = \Delta P$ / Resis

- DALL' AORTA ALLE CAVE LE RESISTENZE DEI VARI SETTORI SI SOMMANO PROGRESSIVAMENTE, AUMENTANDO
- MA IL FLUSSO E' LO STESSO IN OGNI SETTORE
- QUINDI PROGRESSIVA CADUTA DI PRESSIONE



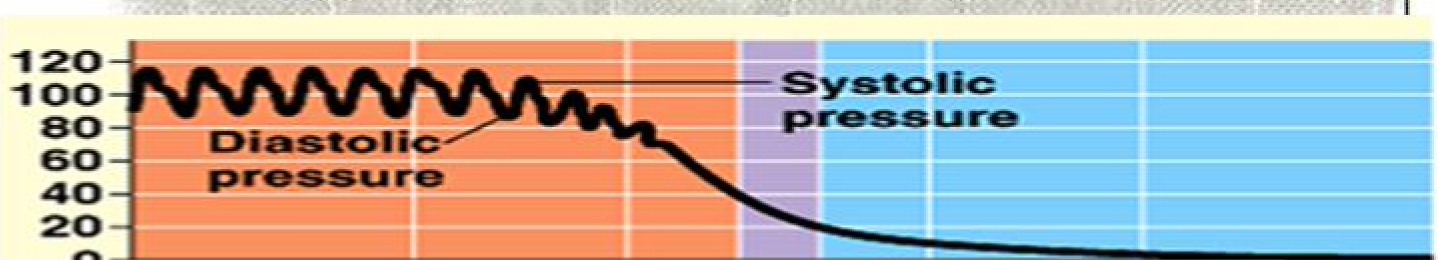
Numero 1 Aumento $0{,}16 \cdot 10^9$ $5 \cdot 10^9$ $0{,}5 \cdot 10^9$ Riduzione 2

1 Percentuale al RPT

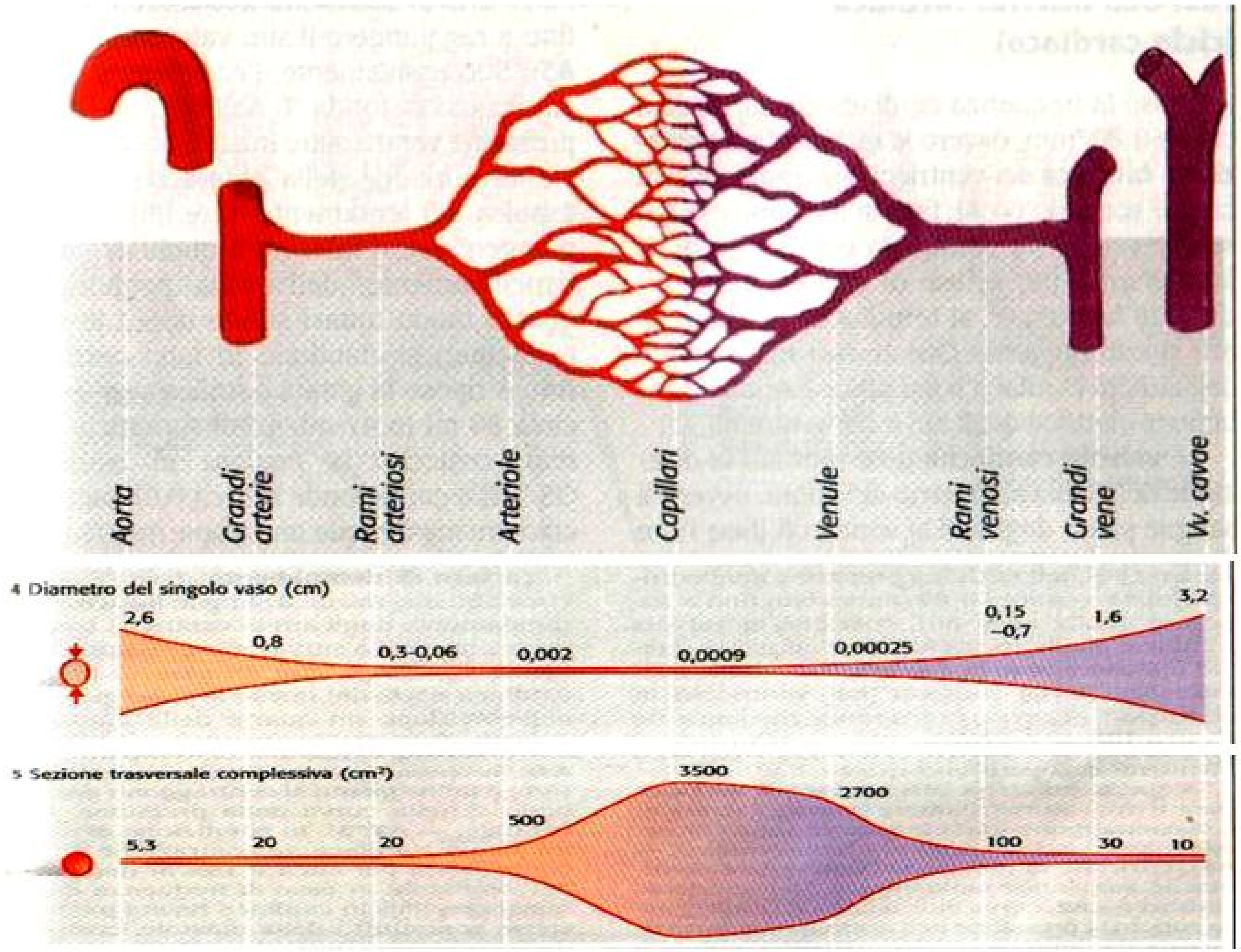
19% 47% 27% 7%

2 Pressione sanguigna media $\bar{P}$ (mmHg)

100 40 25 20 2-4



PROGRESSIVA CADUTA DI PRESSIONE:

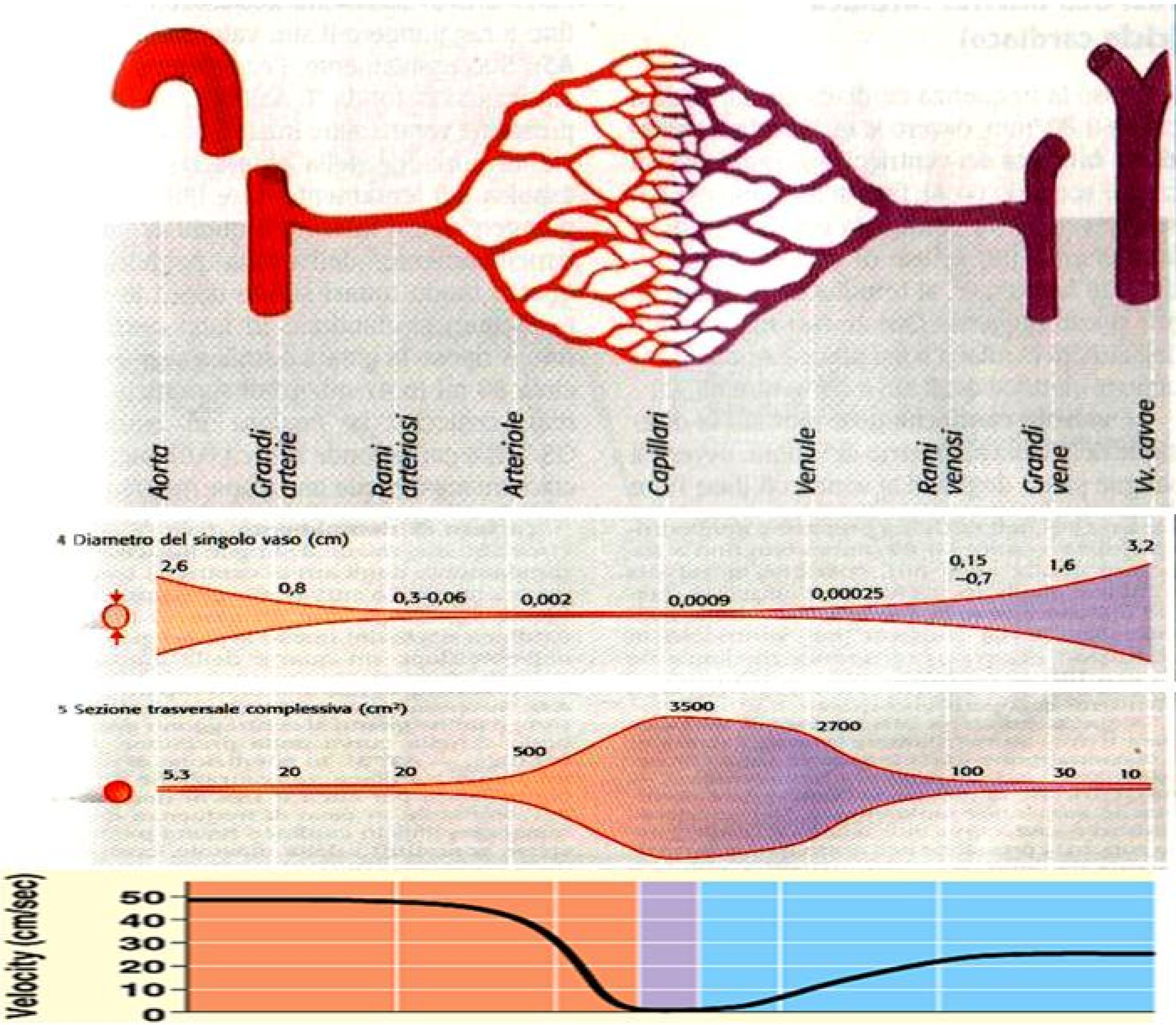


$$F = v \cdot S$$

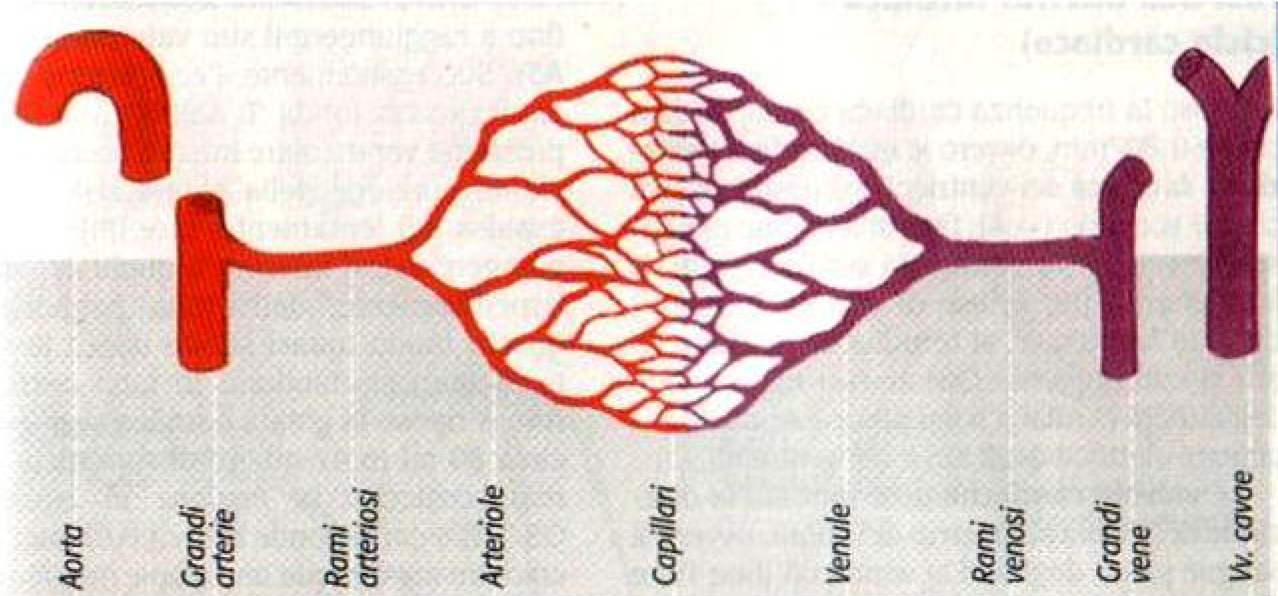
$$v = F / S$$

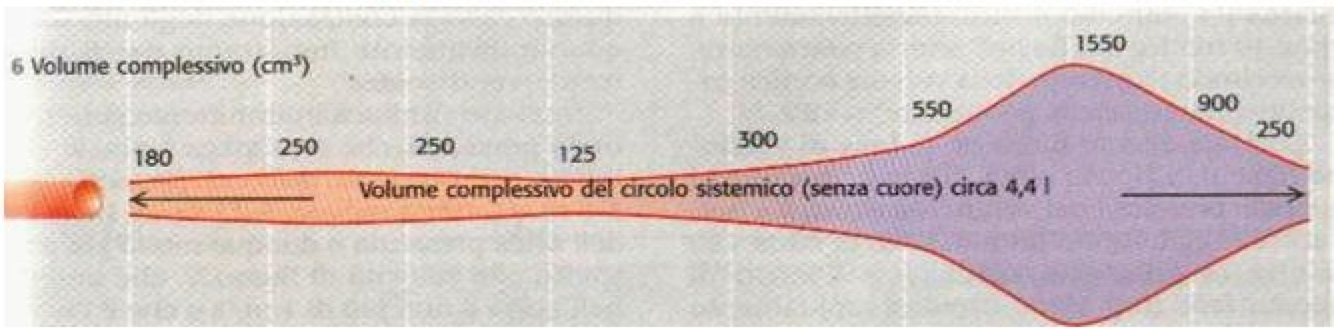
I CAPILLARI SONO PICCOLISSIMI MA MOLTISSIMI, QUINDI LA SEZIONE COMPLESSIVA PER SETTORE E' MASSIMA NEI CAPILLARI:

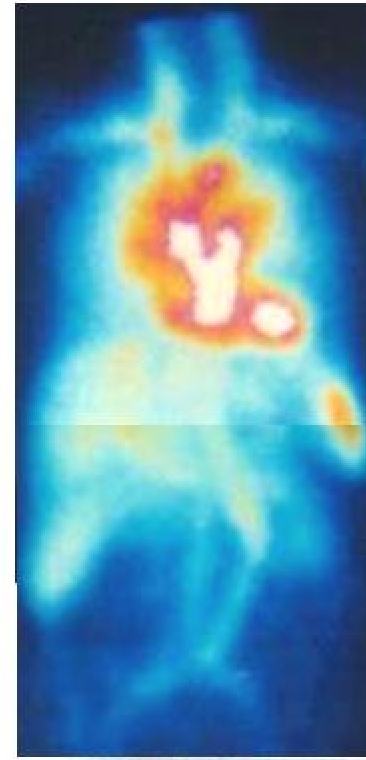
MA IL FLUSSO E' LO STESSO IN OGNI SETTORE -QUINDI VELOCITA' MINIMA NEI CAPILLARI

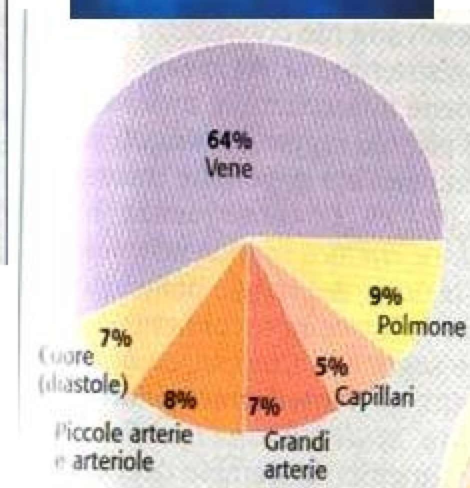


VELOCITA'
MINIMA NEI
CAPILLARI

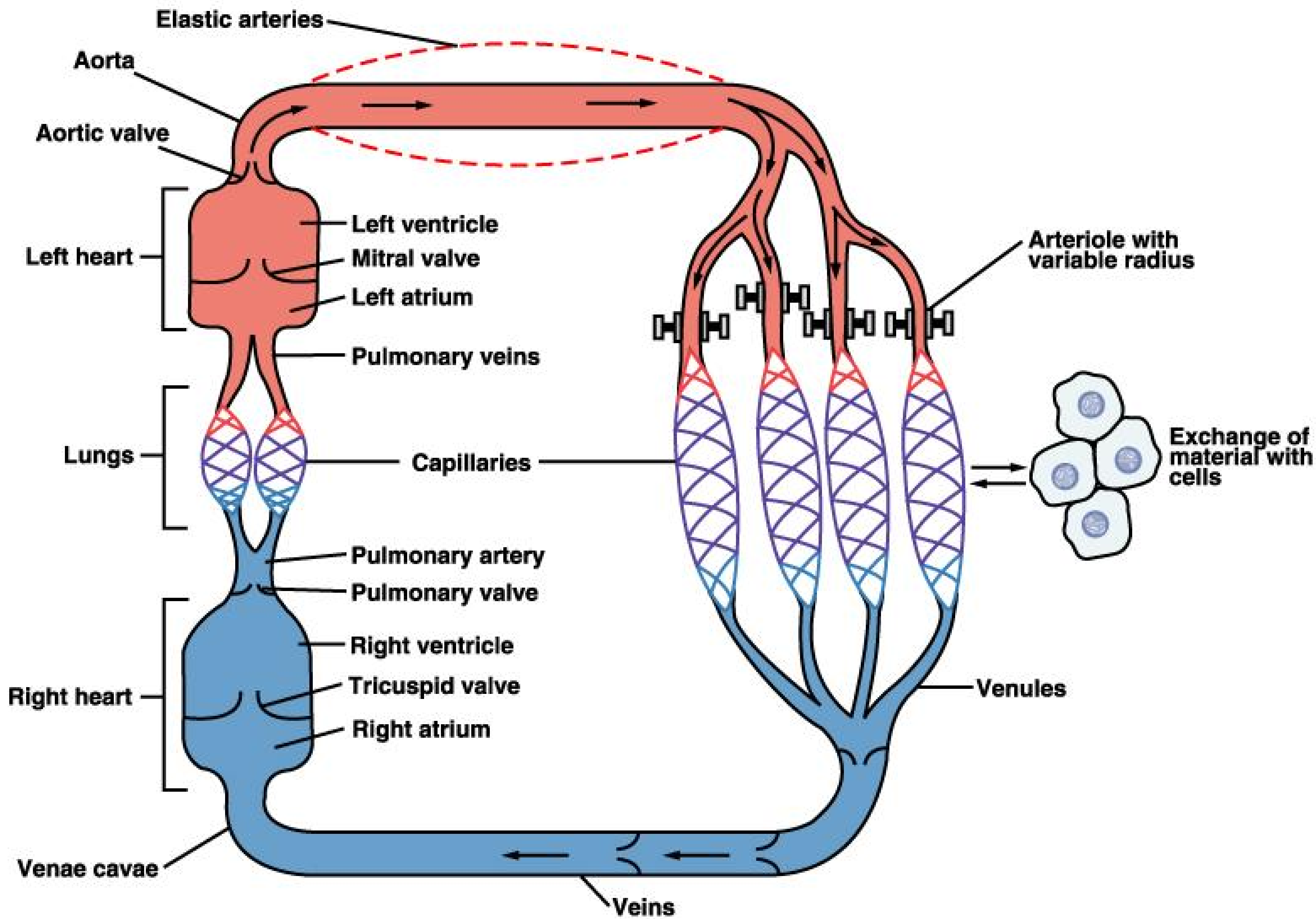






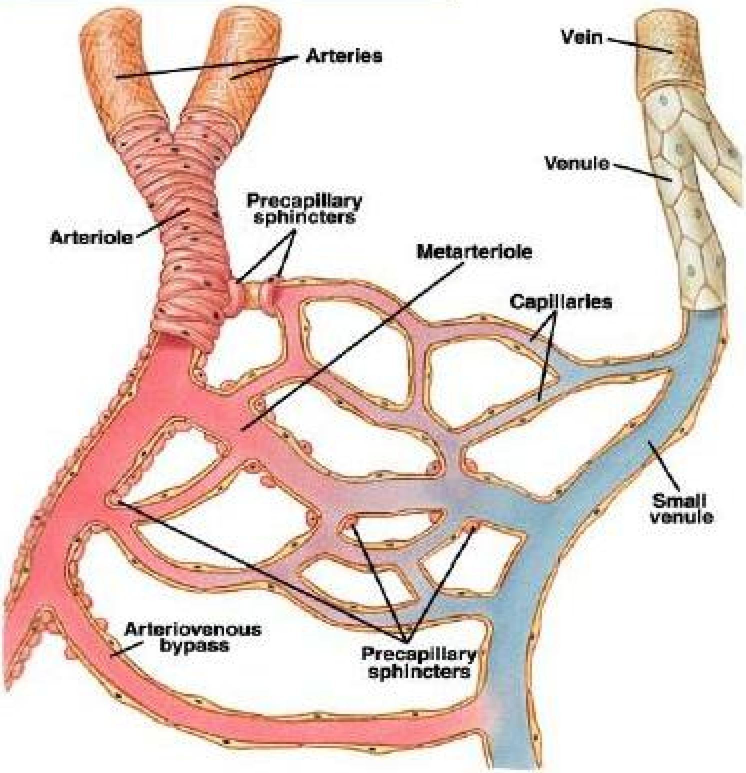


Distribuzione dei volumi

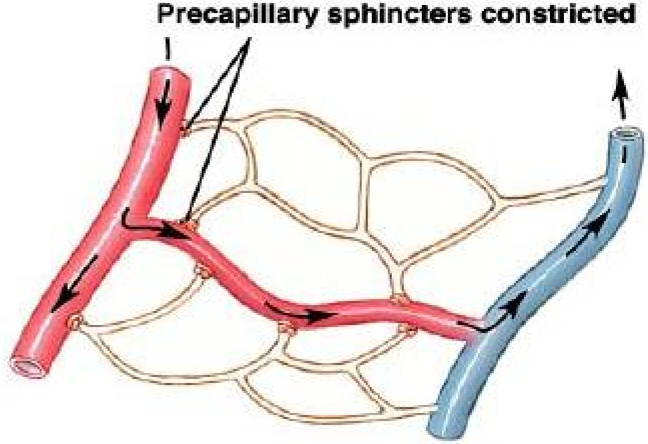


Elastic arteries
Aorta
Aortic valve
Left heart
Left ventricle
Mitral valve
Left atrium
Pulmonary veins
Lungs
Capillaries
Pulmonary artery
Pulmonary valve
Right heart
Right ventricle
Tricuspid valve
Right atrium
Venae cavae
Veins
Venules
Arteriole with
variable radius
Exchange of
material with
cells

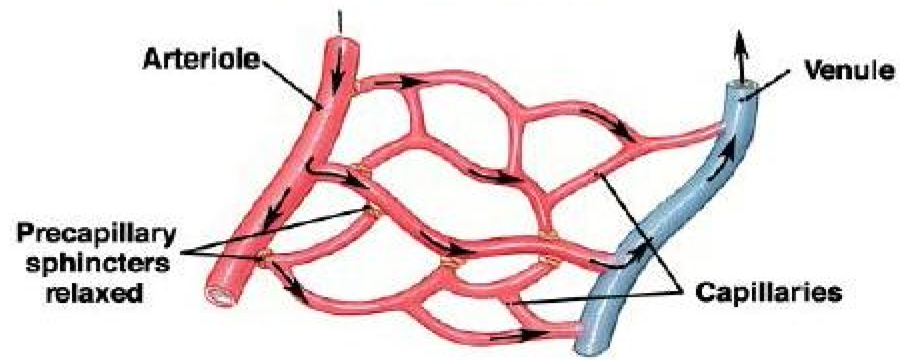
VASOMOTILITA'

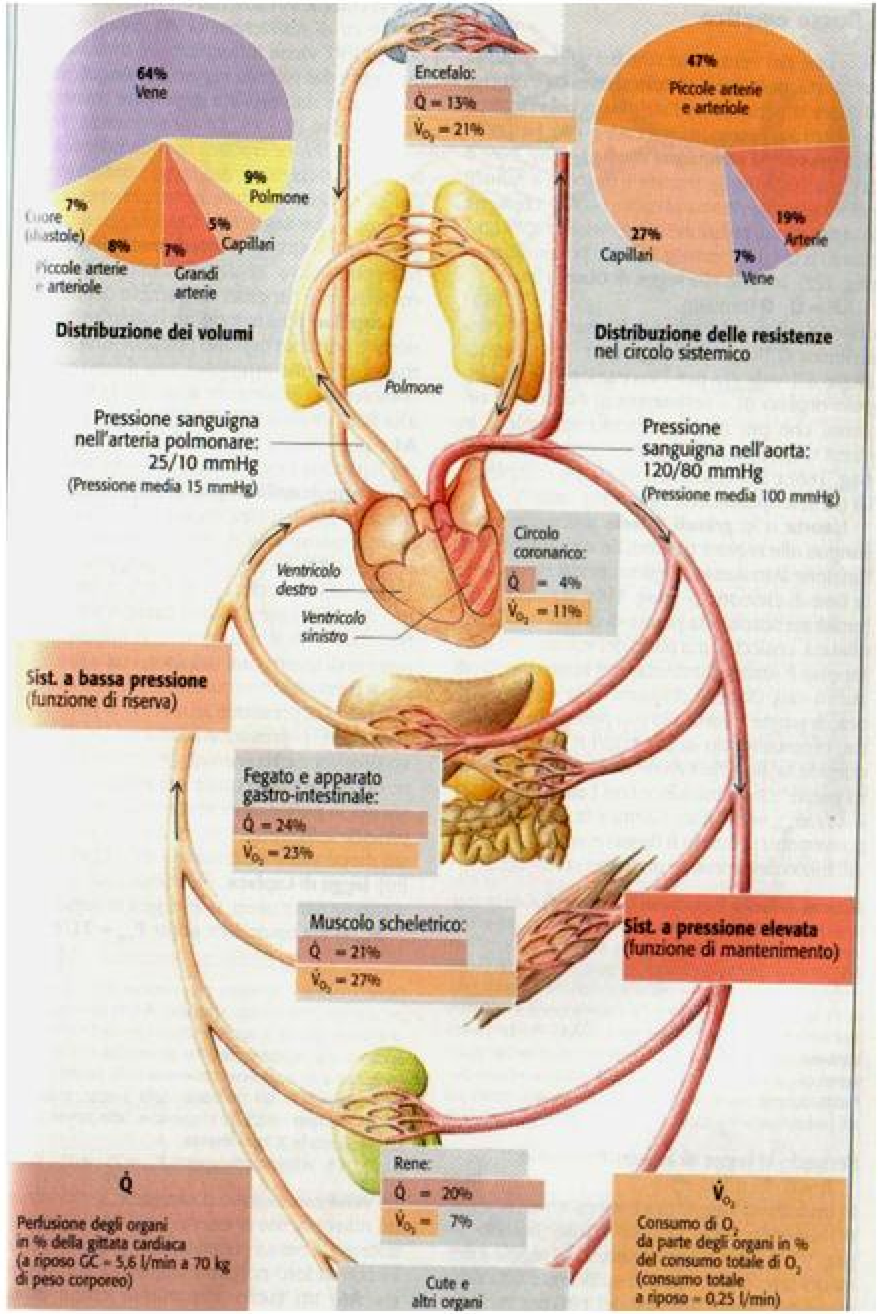


Massima vasocostrizione

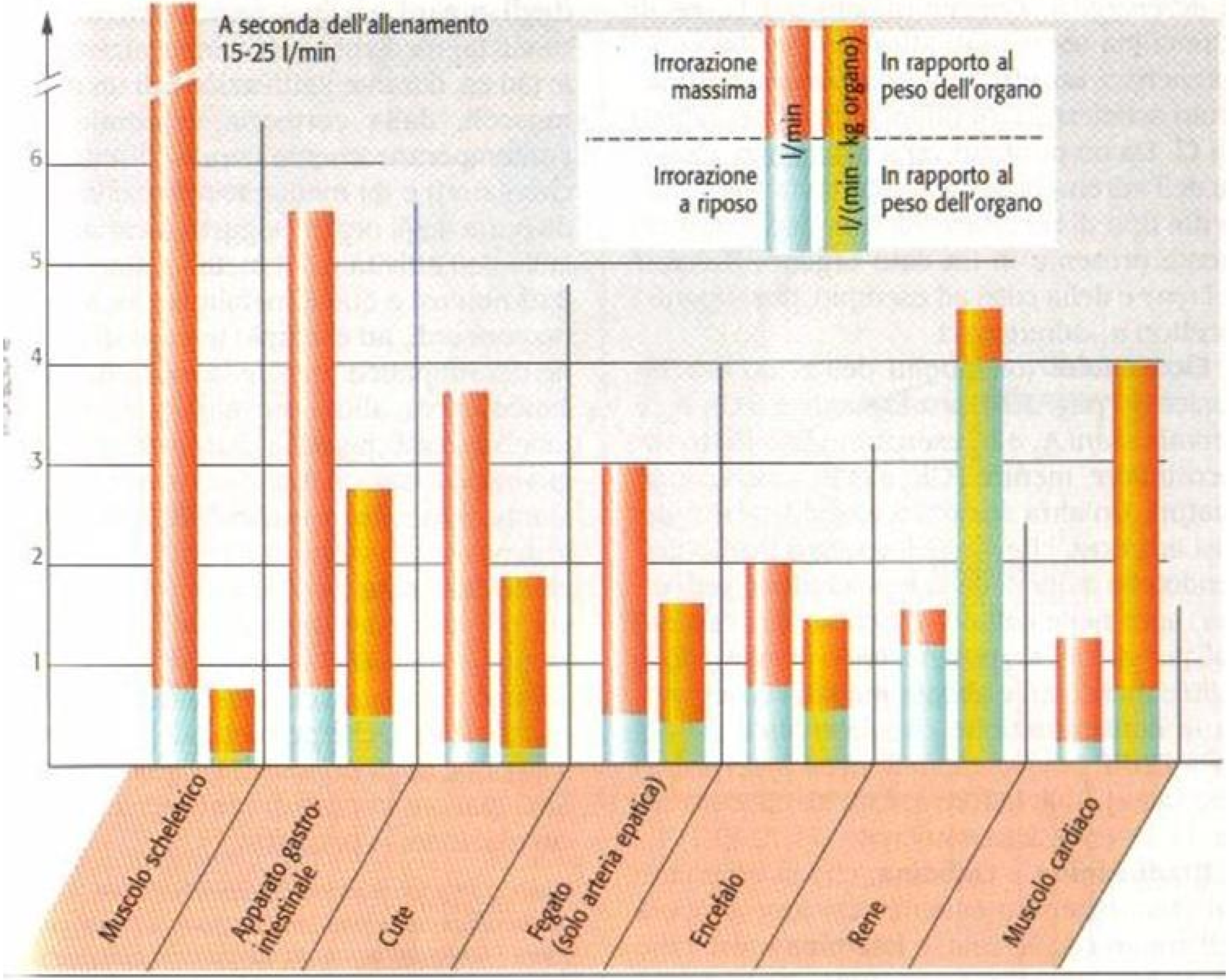


Massima vasodilatazione




64%
Vene
9%
Polmone
7%
Cuore
(diastole)
5%
Capillari
8%
7%
Piccole arterie
e arteriole
Grandi
arterie
Distribuzione dei volumi
Encefalo:
Q̇ = 13%
$\dot{V}_{O_2}$ = 21%
47%
Piccole arterie
e arteriole
19%
Arterie
27%
Capillari
7%
Vene
Distribuzione delle resistenze
nel circolo sistemico
Polmone
Pressione sanguigna
nell'arteria polmonare:
25/10 mmHg
(Pressione media 15 mmHg)
Pressione
sanguigna nell'aorta:
120/80 mmHg
(Pressione media 100 mmHg)
Circolo
coronarico:
Q̇ = 4%
$\dot{V}_{O_2}$ = 11%
Ventricolo
destro
Ventricolo
sinistro
Sist. a bassa pressione
(funzione di riserva)
Fegato e apparato
gastro-intestinale:
Q̇ = 24%
$\dot{V}_{O_2}$ = 23%
Muscolo scheletrico:
Q̇ = 21%
$\dot{V}_{O_2}$ = 27%
Sist. a pressione elevata
(funzione di mantenimento)
Rene:
Q̇ = 20%
$\dot{V}_{O_2}$ = 7%
Q̇
Perfusione degli organi
in % della gittata cardiaca
(a riposo GC = 5,6 l/min a 70 kg
di peso corporeo)
Cute e
altri organi
$\dot{V}_{O_2}$
Consumo di O_2
da parte degli organi in %
del consumo totale di O_2
(consumo totale
a riposo = 0,25 l/min)

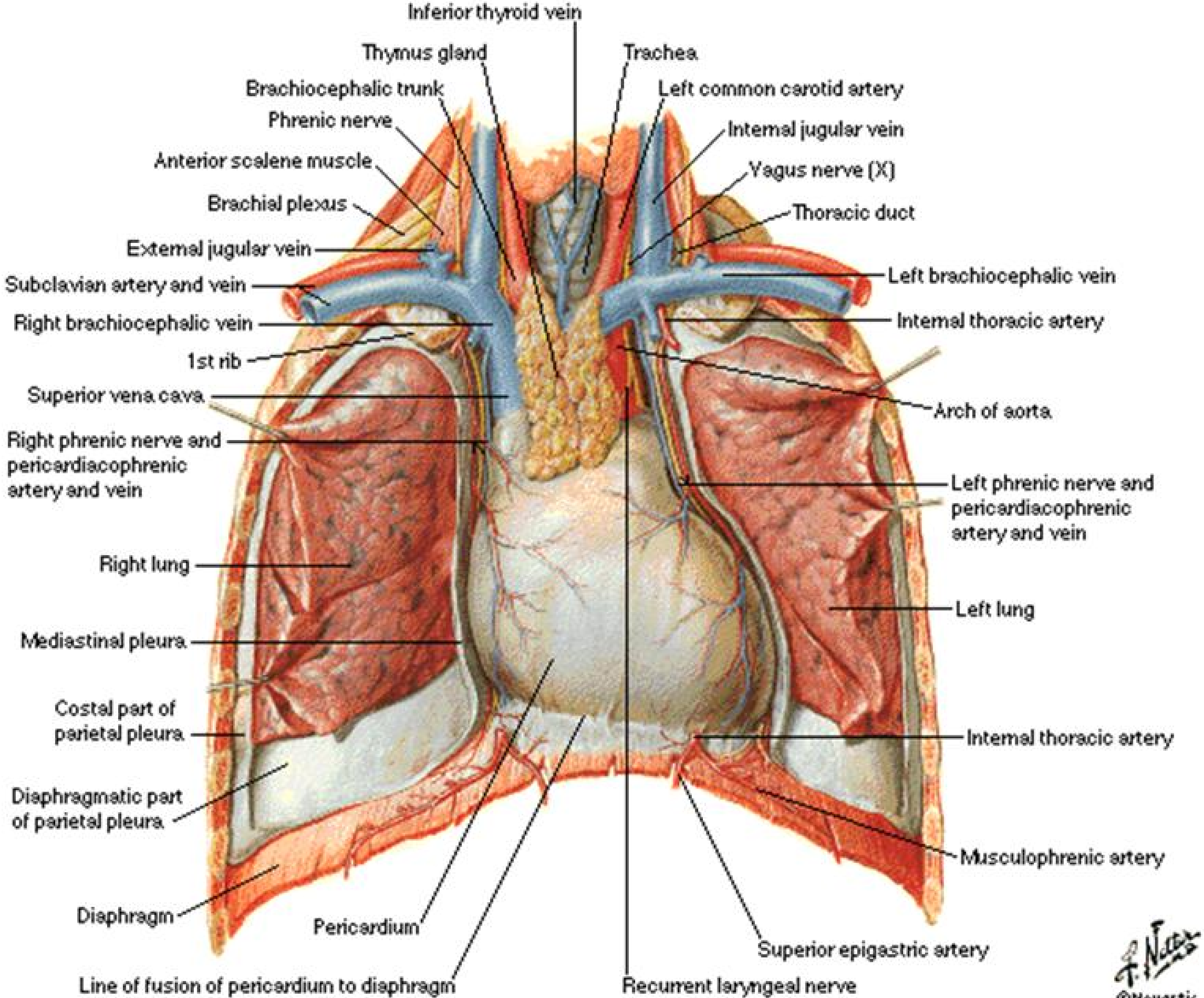
A. Irrorazione degli organi

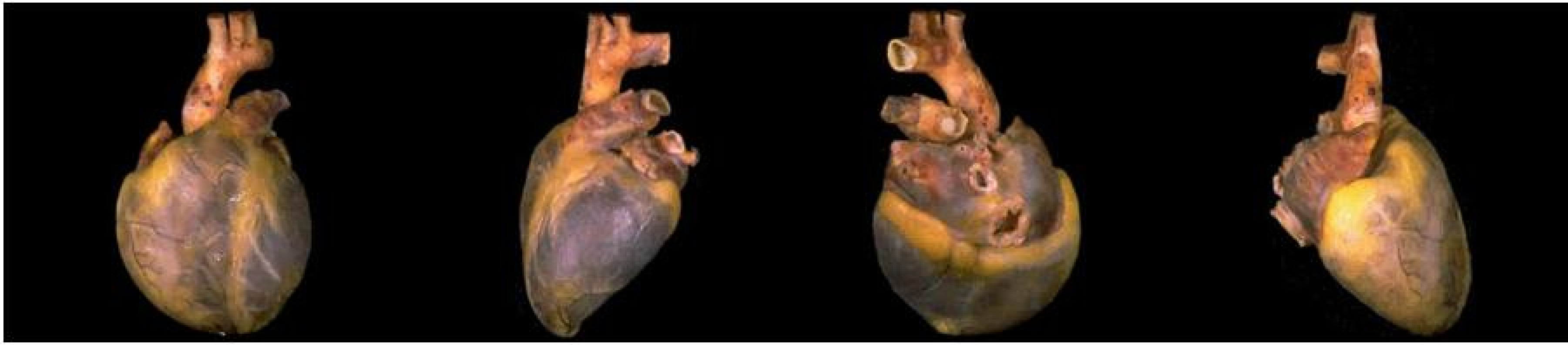


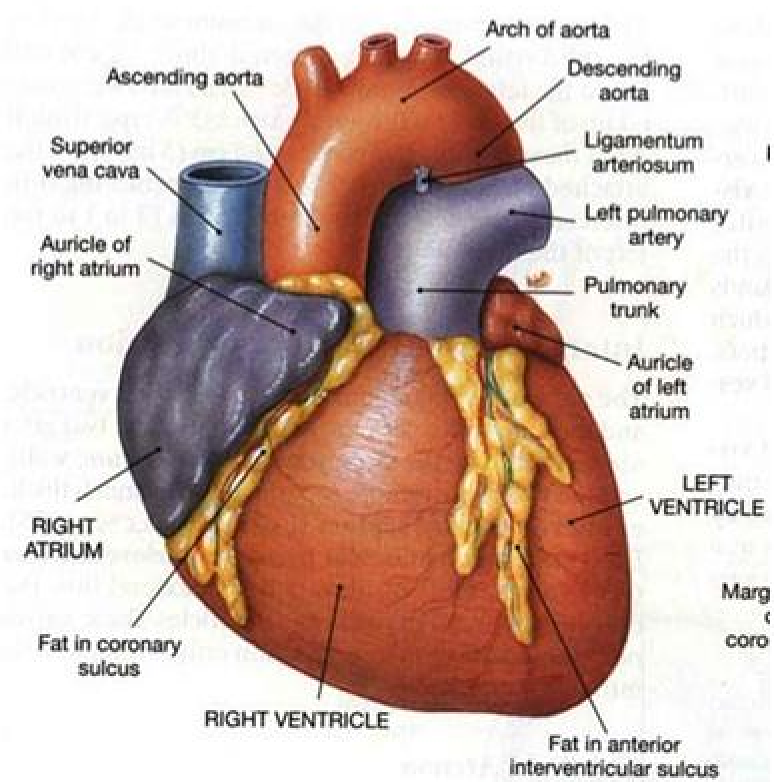
SISTEMA CIRCOLATORIO:

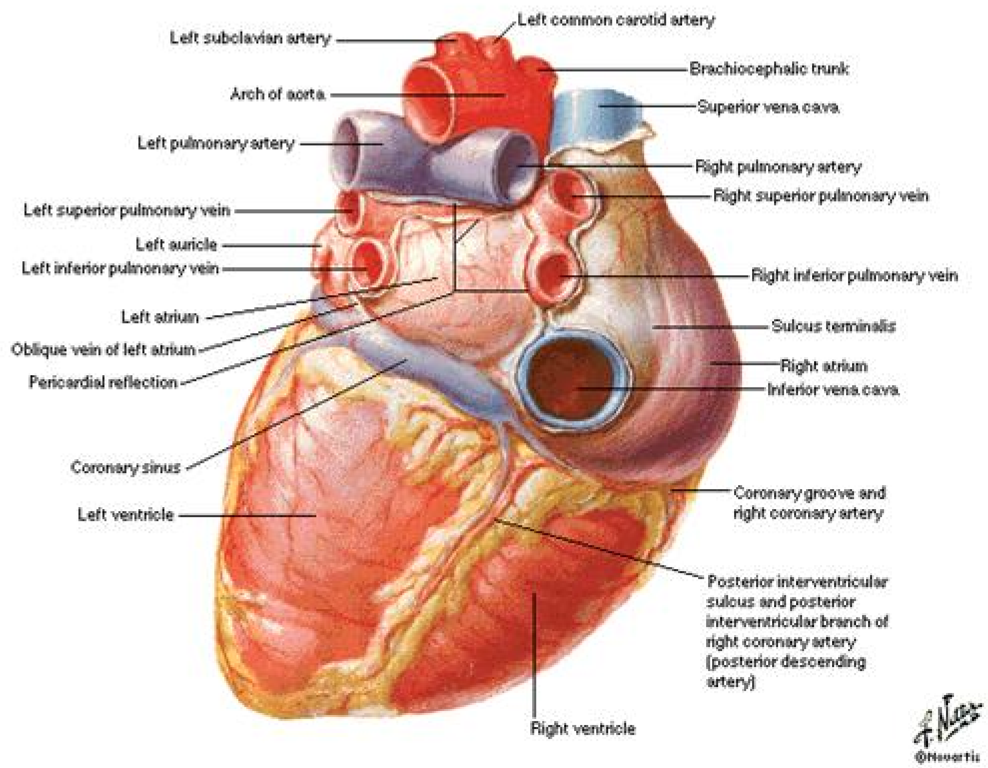
CUORE
Struttura

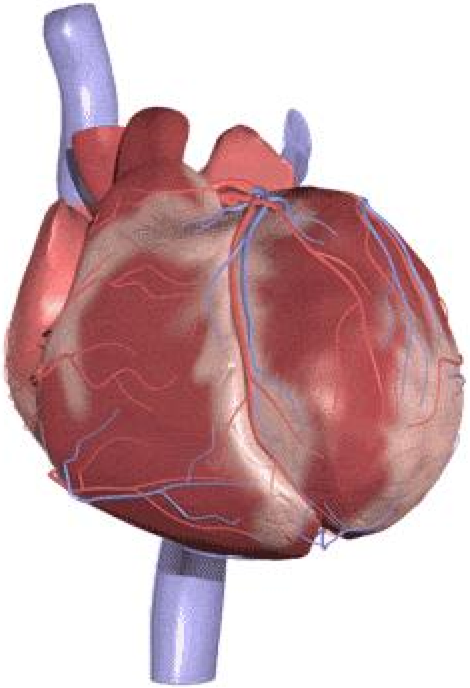
Heart in Situ



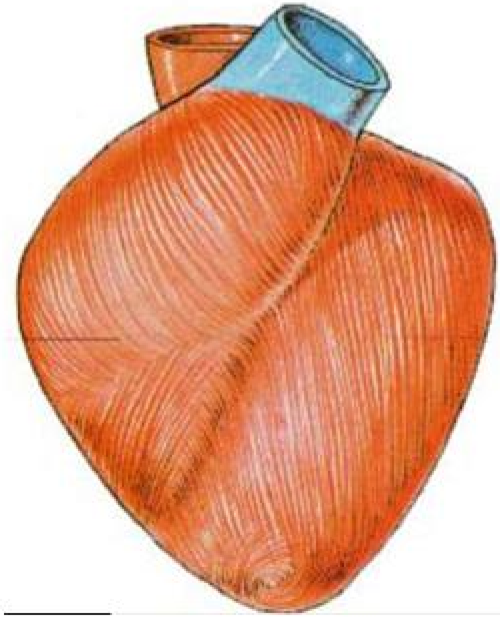


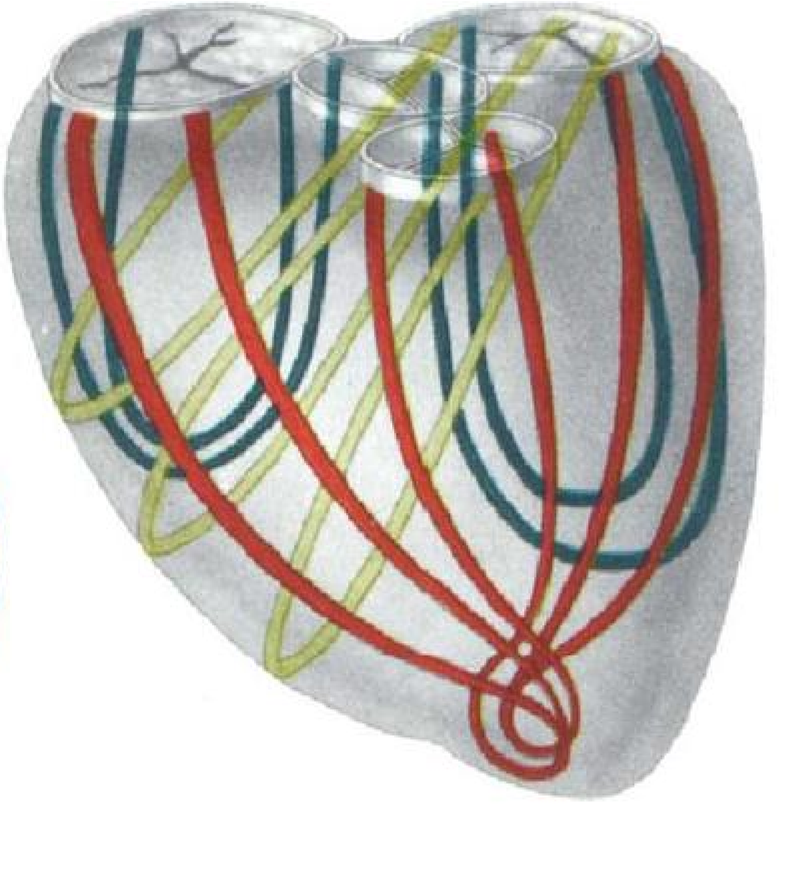

Arch of aorta
Ascending aorta
Descending aorta
Superior vena cava
Ligamentum arteriosum
Left pulmonary artery
Auricle of right atrium
Pulmonary trunk
Auricle of left atrium
LEFT VENTRICLE
RIGHT ATRIUM
Fat in coronary sulcus
RIGHT VENTRICLE
Fat in anterior interventricular sulcus


Left common carotid artery
Left subclavian artery
Brachiocephalic trunk
Arch of aorta
Superior vena cava
Left pulmonary artery
Right pulmonary artery
Right superior pulmonary vein
Left superior pulmonary vein
Left auricle
Left inferior pulmonary vein
Right inferior pulmonary vein
Left atrium
Sulcus terminalis
Oblique vein of left atrium
Right atrium
Pericardial reflection
Inferior vena cava
Coronary sinus
Coronary groove and right coronary artery
Left ventricle
Posterior interventricular sulcus and posterior interventricular branch of right coronary artery (posterior descending artery)
Right ventricle
©Novartis

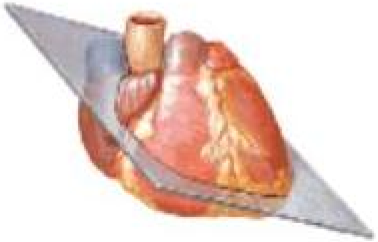


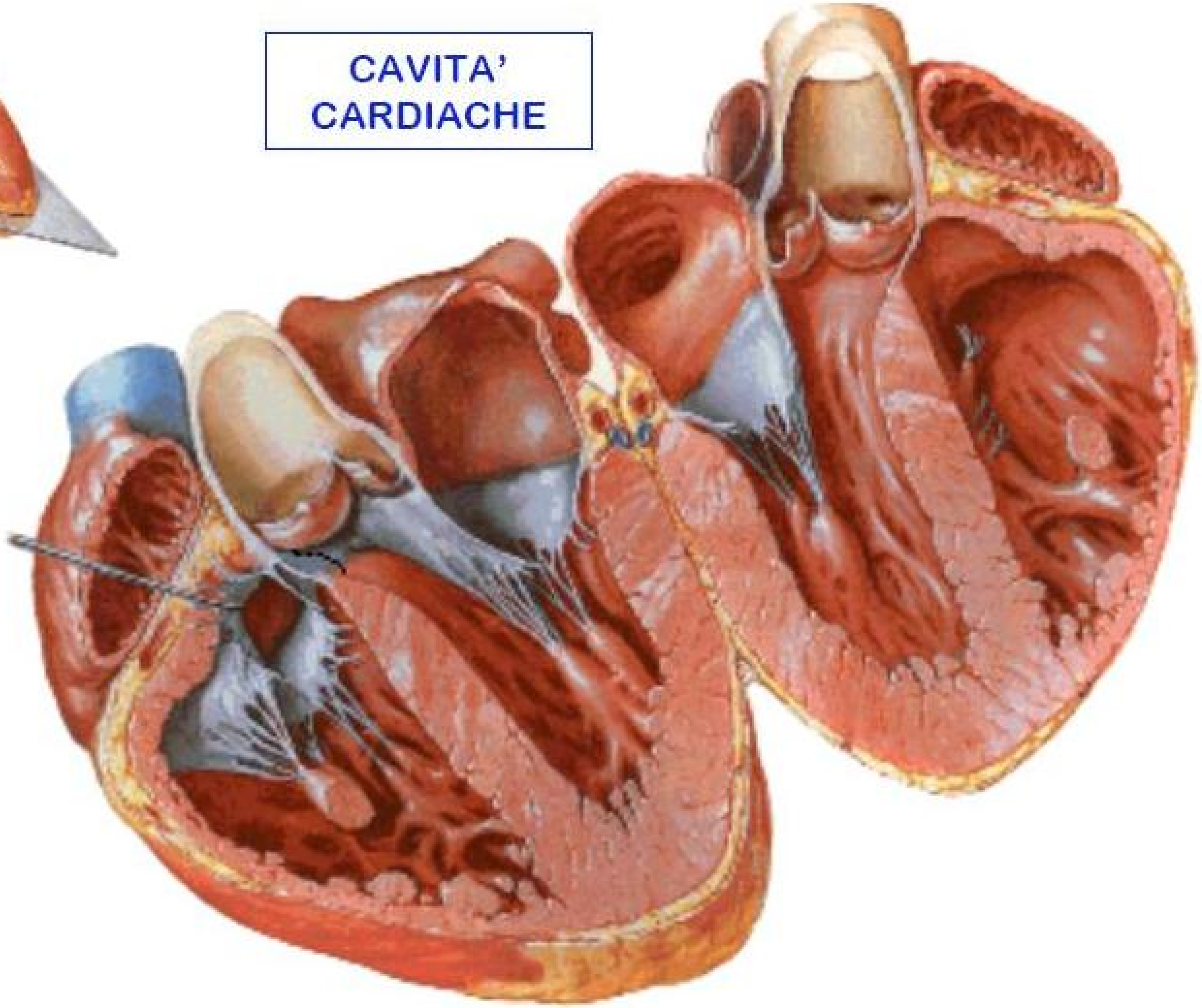
FASCI
MUSCOLARI
VENTRICOLARI

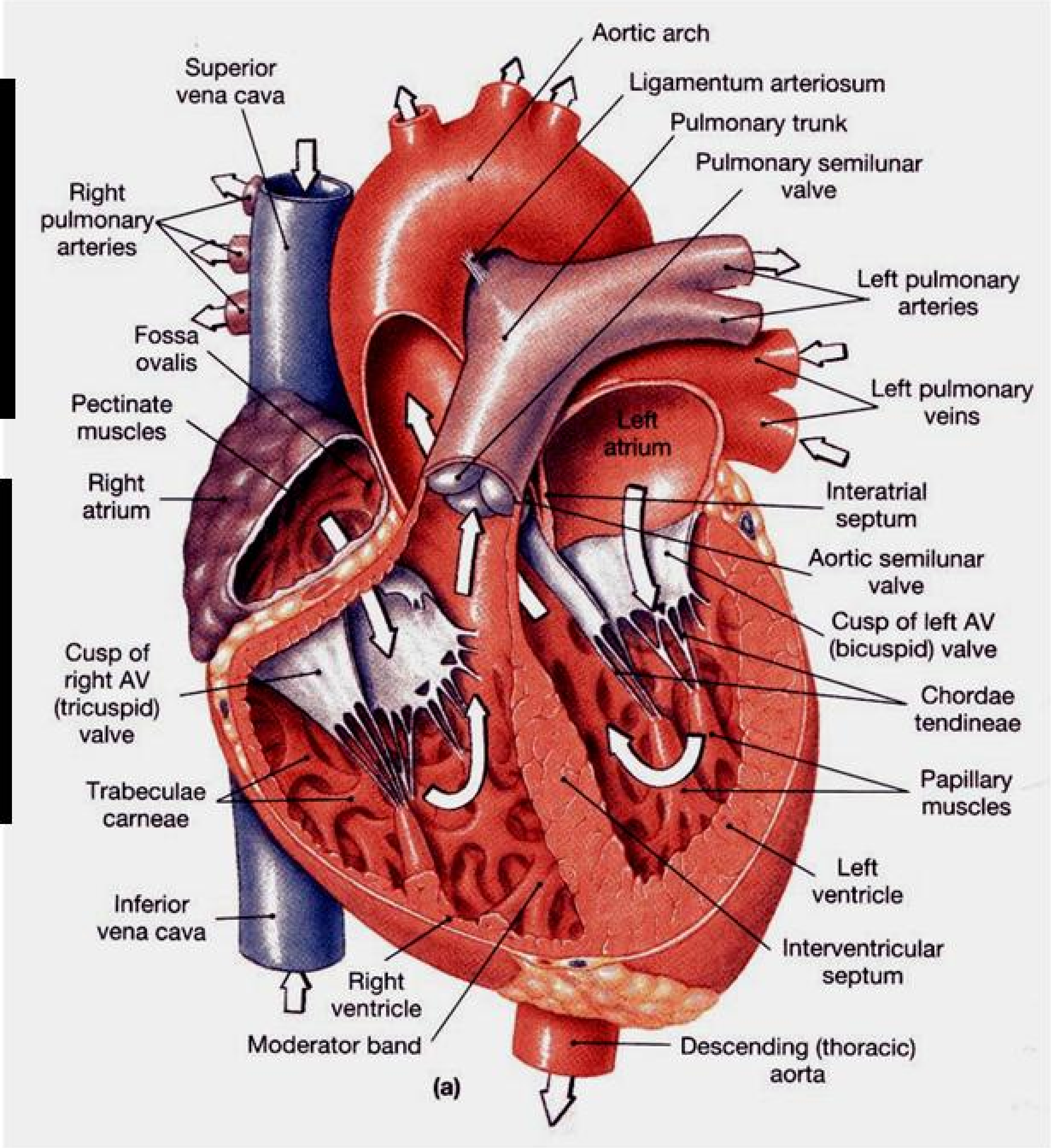




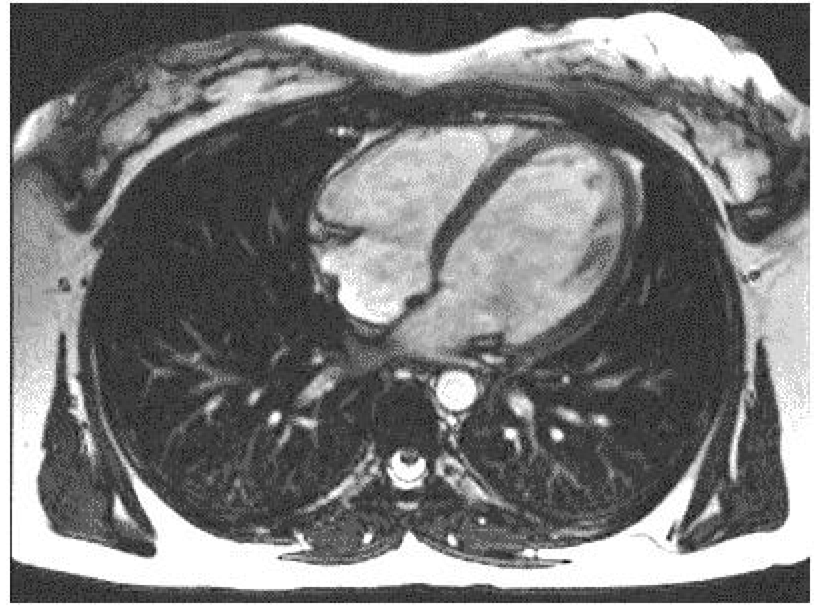
CAVITA' CARDIACHE



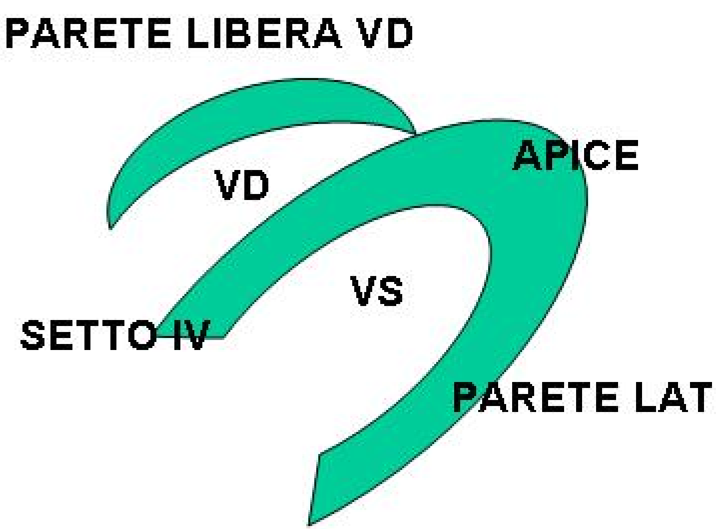


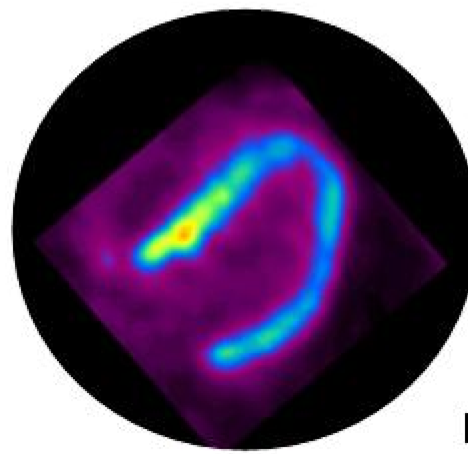


Aortic arch
Superior vena cava
Ligamentum arteriosum
Pulmonary trunk
Pulmonary semilunar valve
Right pulmonary arteries
Left pulmonary arteries
Fossa ovalis
Left pulmonary veins
Pectinate muscles
Left atrium
Right atrium
Interatrial septum
Aortic semilunar valve
Cusp of left AV (bicuspid) valve
Cusp of right AV (tricuspid) valve
Chordae tendineae
Papillary muscles
Trabeculae carneae
Left ventricle
Inferior vena cava
Interventricular septum
Right ventricle
Moderator band
Descending (thoracic) aorta
(a)



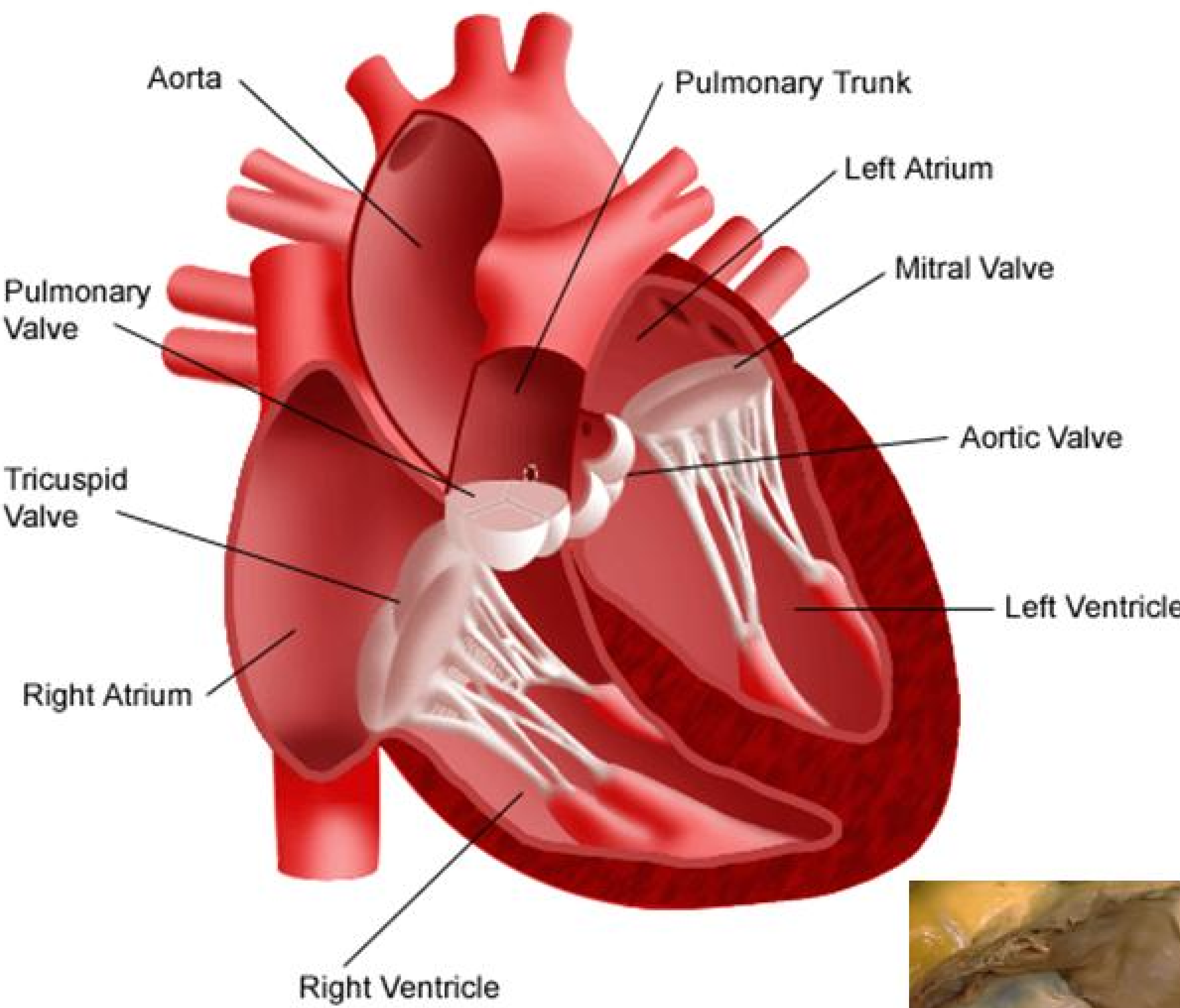
MRI

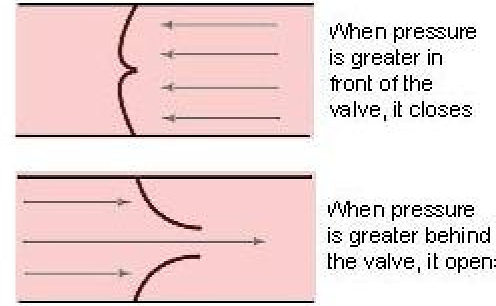


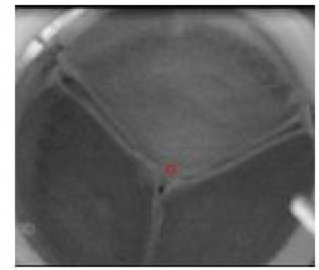


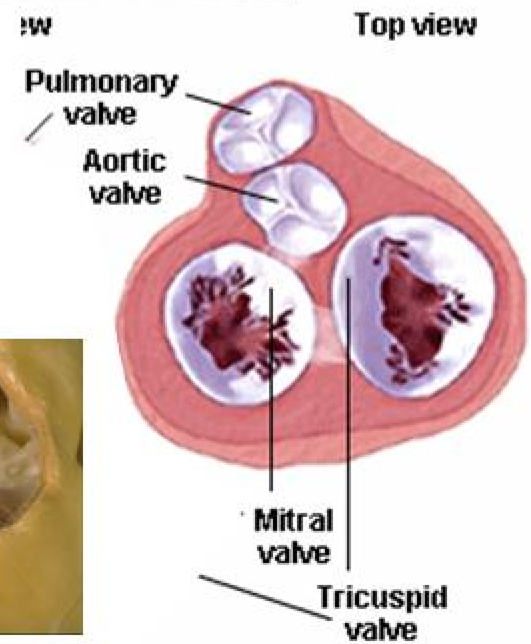
PET

Valves of the Heart



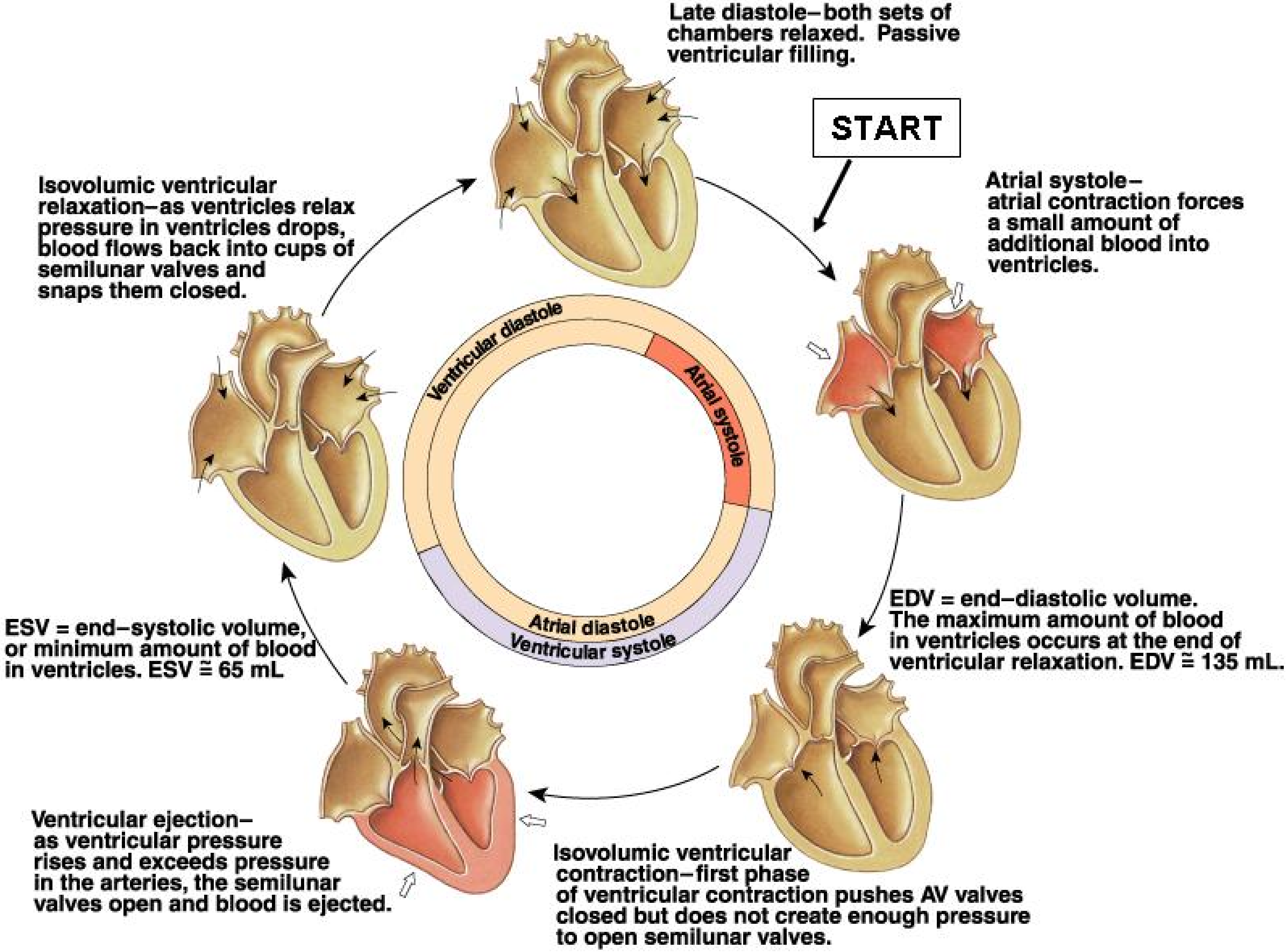




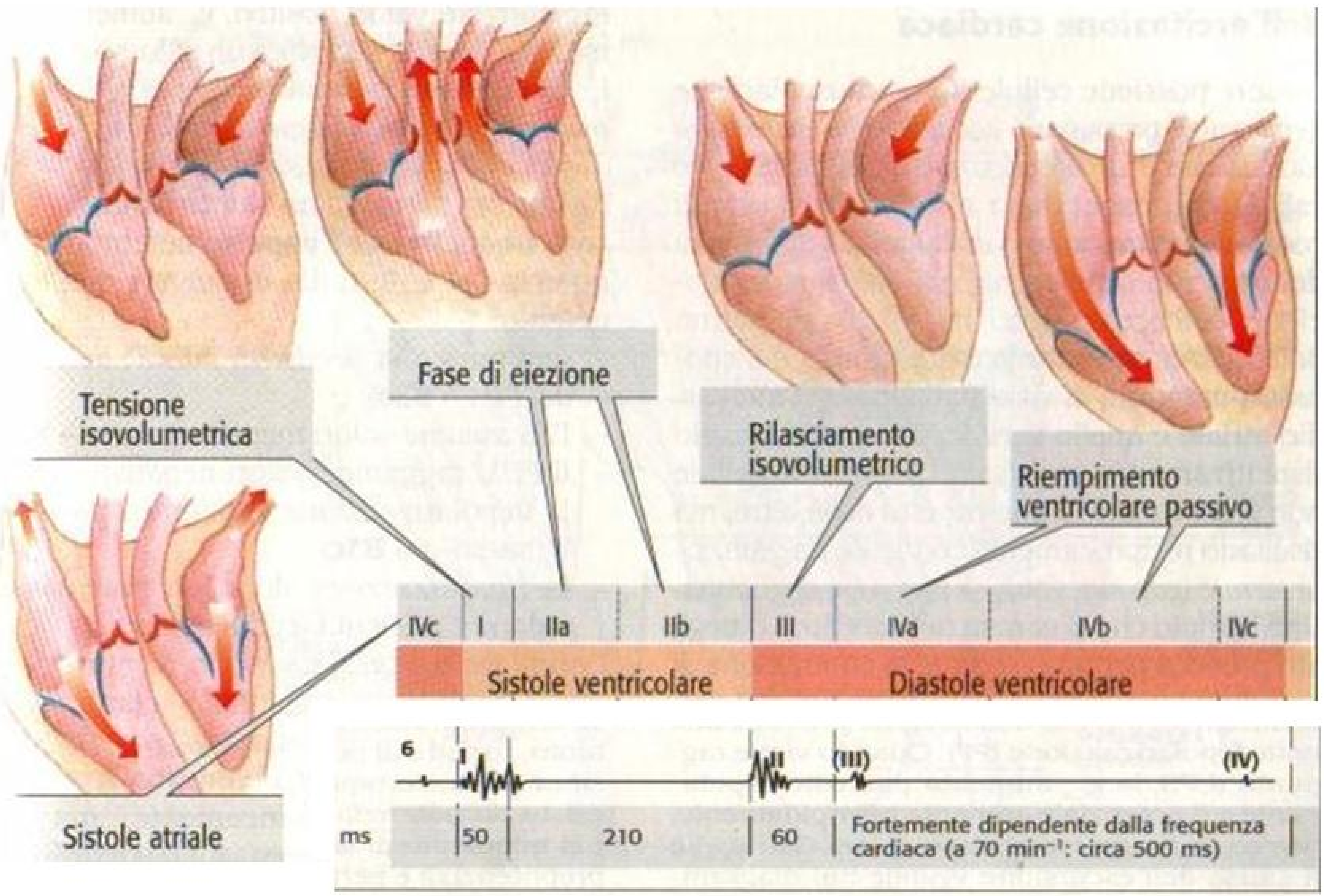


SISTEMA CIRCOLATORIO:

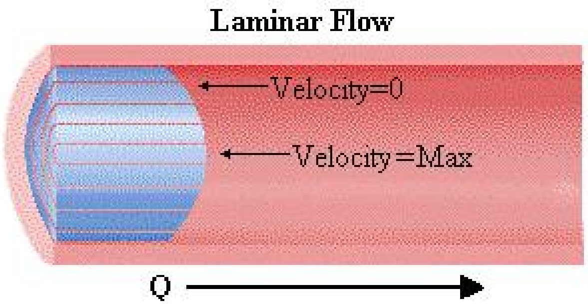
CUORE
Ciclo cardiaco



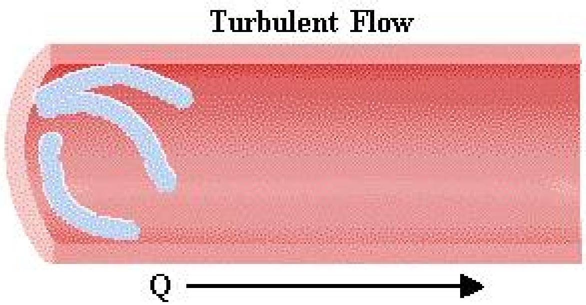
Late diastole–both sets of chambers relaxed. Passive ventricular filling.
START
Atrial systole– atrial contraction forces a small amount of additional blood into ventricles.
EDV = end–diastolic volume. The maximum amount of blood in ventricles occurs at the end of ventricular relaxation. EDV ≅ 135 mL.
Isovolumic ventricular contraction–first phase of ventricular contraction pushes AV valves closed but does not create enough pressure to open semilunar valves.
Ventricular ejection– as ventricular pressure rises and exceeds pressure in the arteries, the semilunar valves open and blood is ejected.
ESV = end–systolic volume, or minimum amount of blood in ventricles. ESV ≅ 65 mL
Isovolumic ventricular relaxation–as ventricles relax pressure in ventricles drops, blood flows back into cups of semilunar valves and snaps them closed.
Ventricular diastole
Atrial systole
Atrial diastole
Ventricular systole



Tensione isovolumetrica
Fase di eiezione
Rilasciamento isovolumetrico
Riempimento ventricolare passivo
Sistole atriale
IVc
I
IIa
IIb
III
IVa
IVb
IVc
Sistole ventricolare
Diastole ventricolare
6
I
II
(III)
(IV)
ms
50
210
60
Fortemente dipendente dalla frequenza cardiaca (a 70 min^{-1}: circa 500 ms)



Re <2300



Re >4000

$$\text{Reynold's Number} = \frac{\rho \times \nu \cdot d}{\eta}$$

where ρ = density of fluid

ν = linear velocity

d = diameter of tube

η = viscosity of fluid

with turbulent flow $\Delta p = R\,\dot{V}^2$

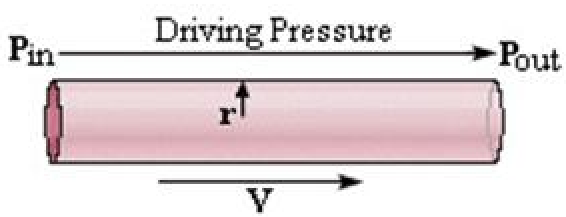
$$R = \frac{\Delta P}{V}$$

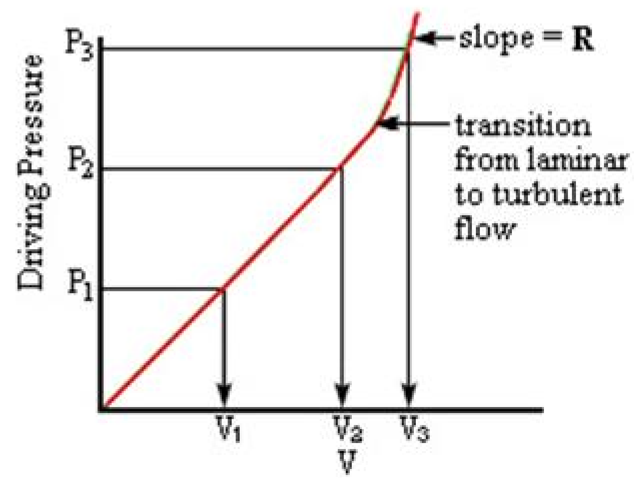
hence

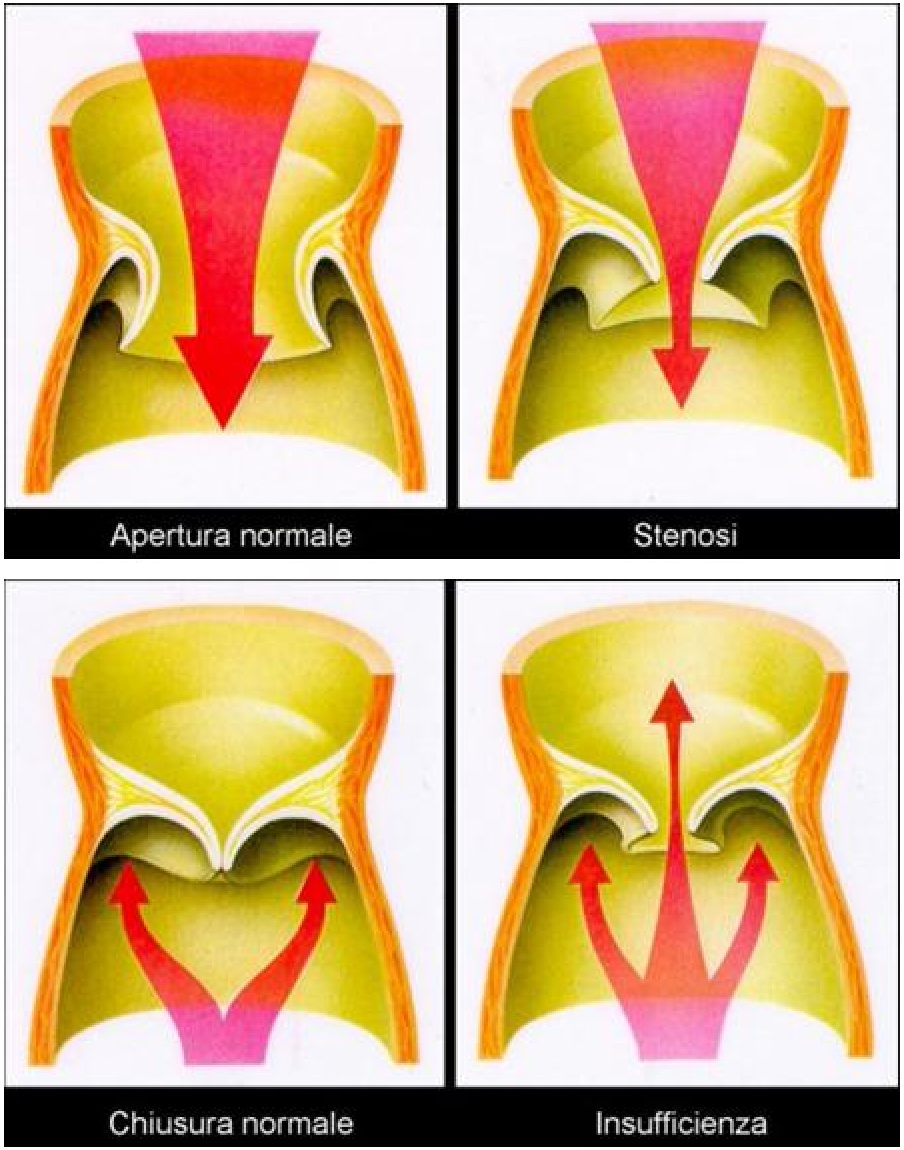
$$P = RV$$

or

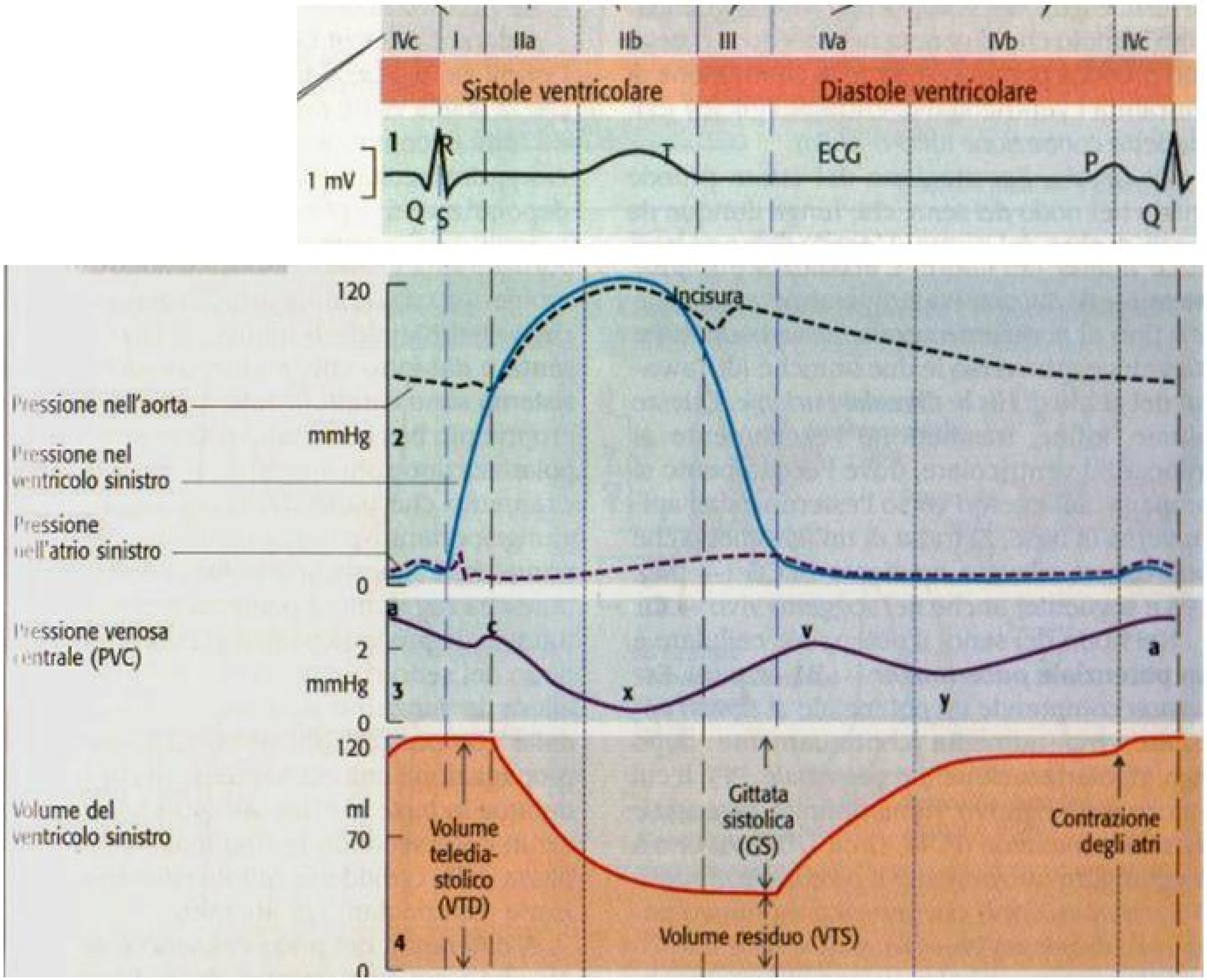
$$P_{in} - P_{out} = RV$$





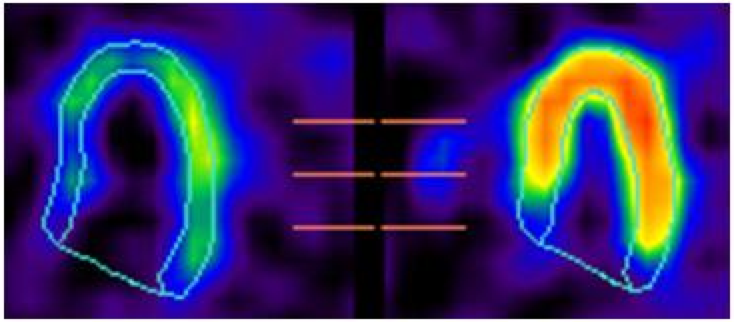



Standard or Transthoracic Echo



IVc
I
IIa
IIb
III
IVa
IVb
IVc
Sistole ventricolare
Diastole ventricolare
1
1 mV
R
T
ECG
P
Q
S
Q
120
Incisura
Pressione nell'aorta
mmHg
2
Pressione nel ventricolo sinistro
Pressione nell'atrio sinistro
0
a
c
Pressione venosa centrale (PVC)
2
v
a
mmHg
3
x
y
0
120
Volume del ventricolo sinistro
ml
70
Volume telediastolico (VTD)
Gittata sistolica (GS)
Contrazione degli atri
4
Volume residuo (VTS)
0

VTD= volume telediastolico (ml)
VTS= volume telesistolico (ml)



GITTATA PULSATORIA (GP) = VTD – VTS

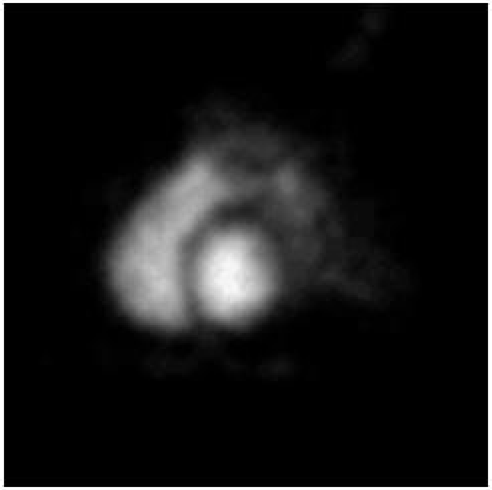
FRAZIONE D'EIEZIONE (FE)= GP / VTD .100

FE=(VTD-VTS) .100 / VTD

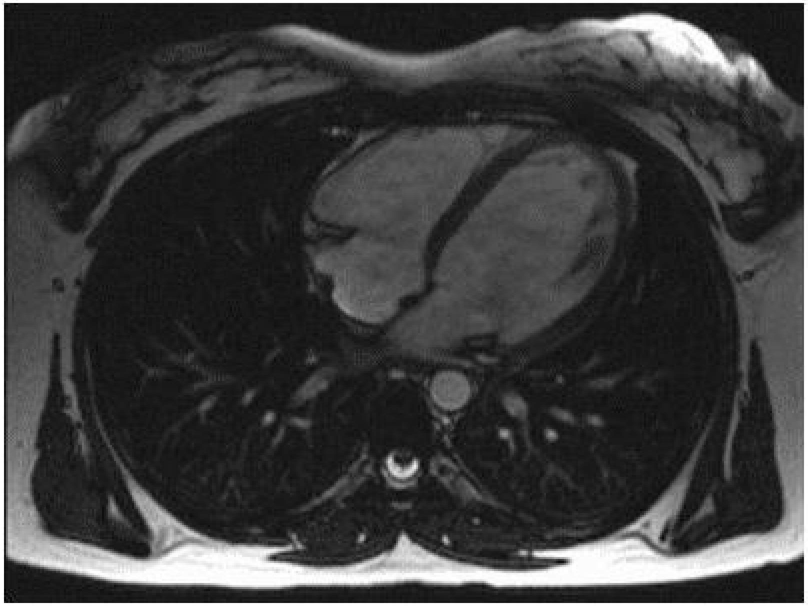
FREQUENZA CARDIACA (FC) = battiti / min

con ECG a 25mm/s: FC=1500/ RR(mm)

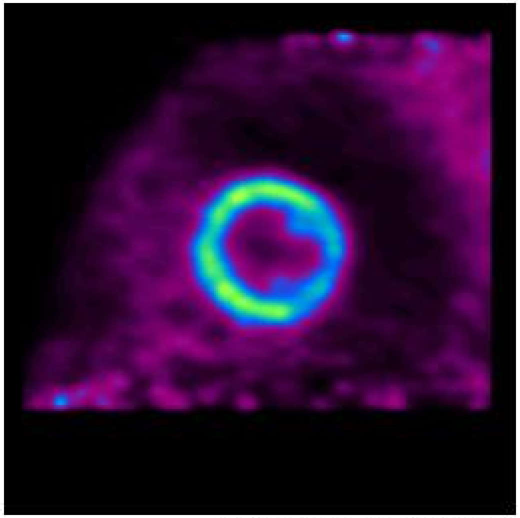
GITTATA CARDIACA (GC) = GP . FC (ml/min)



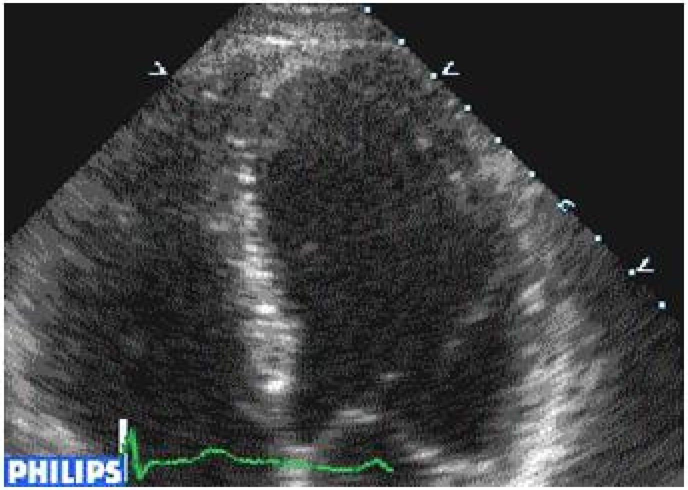
SCINTIGRAFIA
VENTRICOLARE



MRI

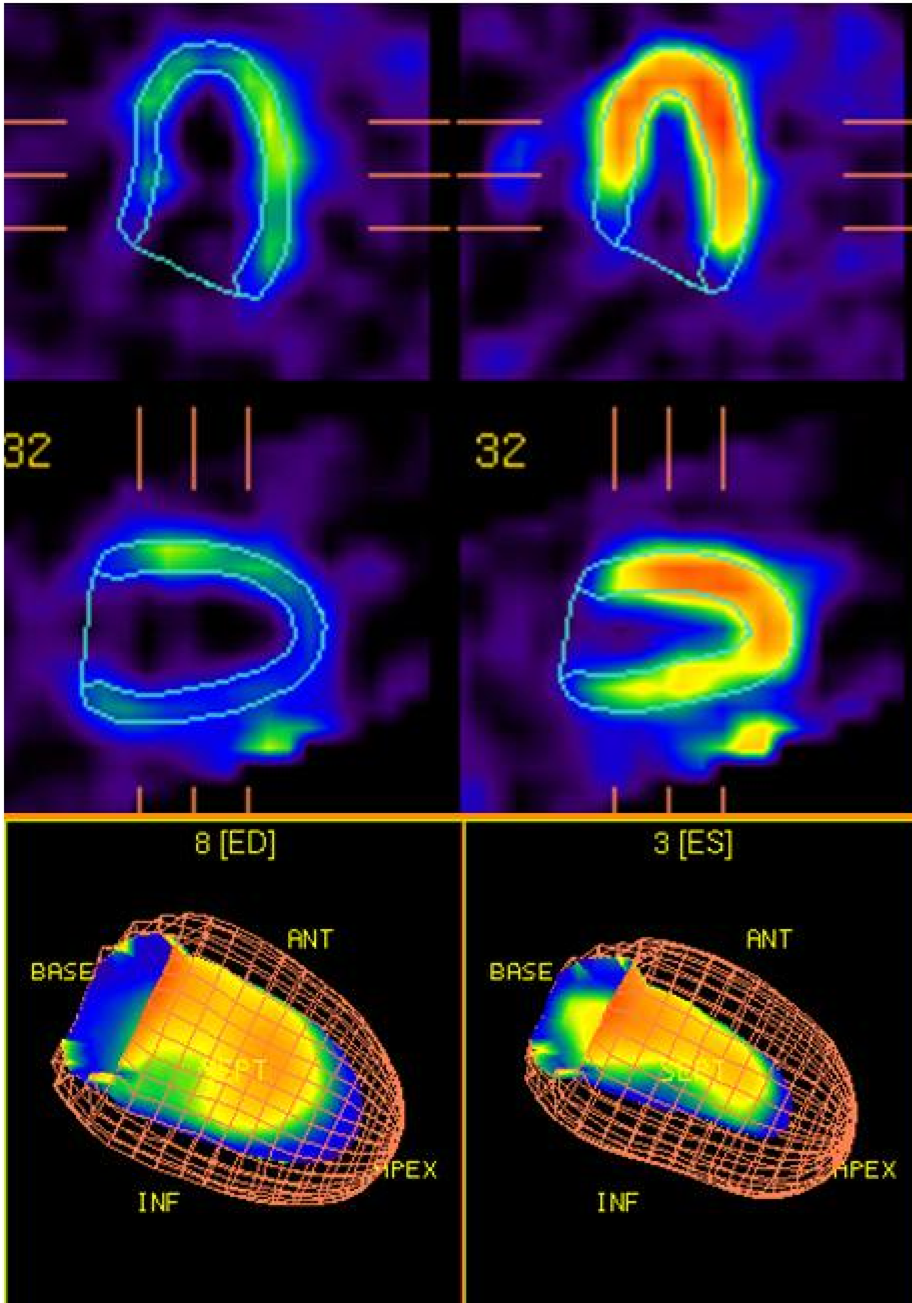


SCINTIGRAFIA
MIOCARDICA



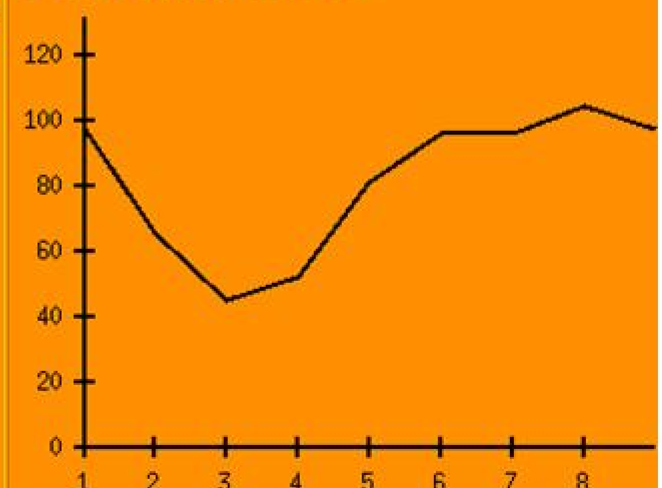
ECOCARDIOGRAMMA

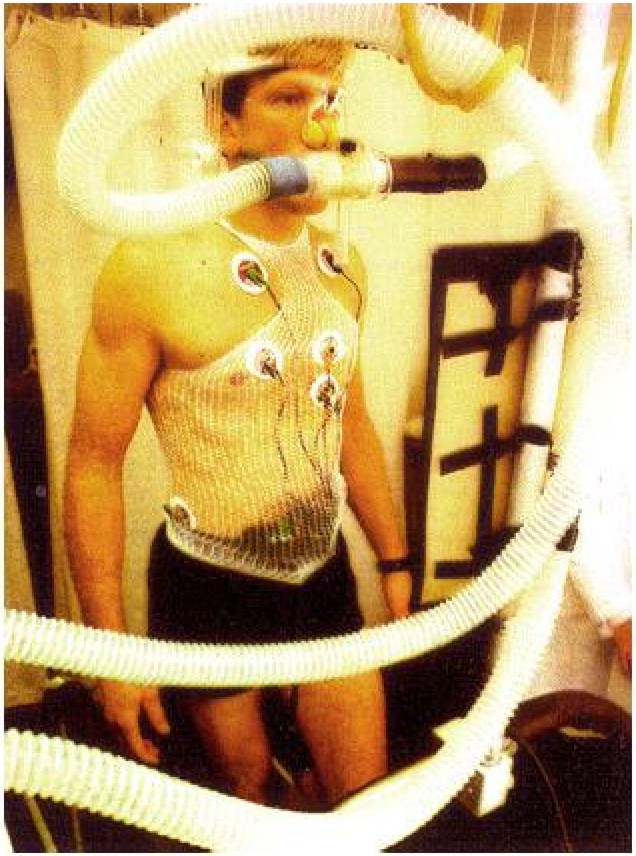
SCINTIGRAFIA MIOCARDICA



Volume	98ml [1]
EDV	104ml [8]
ESV	45ml [3]
EF	57%
Mot Ext	11%, 15cm² [1]
Thk Ext	2%, 2cm² [1]

Volume (ml) / Interval





$$\text{CARDIAC OUTPUT } (\dot{Q}) = \frac{\dot{V}O_2}{[O_2]_a - [O_2]_v}$$

$$= \frac{250 \text{ ml/min}}{20 \text{ ml\%} - 15 \text{ ml\%}} = 5 \text{ L/min}$$

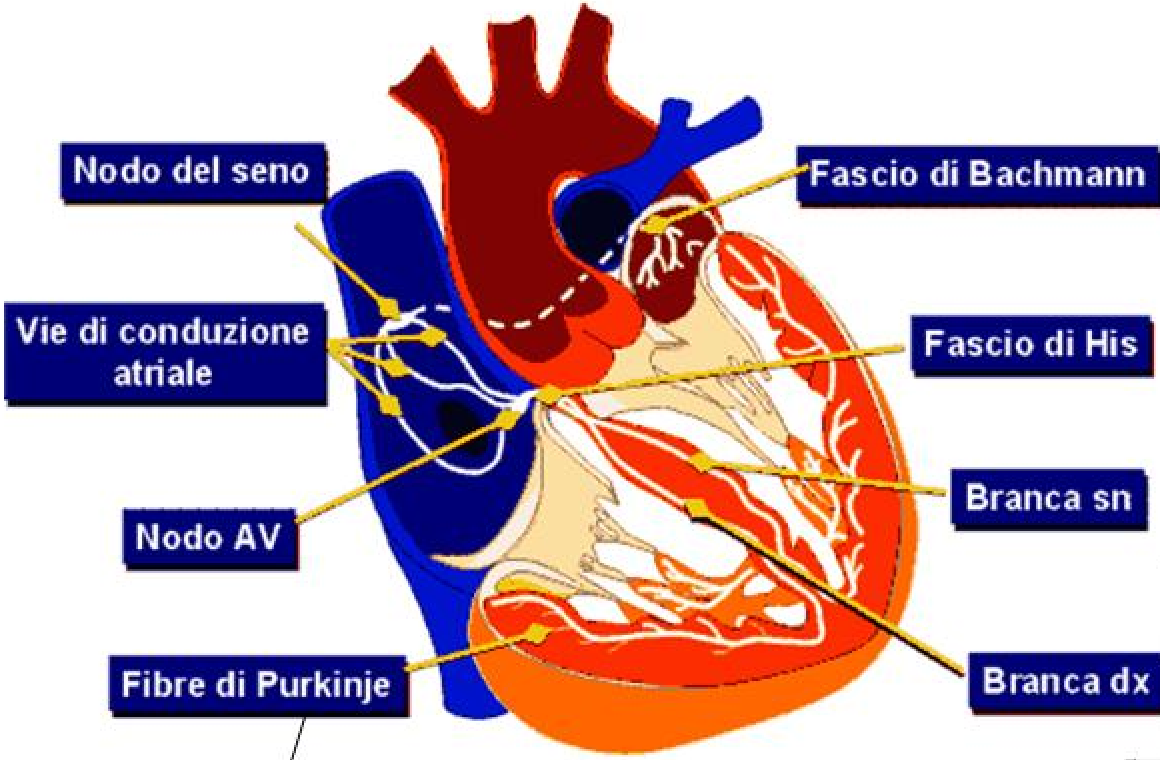
$$\text{CARDIAC INDEX} = \frac{\dot{Q}}{m^2 \text{ body surface}}$$

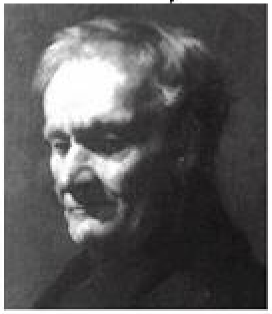
$$= \frac{5 \text{ L/min}}{1.6 \text{ m}^2} = 3.1 \text{ L/min/m}^2$$

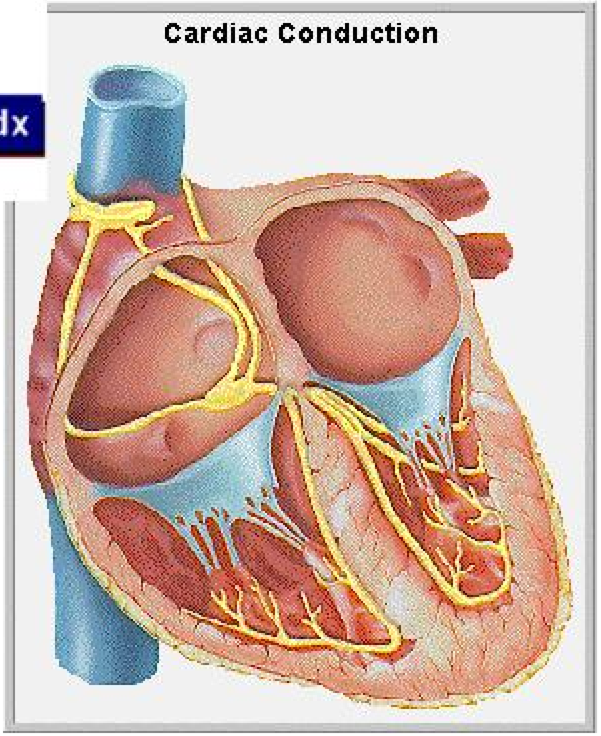
MISURA CONSUMO OSSIGENO

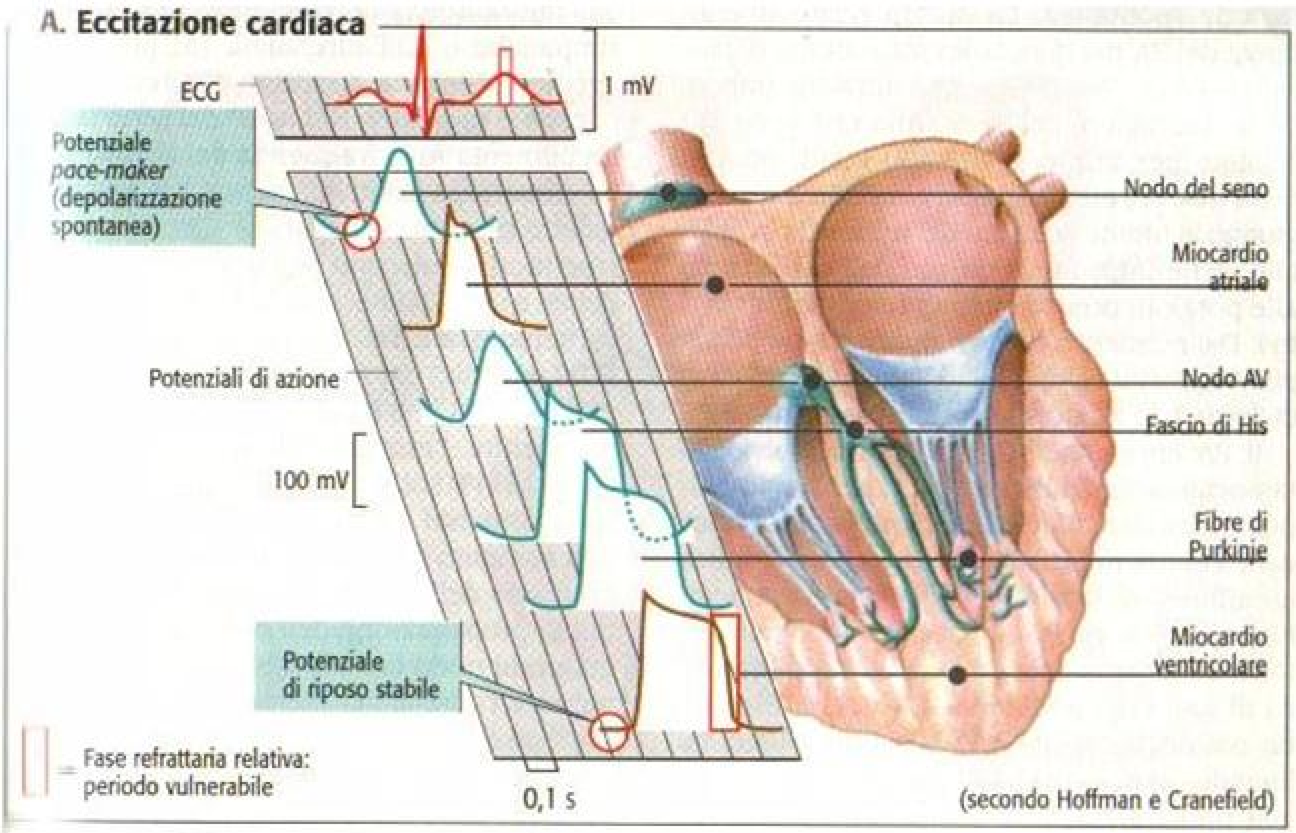
SISTEMA CIRCOLATORIO:

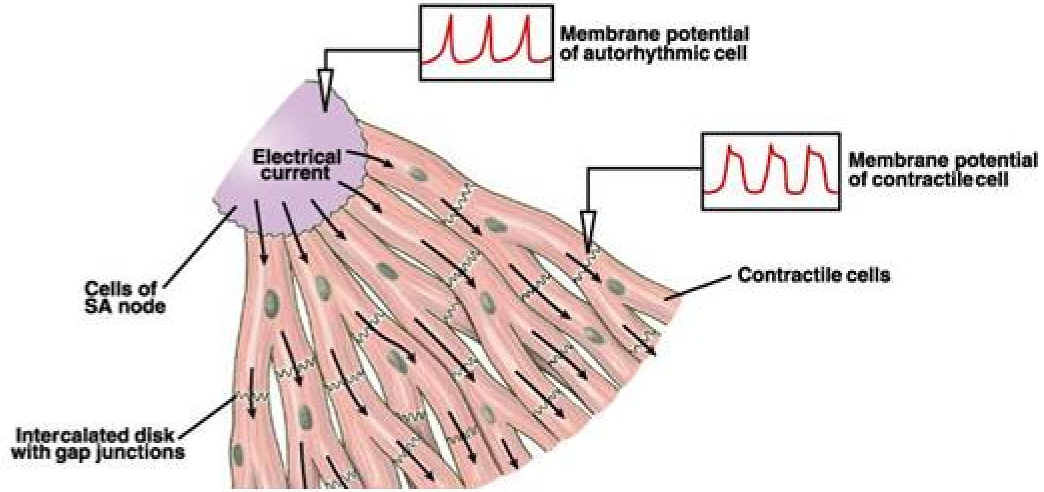
CUORE
Sistema di conduzione


Nodo del seno
Fascio di Bachmann
Vie di conduzione atriale
Fascio di His
Branca sn
Nodo AV
Branca dx
Fibre di Purkinje

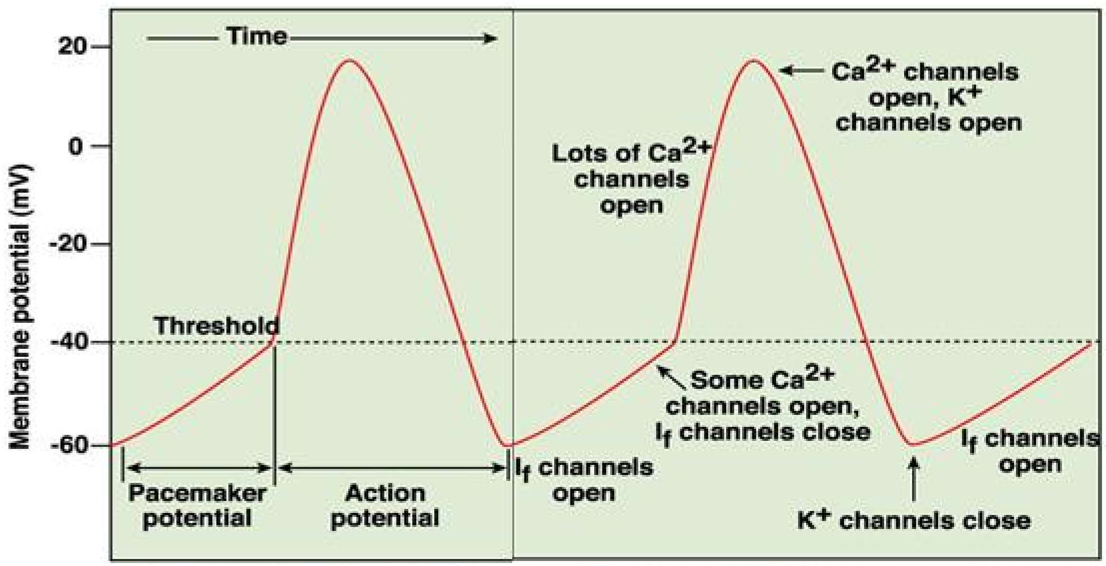


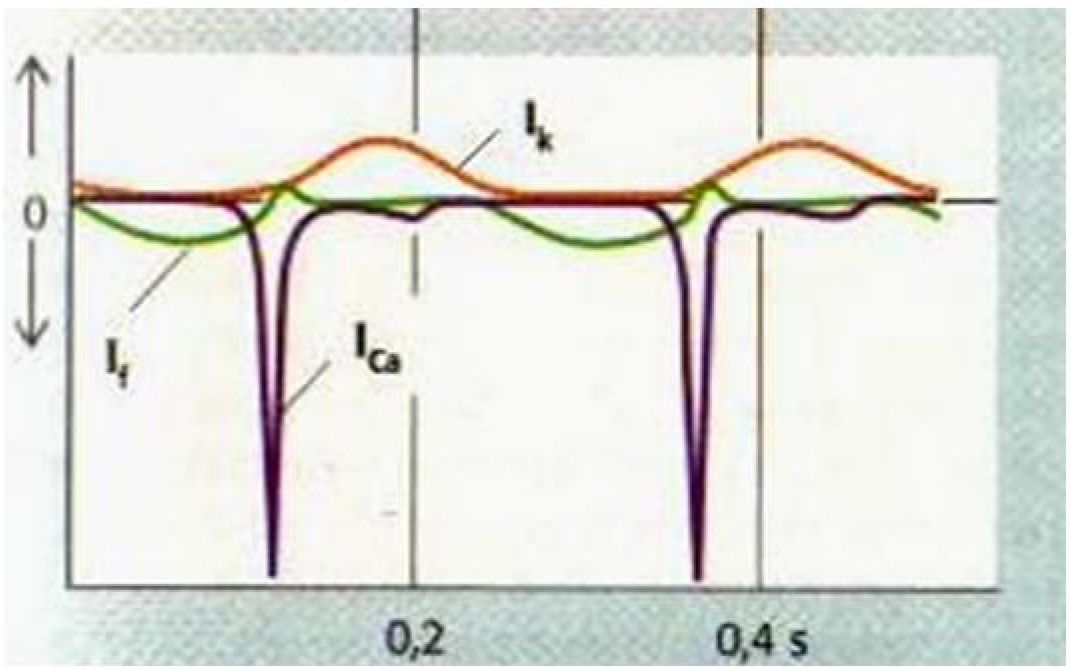

Cardiac Conduction

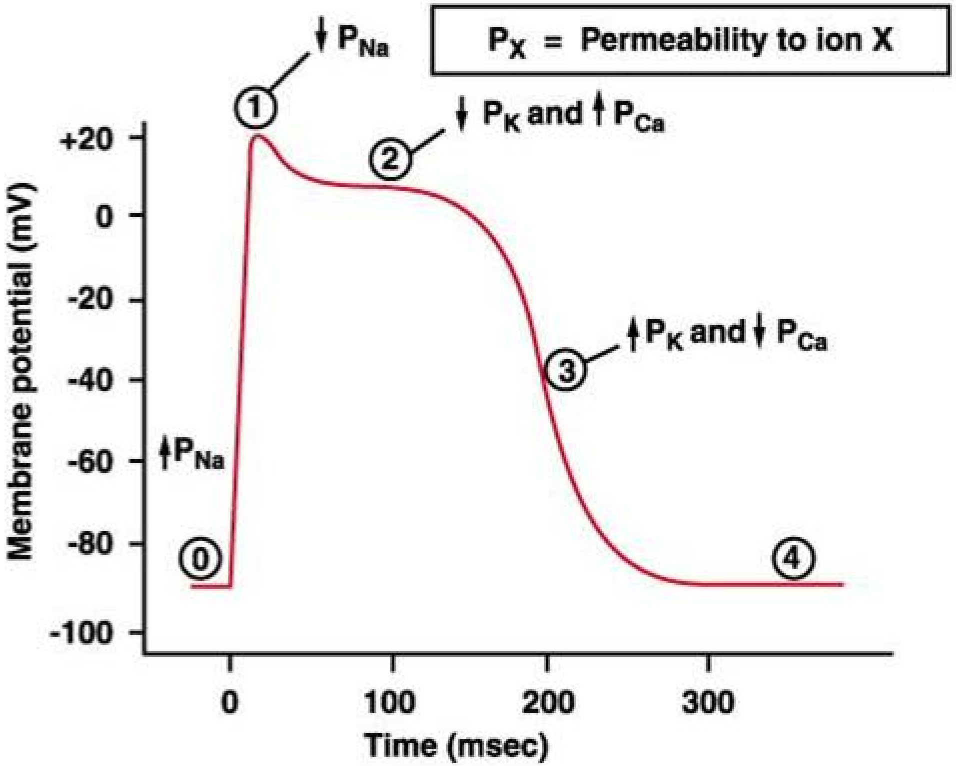

A. Eccitazione cardiaca
ECG
1 mV
Potenziale
pace-maker
(depolarizzazione
spontanea)
Nodo del seno
Miocardio
atriale
Potenziali di azione
Nodo AV
Fascio di His
100 mV
Fibre di
Purkinje
Miocardio
ventricolare
Potenziale
di riposo stabile
= Fase refrattaria relativa:
periodo vulnerabile
0,1 s
(secondo Hoffman e Cranefield)


Membrane potential
of autorhythmic cell
Electrical
current
Membrane potential
of contractile cell
Cells of
SA node
Contractile cells
Intercalated disk
with gap junctions

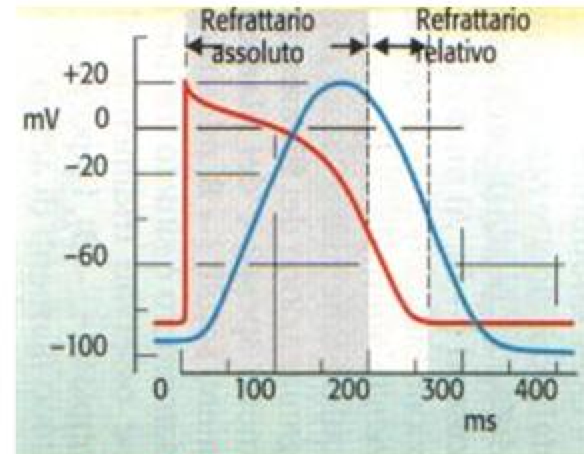
Pacemaker and action potentia





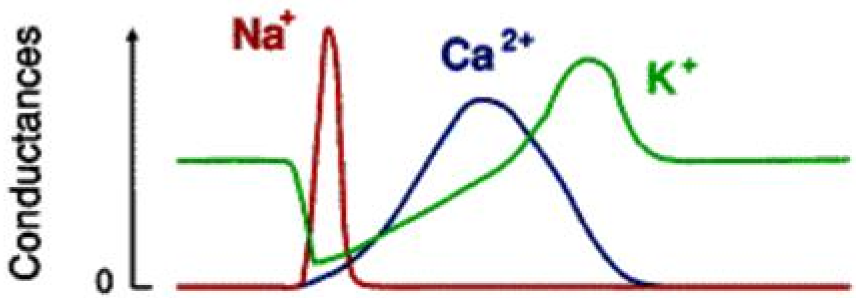


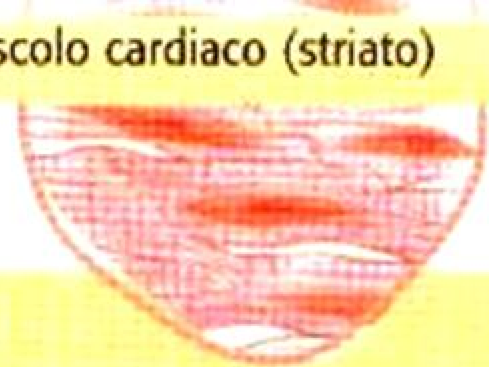
Phase	Membrane channels
0	Na^+ channels open
1	Na^+ channels close
2	Ca^{2+} channels open; fast K^+ channels close
3	Ca^{2+} channels close; slow K^+ channels open
4	Resting potential



— potenziale
— risposta muscolare

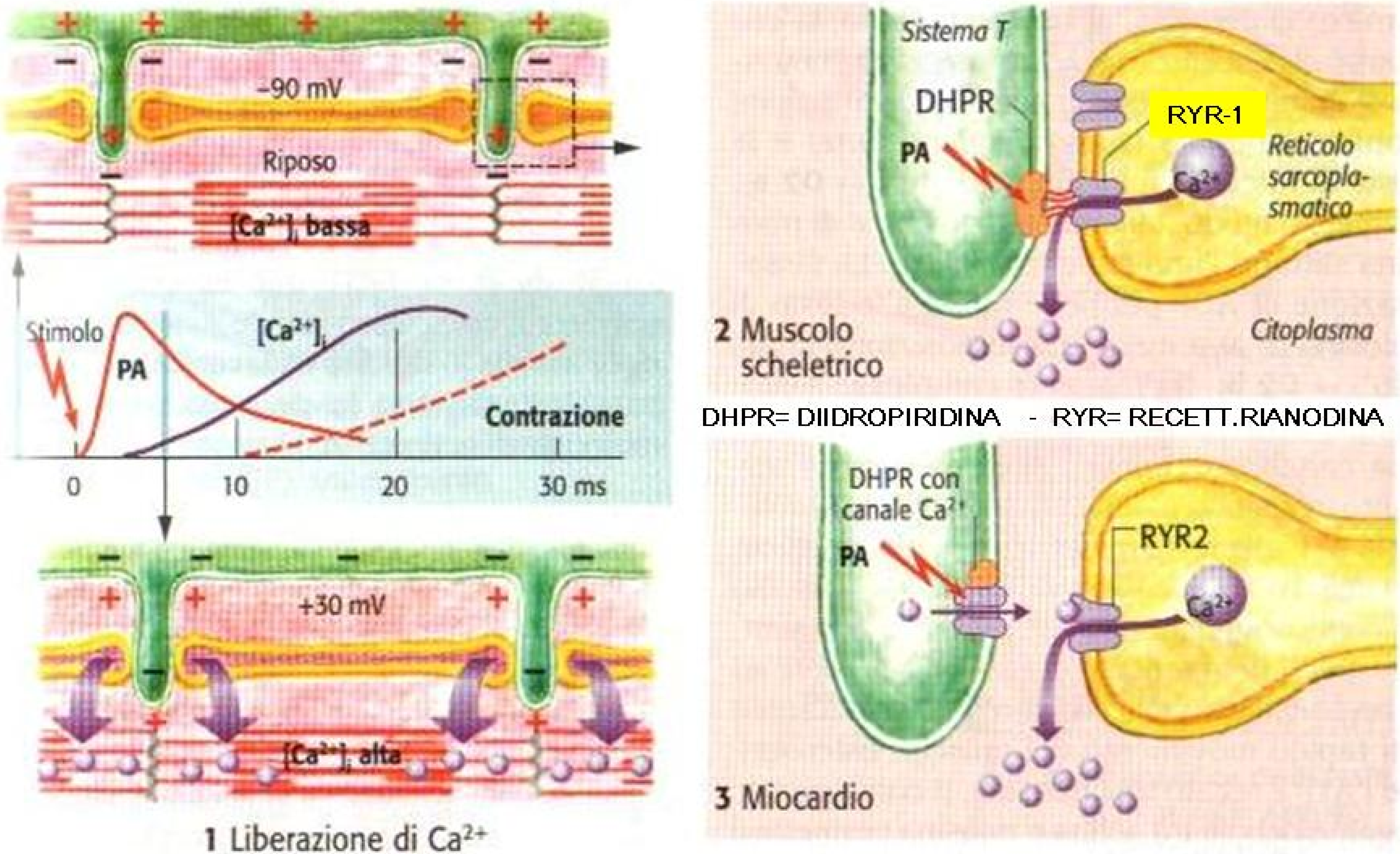
LUNGO PERIODO REFRATTARIO (250ms) quindi TETANO NON POSSIBILE !





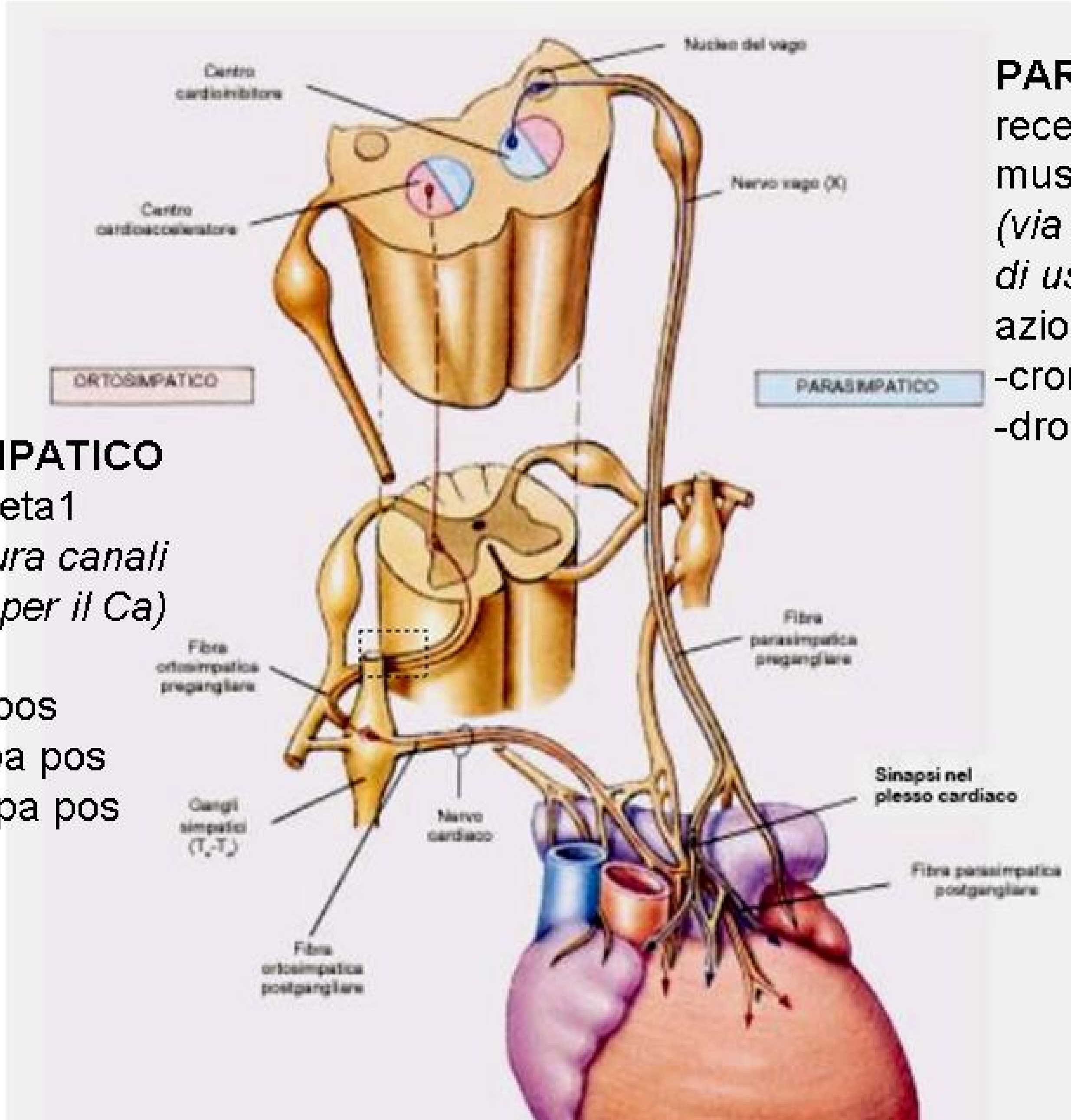
	Muscolo cardiaco (striato)
Placca motrice	assente
Fibre	ramificate
Mitocondri	molti
Nucleo/Fibra	1
Sarcomero	si, lunghezza massima 2,6 μm
Accoppiamento elettrico	si (sincizio funzionale)
Reticolo sarco plasmatico	mediamente sviluppato
«Interruttore» Ca^{2+}	troponina
Pace-maker	si (nodo del seno circa 1 s^{-1})
Risposta allo stimolo	«Tutto o nulla»
Tetanizzabile	no
Ambito di lavoro	nel tratto ascendente della curva forza/lunghezza (vedi **2.15E**)

B. Ca^{2+} come mediatore tra stimolo elettrico e contrazione

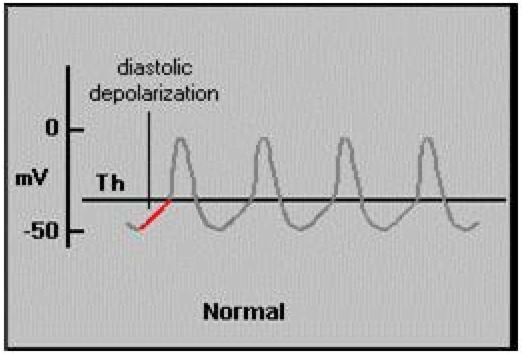


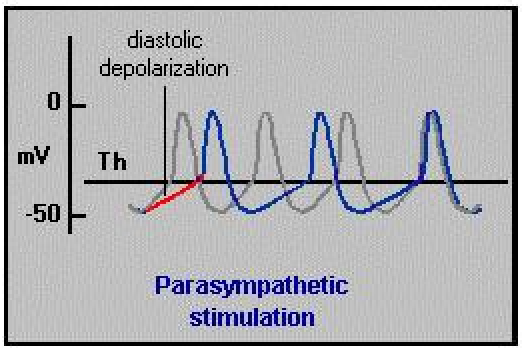
DHPR= DIIDROPIRIDINA - RYR= RECETT.RIANODINA

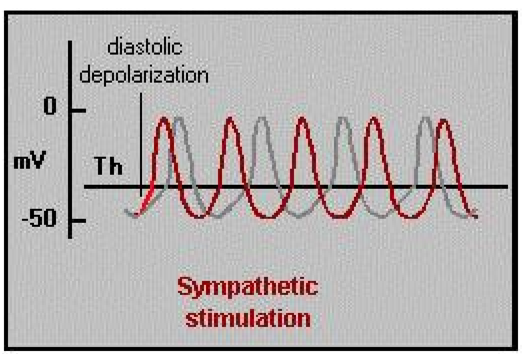
ORTOSIMPATICO
recettori beta1
(via apertura canali di entrata per il Ca)
azione:
-inotropa pos
-cronotropa pos
-dromotropa pos

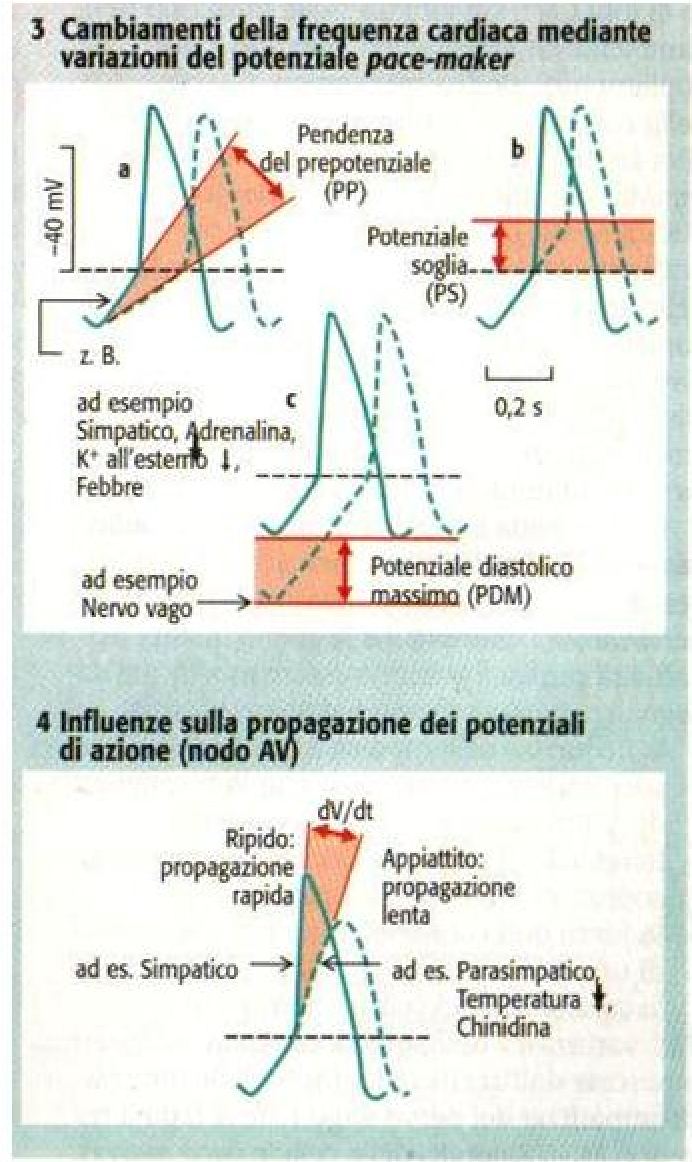


PARASIMPATICO
recettori muscarinici
(via apertura canali di uscita per il K)
azione:
-cronotropa neg
-dromotropa neg


diastolic
depolarization
0
mV
Th
-50
Normal


diastolic
depolarization
0
mV
Th
-50
Parasympathetic
stimulation


diastolic
depolarization
0
mV
Th
-50
Sympathetic
stimulation


3 Cambiamenti della frequenza cardiaca mediante variazioni del potenziale *pace-maker*
a
Pendenza
del prepotenziale
(PP)
−40 mV
z. B.
b
Potenziale
soglia
(PS)
0,2 s
c
ad esempio
Simpatico, Adrenalina,
K⁺ all'esterno ↓,
Febbre
ad esempio
Nervo vago
Potenziale diastolico
massimo (PDM)
4 Influenze sulla propagazione dei potenziali di azione (nodo AV)
dV/dt
Ripido:
propagazione
rapida
Appiattito:
propagazione
lenta
ad es. Simpatico
ad es. Parasimpatico,
Temperatura ↓,
Chinidina