Introduzione ai vasi

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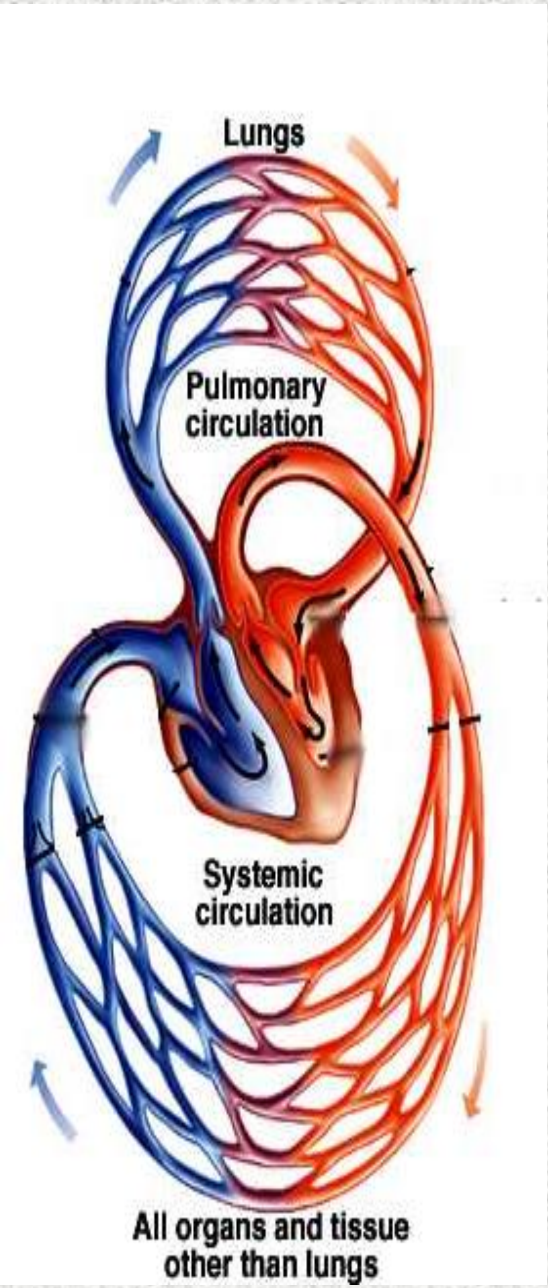
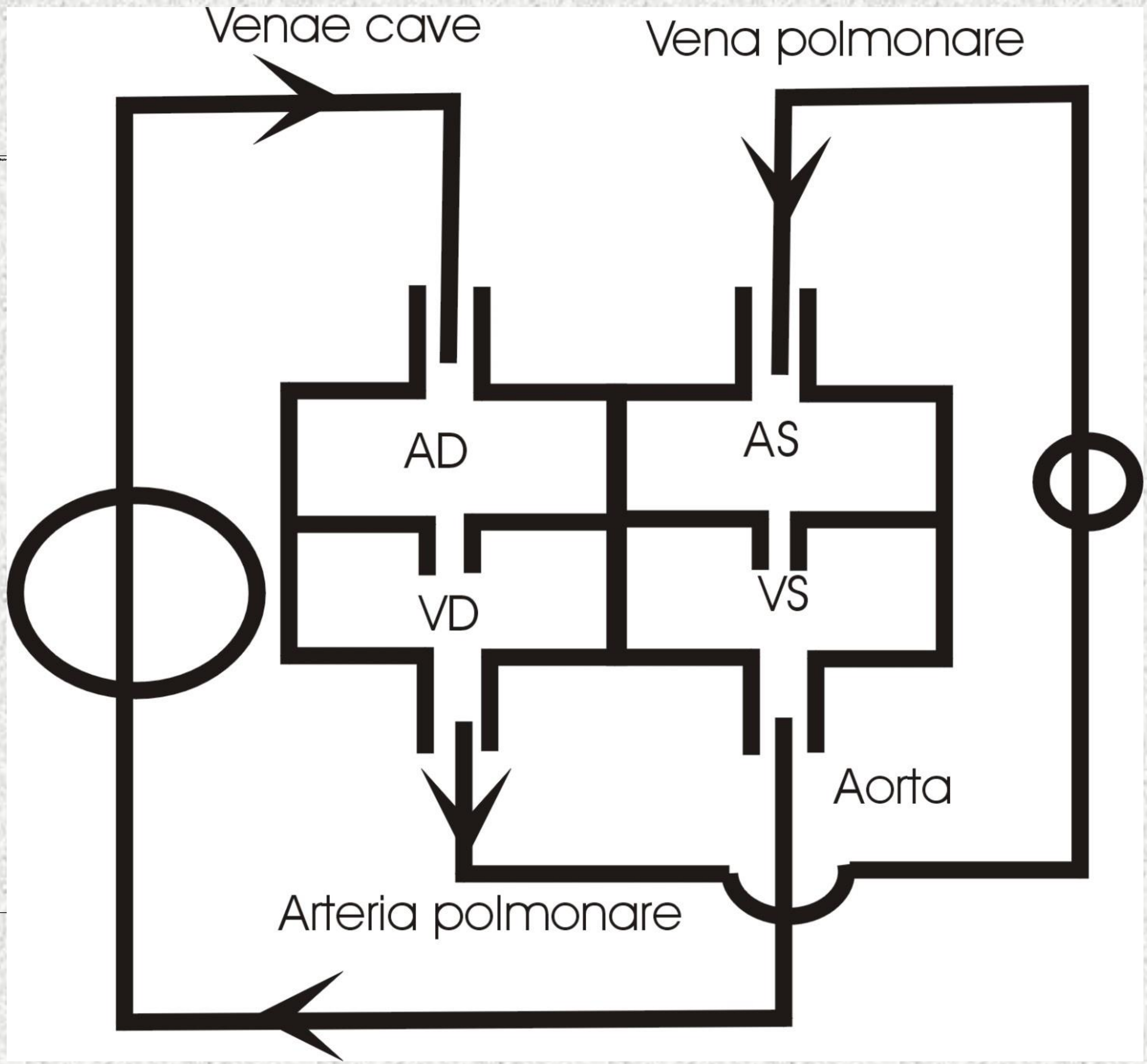
Sistema Cardiovascolare

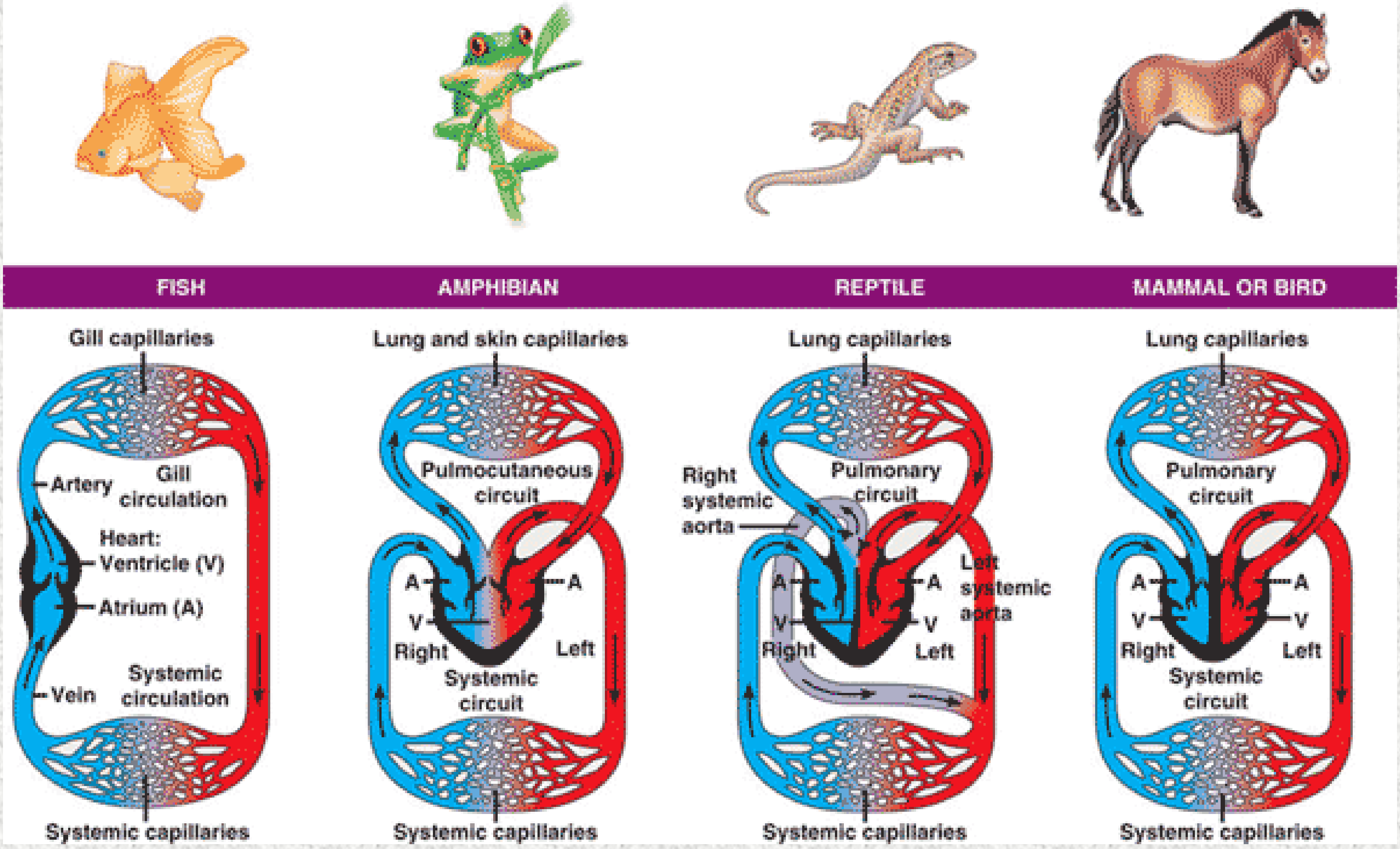
- I vasi sanguini formano un sistema chiuso che parte dal cuore
- E’ un sistema di strutture dinamiche, che si dilatano, contraggono , pulsano e proliferano per adattarsi ai bisogni del corpo.
- La rete di distribuzione del sangue ha una lunghezza di circa 96,000 km

Funzioni

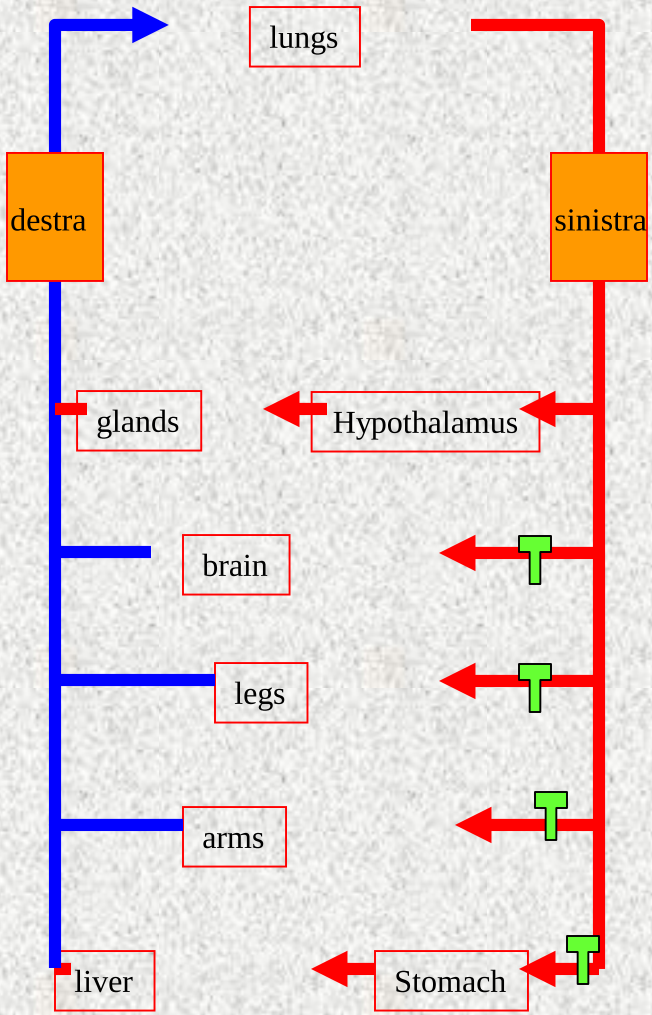
- Transporto
  - O_2 e CO_2
  - Nutrienti
  - Metaboliti
  - Ormoni
  - Calore
- Affidabilita'
  - Quanti battiti fa in una vita?
- Flessibilita'
  - Pompa puo' cambiare portata
  - Vasi possono cambiare direzione di flusso



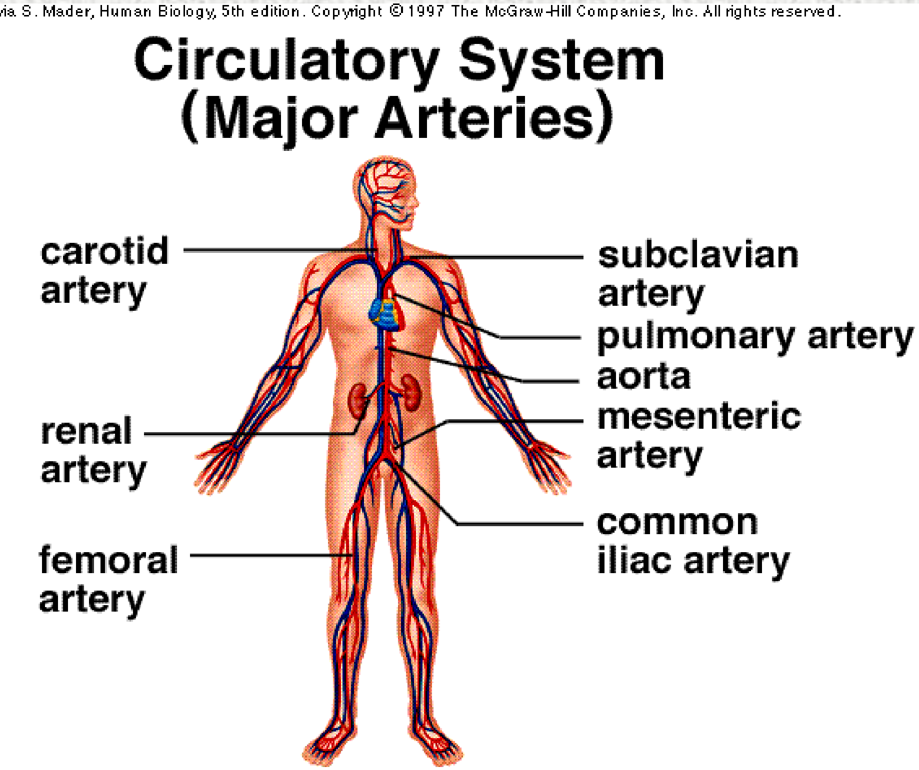

Venae cave
Vena polmonare
AD
AS
VD
VS
Aorta
Arteria polmonare


FISH
AMPHIBIAN
REPTILE
MAMMAL OR BIRD
Gill capillaries
Artery
Gill circulation
Heart:
Ventricle (V)
Atrium (A)
Vein
Systemic circulation
Systemic capillaries
Lung and skin capillaries
Pulmocutaneous circuit
A
A
V
Right
Left
Systemic circuit
Systemic capillaries
Lung capillaries
Right systemic aorta
Pulmonary circuit
Left systemic aorta
A
A
V
V
Right
Left
Systemic capillaries
Lung capillaries
Pulmonary circuit
A
A
V
V
Right
Left
Systemic circuit
Systemic capillaries

Struttura del sistema SCV



- Le pompe D e S, devono essere uguali in uscita
- I letti vascolari sono in parallelo
  - Tutti tessuti vengono ossigenati
  - In zone localizzate, il flusso puo essere ridirezionato
  - Il flusso può essere redirezionato attraverso vasocostrizione e vasodilatazione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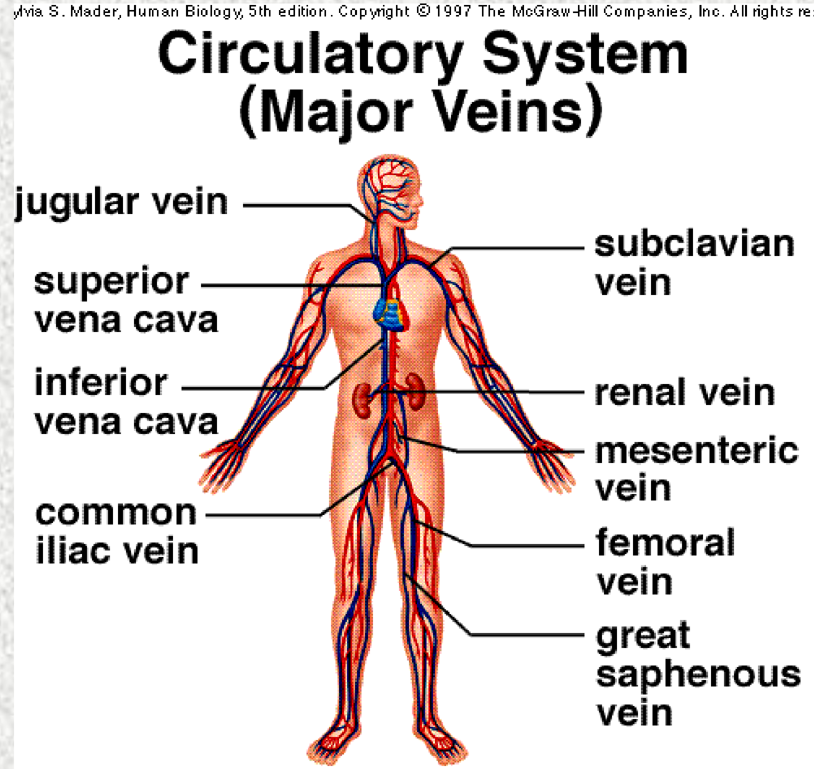
Circulatory System (Major Arteries)
carotid artery
subclavian artery
pulmonary artery
aorta
mesenteric artery
renal artery
common iliac artery
femoral artery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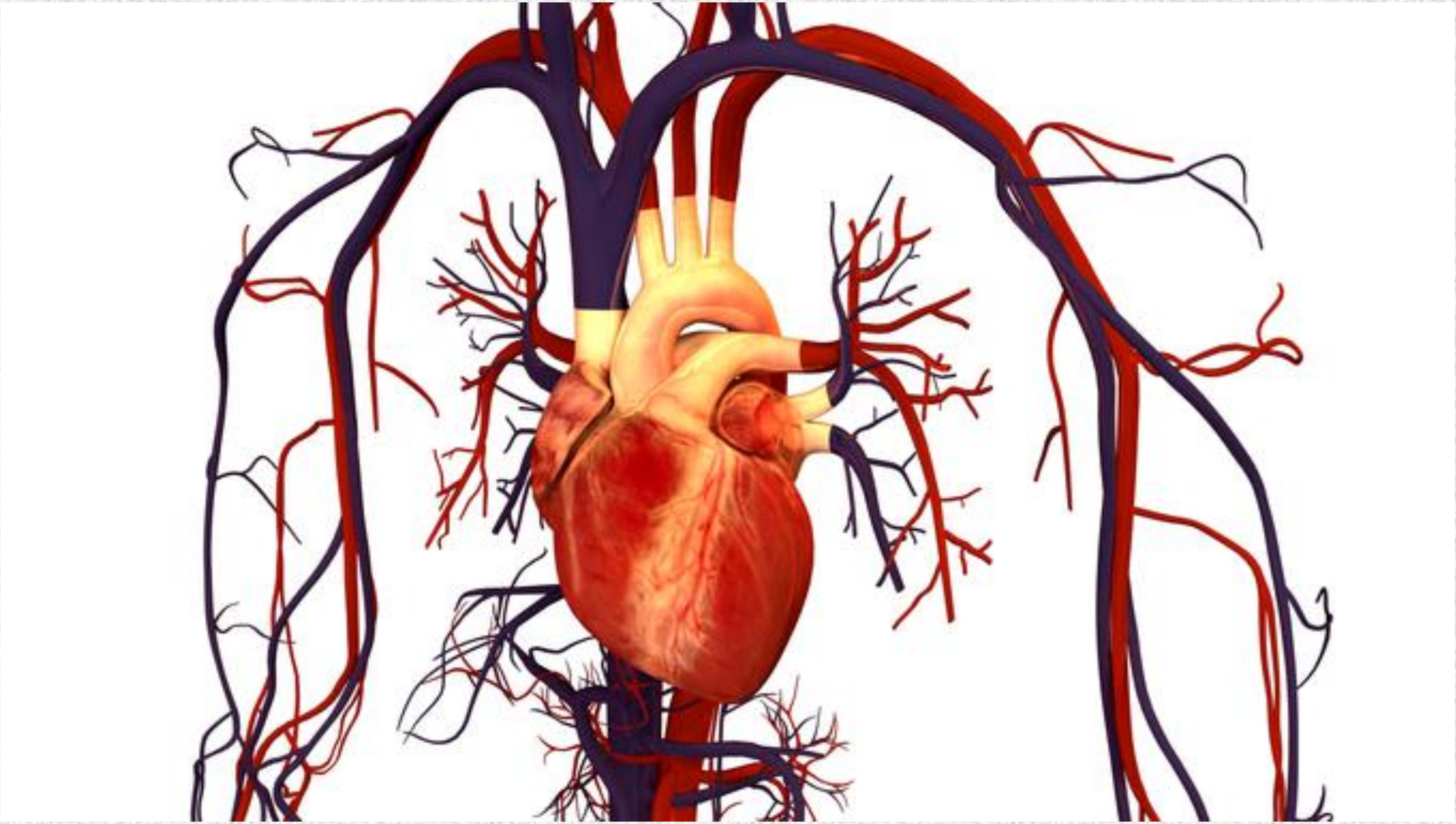
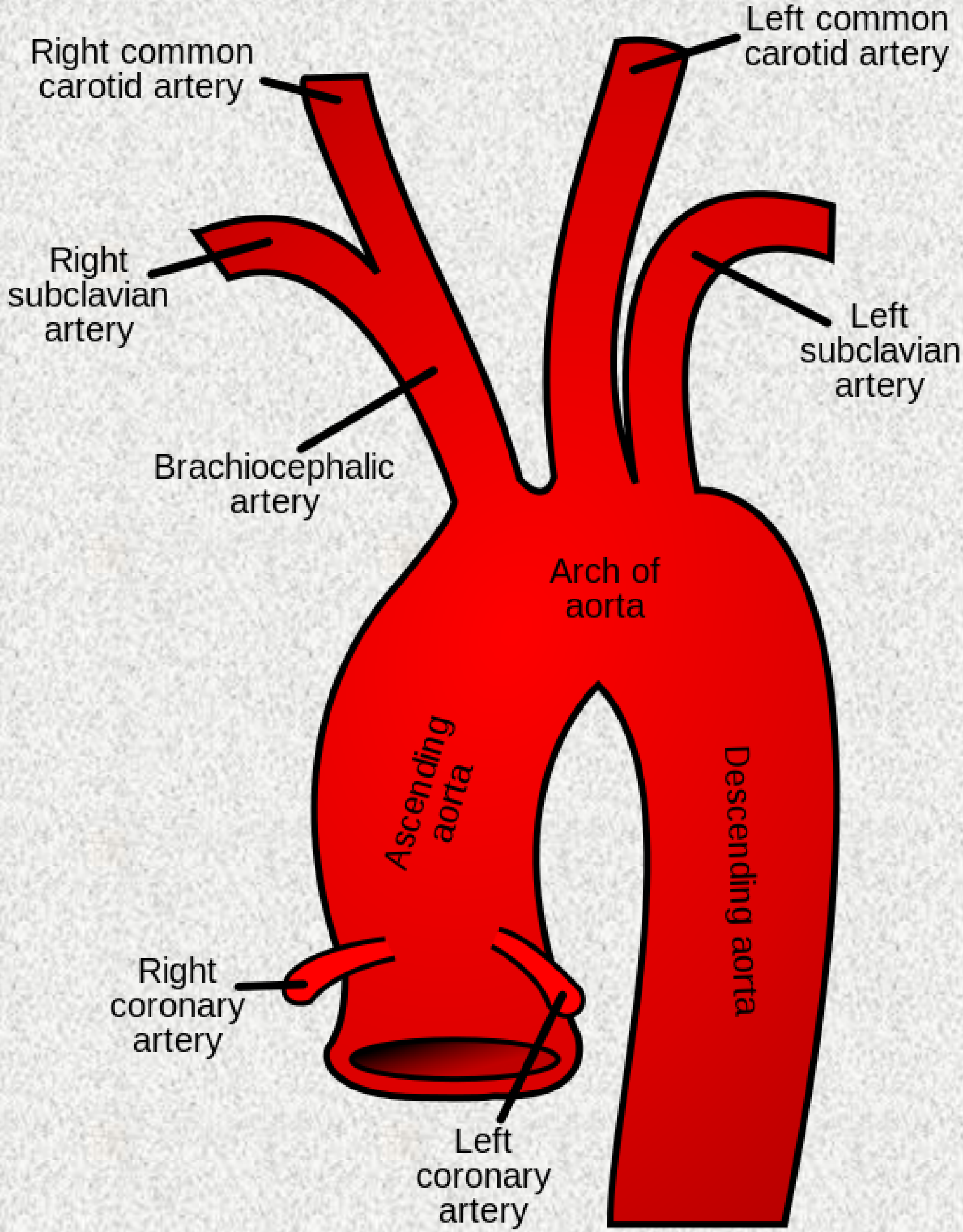
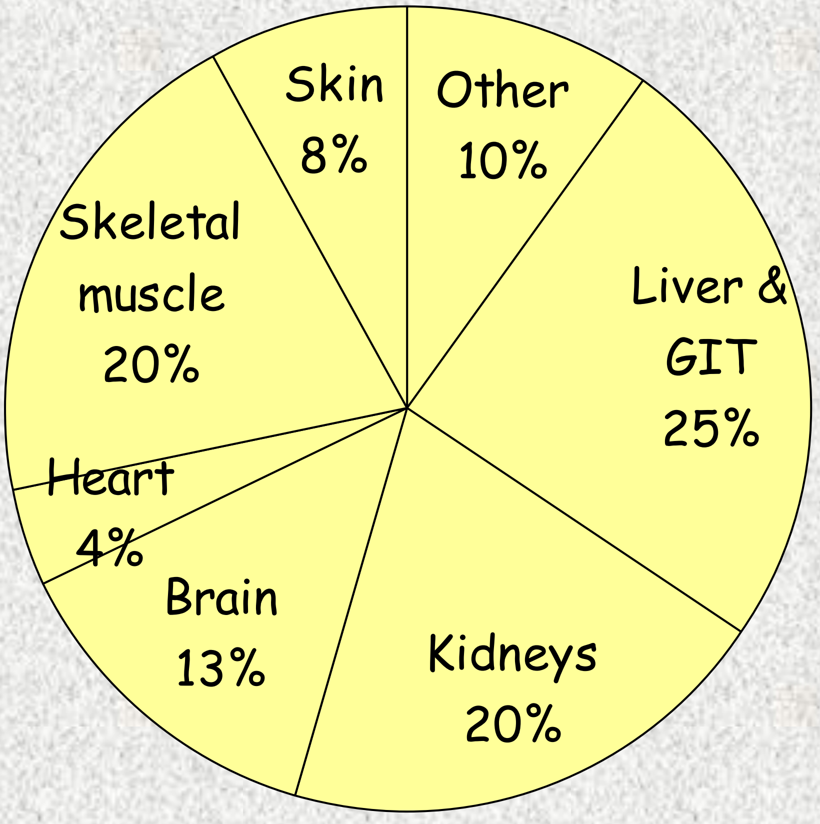
Circulatory System (Major Veins)
jugular vein
subclavian vein
superior vena cava
inferior vena cava
renal vein
mesenteric vein
common iliac vein
femoral vein
great saphenous vein

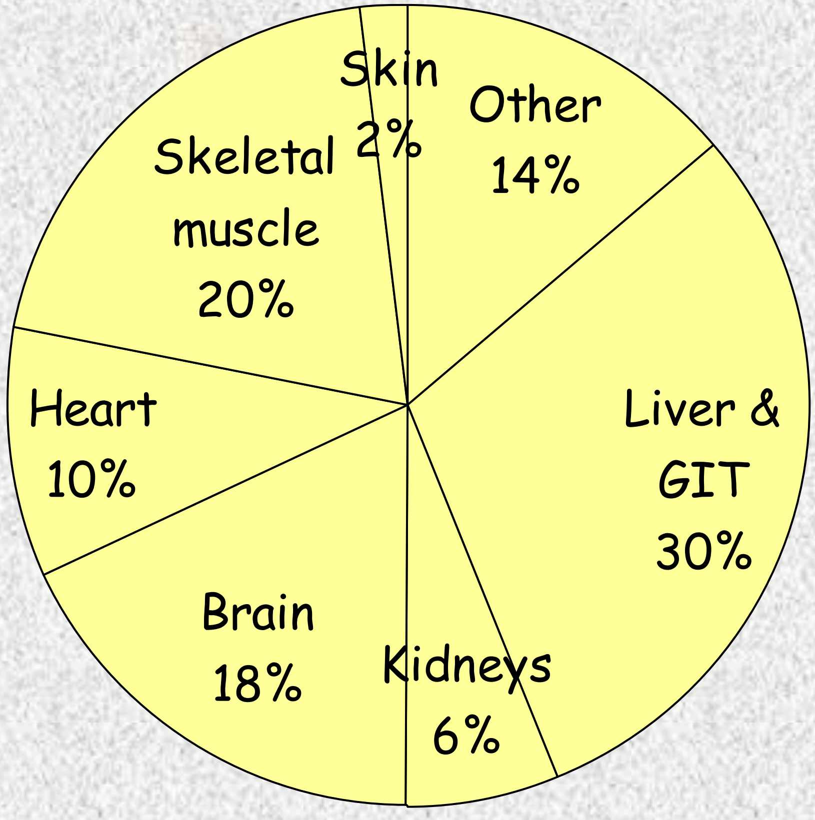



Right common carotid artery
Left common carotid artery
Right subclavian artery
Left subclavian artery
Brachiocephalic artery
Arch of aorta
Ascending aorta
Descending aorta
Right coronary artery
Left coronary artery

Uscita cardiaca



Consumo di O_2



Come viene ridirezionato l'uscita durante uno sforzo fisico?

Classificazione dei Vasi

aorta

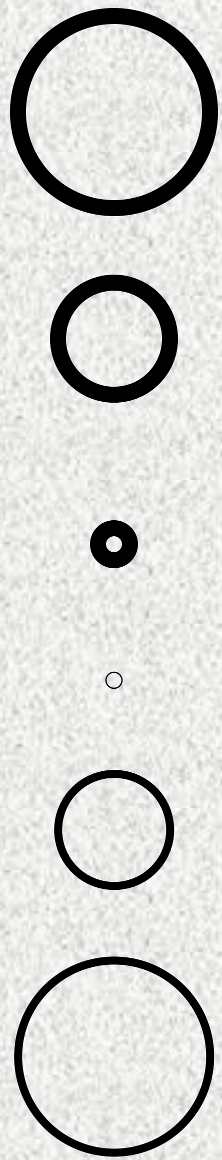
arterie

arteriole

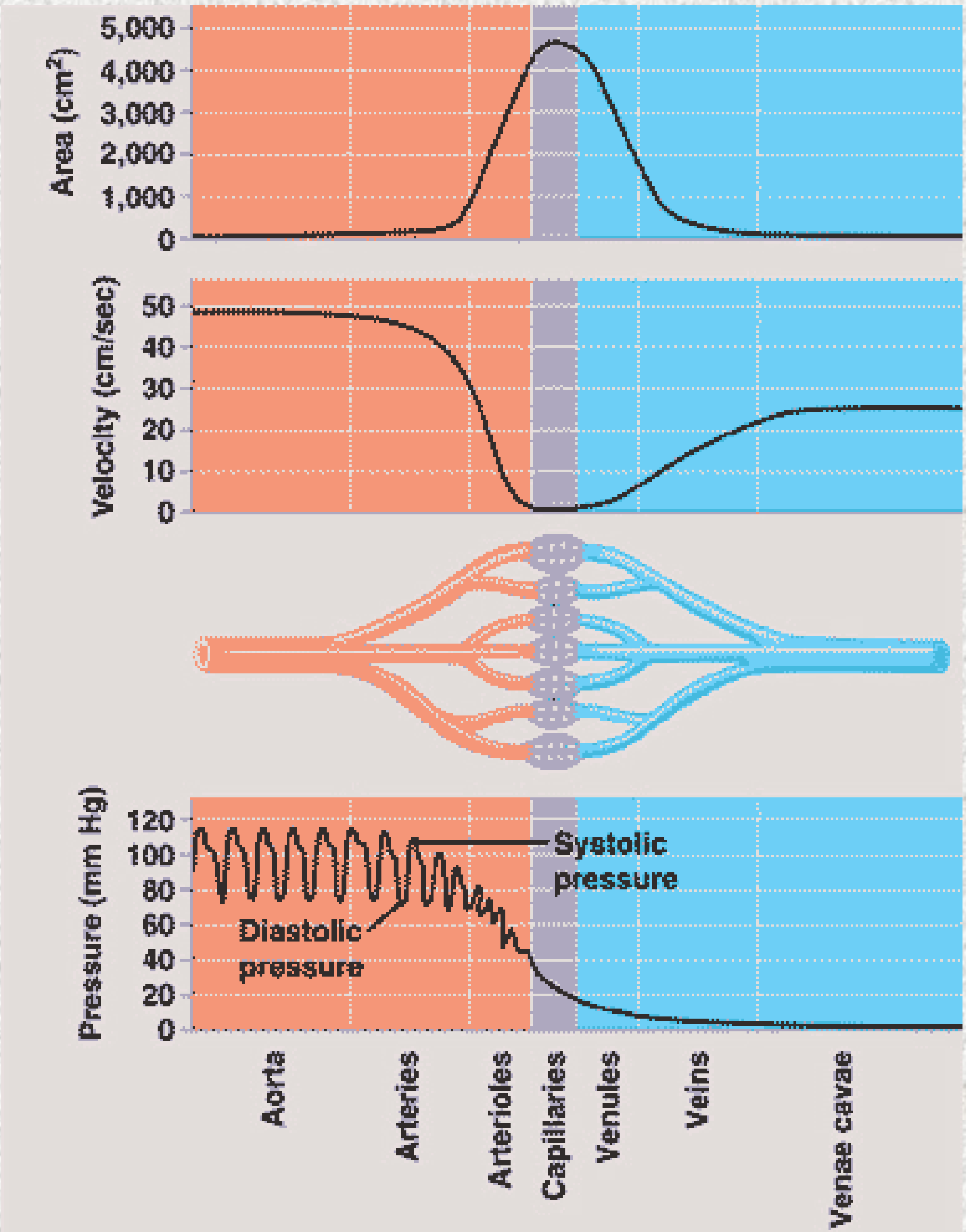
capillari

venule

vene



- Arterie elastiche eg aorta
  - Lume grande, parete elastica
  - Per smorzare variazioni di pressione (perche?)
- Arterie Muscolari eg altre arterie
  - Lume grande, parete forte non- elastica
  - Condotto con bassa resistenza
- Vasi con resistenza eg arterioli
  - Lume piccolo, parete spessa e contrattile
  - Possono controllare resistenza e flusso
  - Permettano la ridirezione del sangue
- Vasi di scambio, eg capillaries
  - Lume piccolo, parete piccolo
- Vasi con elevata capacita’ eg venule & vene
  - Lume grande, parete distensibile
  - Condotto di bassa resistenza



Area (cm²)
5,000
4,000
3,000
2,000
1,000
0
Velocity (cm/sec)
50
40
30
20
10
0
Pressure (mm Hg)
120
100
80
60
40
20
0
Systolic pressure
Diastolic pressure
Aorta
Arteries
Arterioles
Capillaries
Venules
Veins
Venae cavae

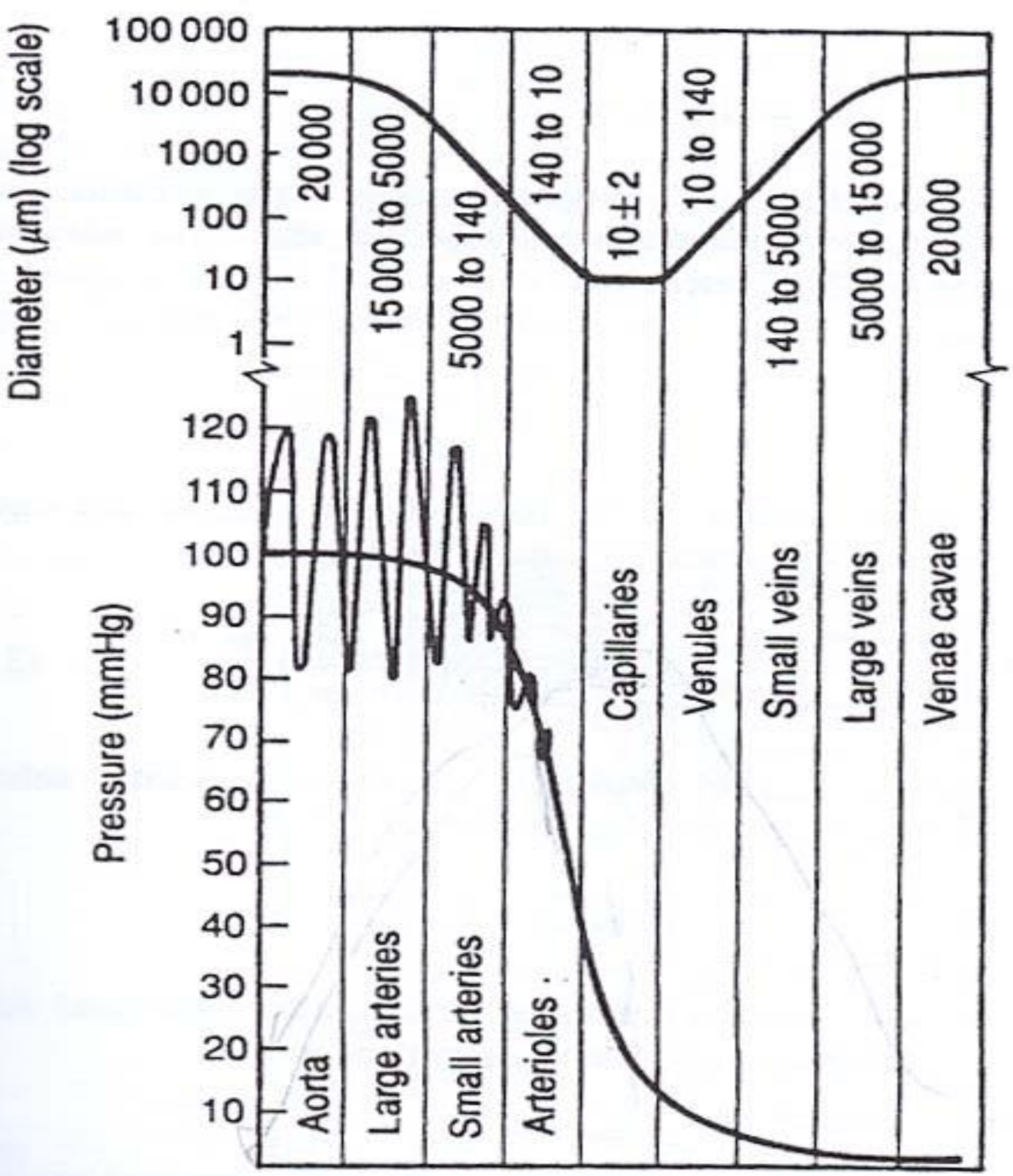


Fig. 3.4 Pressure variation in the systemic circulation.

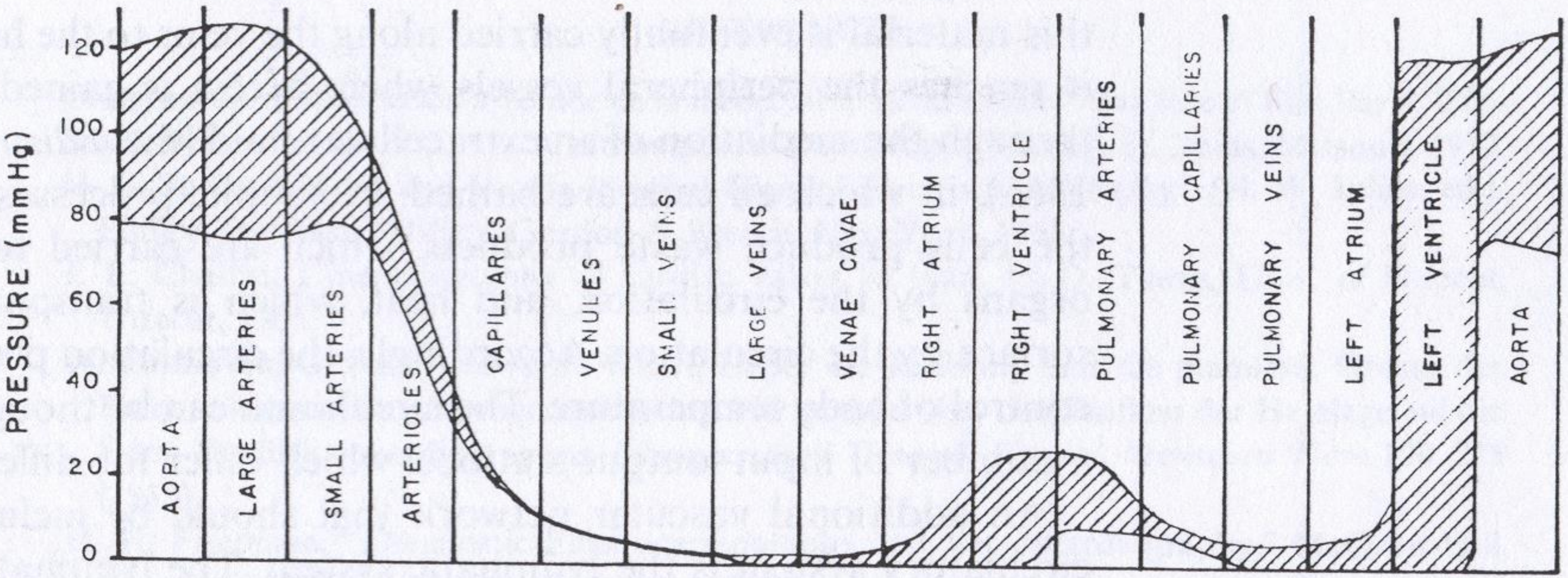
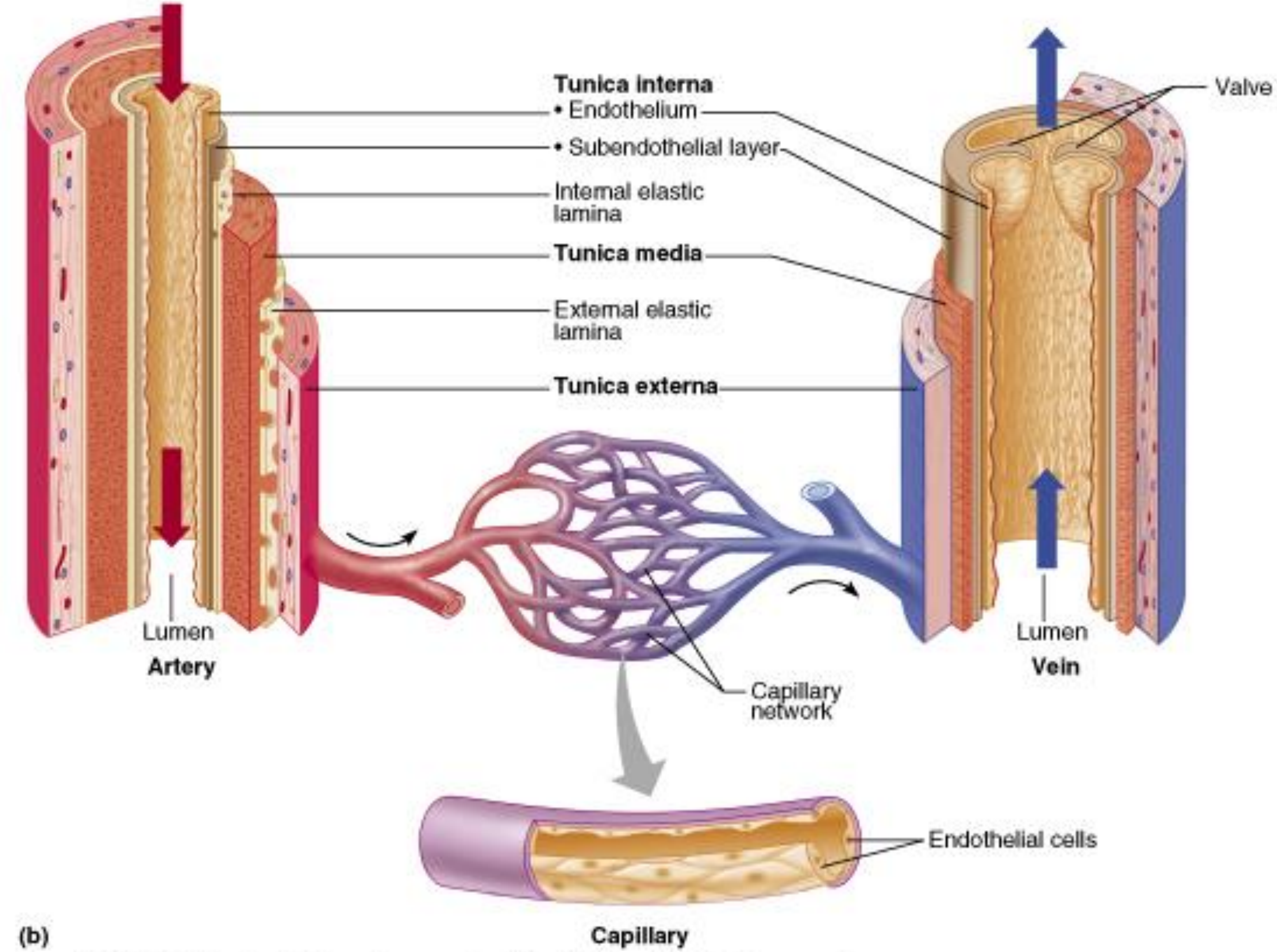


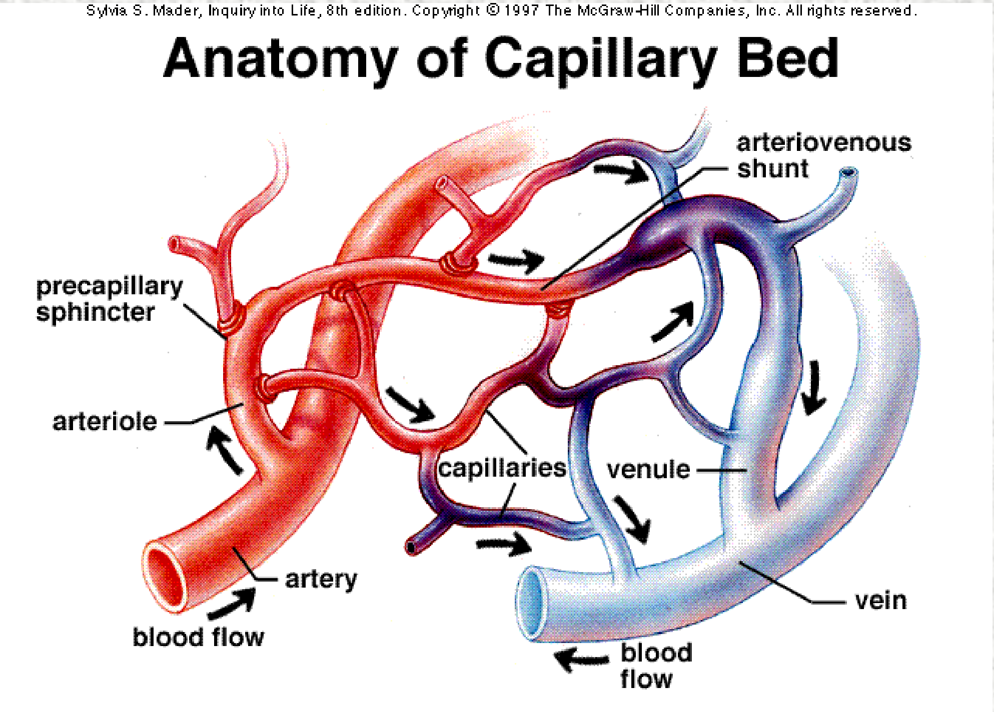
Fig. 1-8. Pressure levels, including oscillatory magnitudes, around the circuit.

Struttura dei vasi: 3 tipi

- Arterie
  - Elastiche, muscolari, arteriole
- Capillari
  - Sangue fluisce da arterioli a capillari
  - Lo scambio di O_2 occore tra le pareti
  - Poi dai capillari passa al sistema venoso.
- Vene (hanno valvole)
  - Venule, vene piccole, medie o grandi


Tunica interna
• Endothelium
• Subendothelial layer
Internal elastic lamina
Tunica media
External elastic lamina
Tunica externa
Valve
Lumen
Artery
Lumen
Vein
Capillary network
Endothelial cells
(b)
Capillary

- La rete parte con arterie → arterioli → capillari → venule → vene
- Solo i capillari vengono in contatto intimo con cellule e tessuti



Grandezza e Composizione

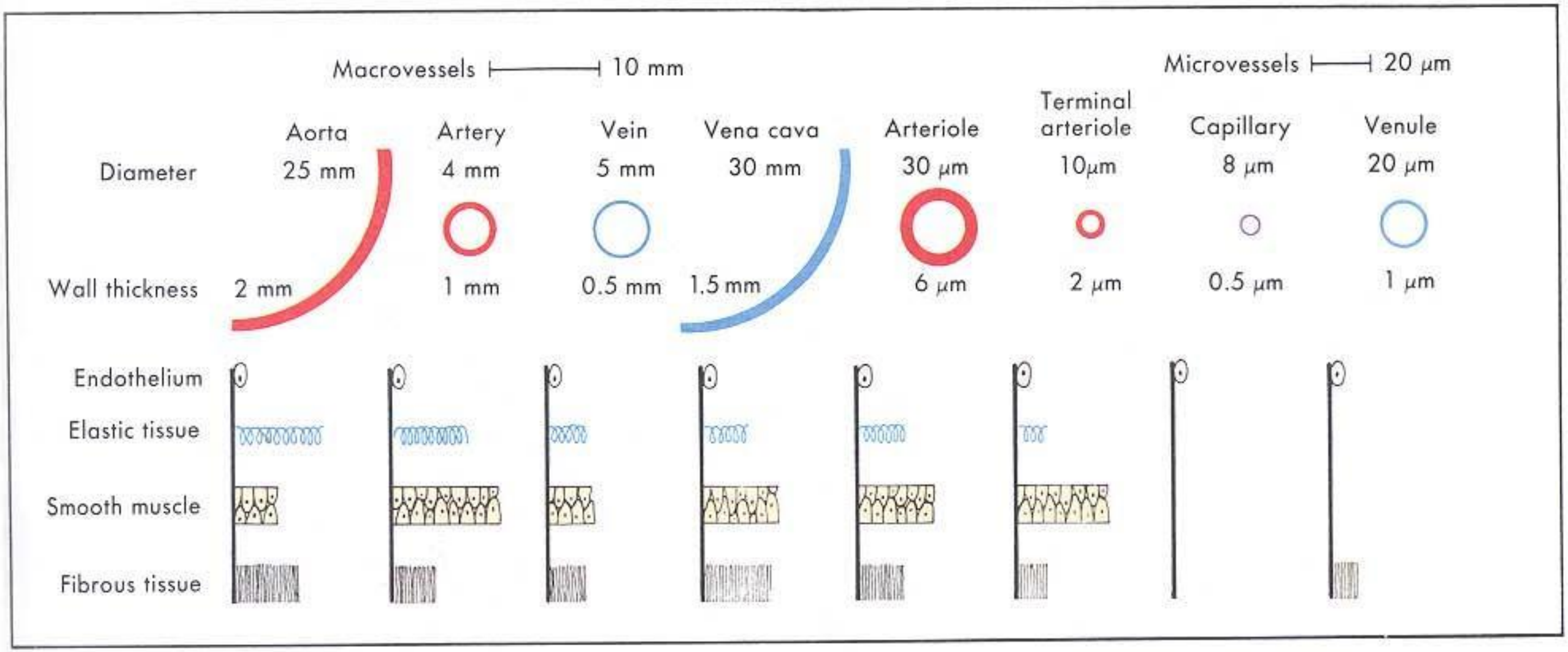


FIGURE 15-1 Internal diameter, wall thickness, and relative amounts of the principal components of the vessel walls of the various blood vessels that compose the circulatory system. Cross sections of the vessels are not drawn to scale because of the huge range from aorta and venae cavae to capillary. (Redrawn from Burton AC: Physiol Rev 34:619, 1954.)

Table 3.1. Some properties of the circulation and blood

Number of red blood cells (mm^{-3})	5×10^6	Specific gravity	1.06
Number of white blood cells (mm^{-3})	10^4	Heart rate (min^{-1})	60–70
Blood volume (L)	5–6	Cardiac output ($L\ min^{-1}$)	5–6
Viscosity of whole blood (mPa s; cP)	3–4*	Stroke volume (mL)	70

Vessels	Diameter (mm)	Length (cm)	Wall thickness (mm)	Contained volume (cm^3 or mL)	Mean pressure (mmHg)	Average velocity ($cm\ s^{-1}$)	Reynolds number	
							Average	Maximum
Aorta	25.0	40.0	2.0	100	100(av.)	40(av.)	3000	8500
Arteries	15–0.15	15.0	0.8	350	90(av.)	40–10	500	1000
Arterioles	0.14–0.01	0.2	0.02	50	60	10–0.1	0.7	—
Capillaries	0.008	0.05	0.001	300	30–20	< 0.1	0.002	—
Venules	0.01–0.14	0.2	0.002	300	20	< 0.3	0.01	—
Veins	0.15–15	18.0	0.6	2500	15–10	0.3–5	150	—
Vena cava	30.0	40.0	1.5	300	10–5	5–30	3000	—

Rapporto tra flusso e pressione

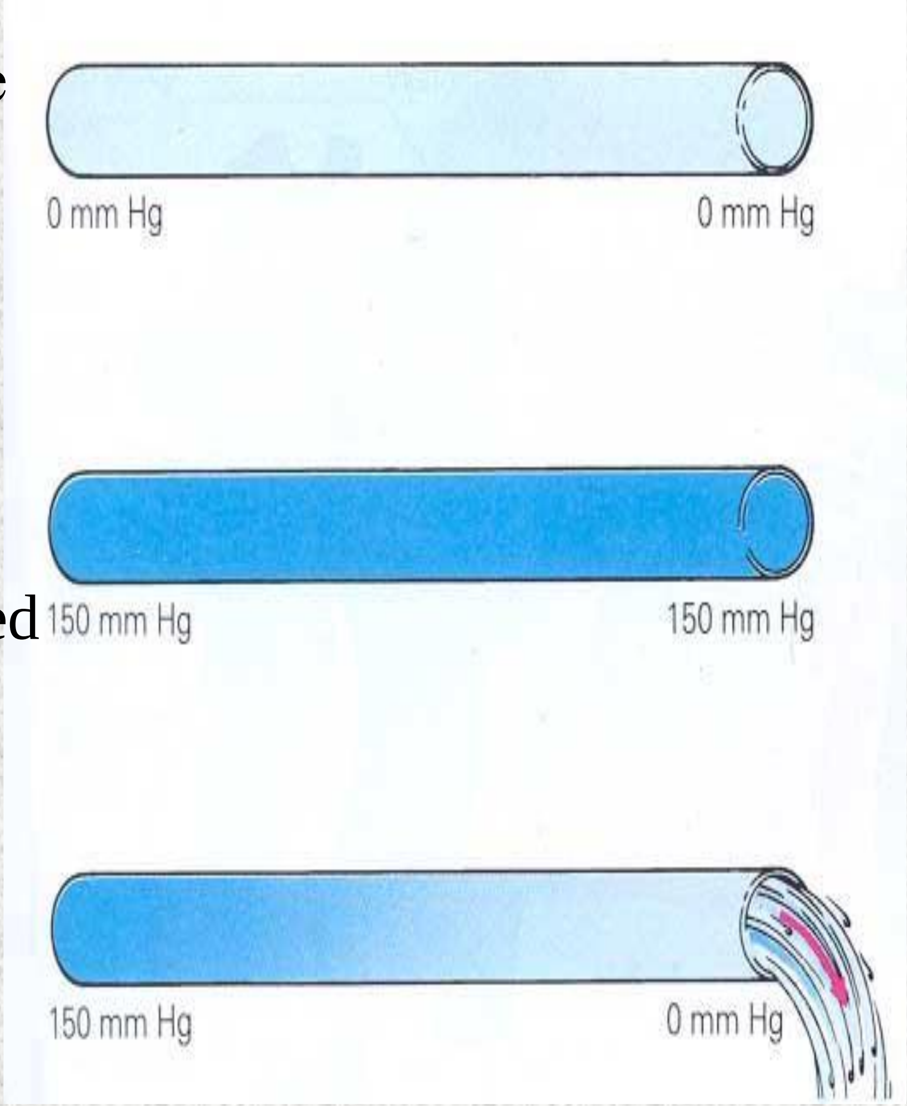
Flusso (Q) e' il volume che pass per secondo

$$\dot{Q} = \frac{\Delta Q}{\Delta t}$$

Il flusso nel sistema CVS e' dovuto alla differenza di pressione tra arterie e vene, ed e' proporzionale alla differenza di pressione.

$$\dot{Q} = \frac{P_a - P_v}{R}$$

R è la resistenza vascolare



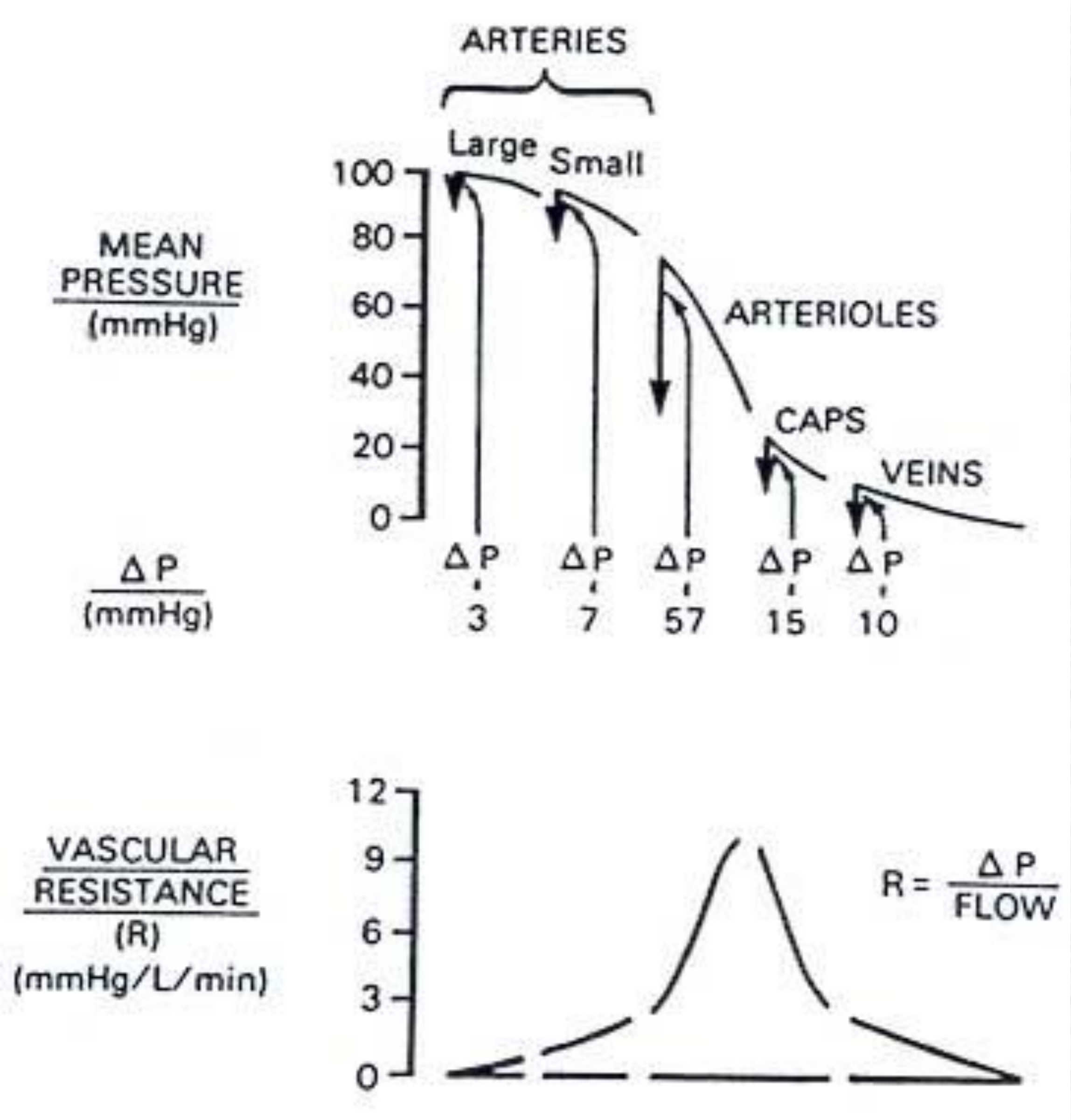
Qunidi resistenza vascolare è $$R = \frac{dp}{Q} = \frac{8\mu L}{\pi a^4}$$

Un piccolo cambiamento in a cambia molto la resistenza al flusso. Questo è la base di vasodilatazione e vasocostrizione. Quindi l'ipertensione puo essere ridotto usando farmaci che rilassano i muscoli, diminuendo la viscosità del sangue o riducendo la quantità di sale (perche?)

E' utile misurare la resistenza vascolare, ma non

- Indica il luogo della costrizione or dilatazione
- Indica la causa
- Fornisce informazione è netta non locale
- Non è capace di distinguere tra formazone di nuovi vasi, dilatazione o emorragia

Resistenza lungo il sistema vascolare



La resistenza e' massima nelle arteriole.

La resistenza totale e' controllata dalle arteriole.

Le arteriole controllono la perfusione attraverso gli organi e la distribuzione del uscita' cardiaca. Come?

Mechanical Properties of Blood Vessels

Blood vessels are composed of a variety of materials, principally collagen and elastin. The stress strain curve can be modeled quite well using the recruitment model.

The mechanical properties arise from the orientation of the proteins and cells in the various layers, their interaction, not possible to reproduce with synthetic materials

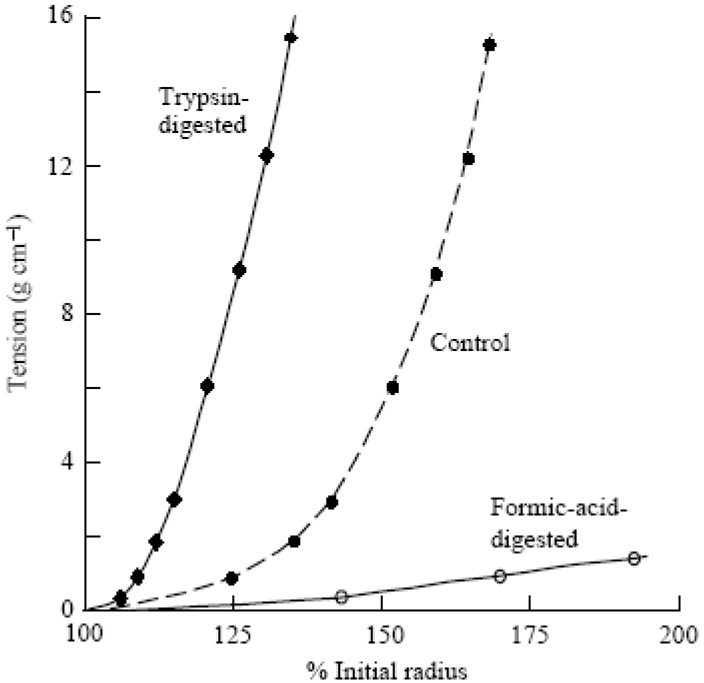
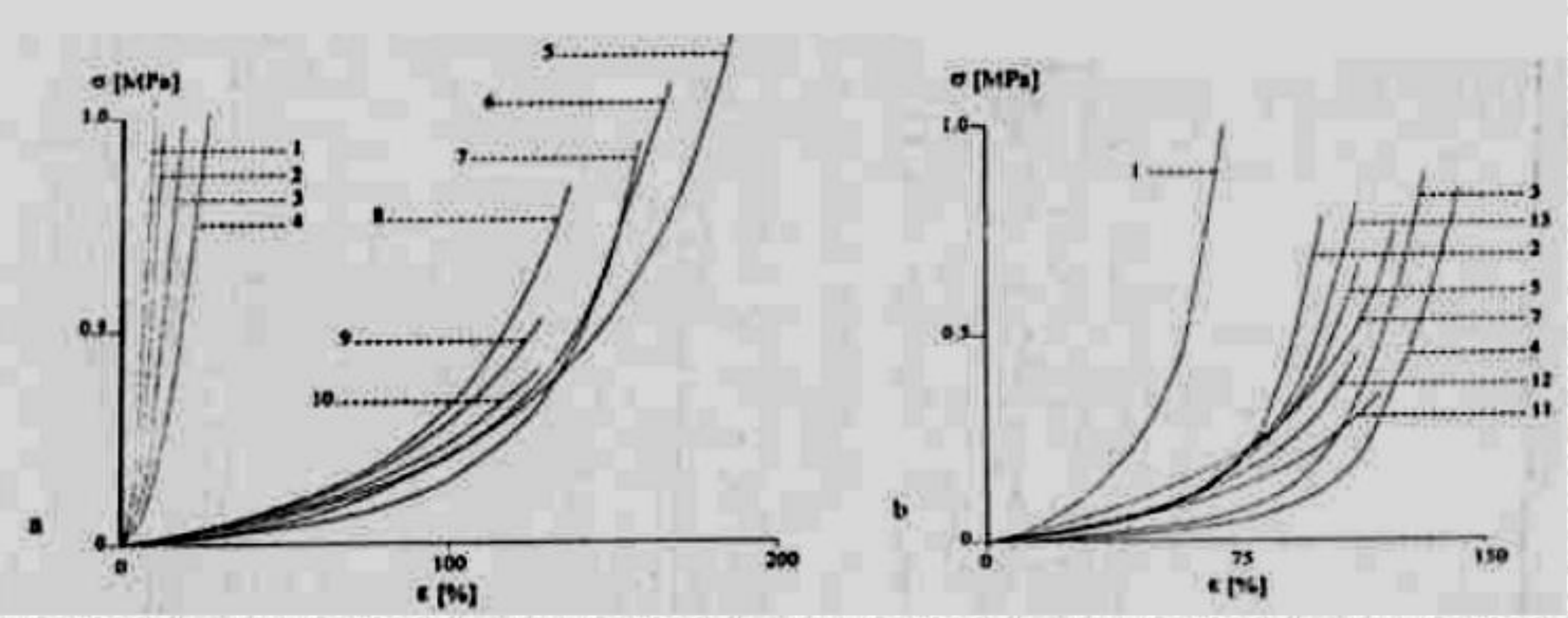


Fig. 4. The contributions of elastin and collagen to the tension–length response of human iliac arteries. When elastin is removed by trypsin digestion, the curve (diamonds) represents the properties of the remaining collagen. Alternatively, when collagen is removed by formic acid digestion, the curve (open circles) represents the properties of the elastin fibres. The broken curve (filled circles) is for an untreated artery (redrawn from Roach and Burton, 1957).



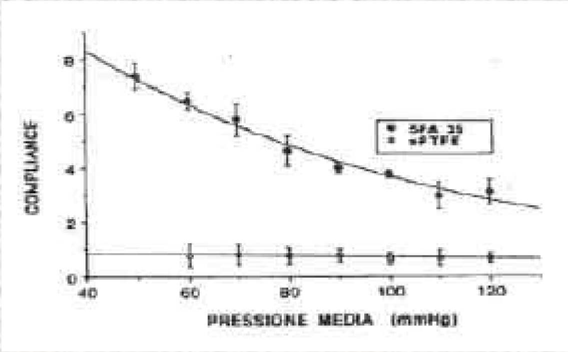
Blood vessels are highly anisotropic: Left: Stress strian in the circumferential direction, Right: longitudinal 1: prosthesis in PET woven, 2: woven PTFE 3: knitted PET a; 4: PTFE knitted; 5. iliac artery; 6: aorta
Distal abdominal artery 7: femoral artery; 8: abdominal artery , others

Characterisation of vascular grafts and vessels

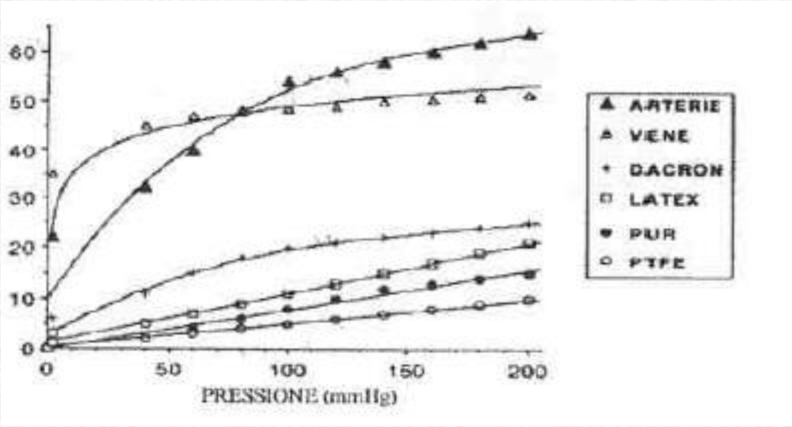
The most important parameters to consider are permeability, porosity, compliance, tensile strenghth, burst strength and durability.

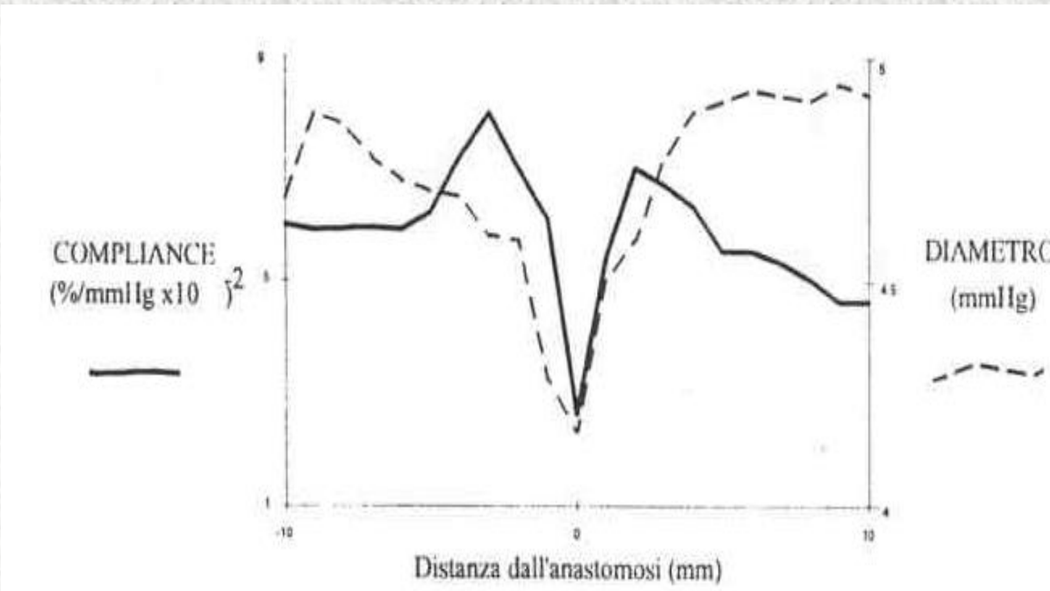
Compliance is a measure of radial distensibility of a vessel, and is the parameter which is most difficult to reproduce in synthetic materials.

Dacron	Permeabilità $[ml/min*cm^2]$	Precoagulazione
Protesi a rete	50÷200	No
Protesi a maglia	2000 (media)	Sì
Protesi con velour	1300 (uniforme)	Sì



$\frac{\Delta d}{d}\%$





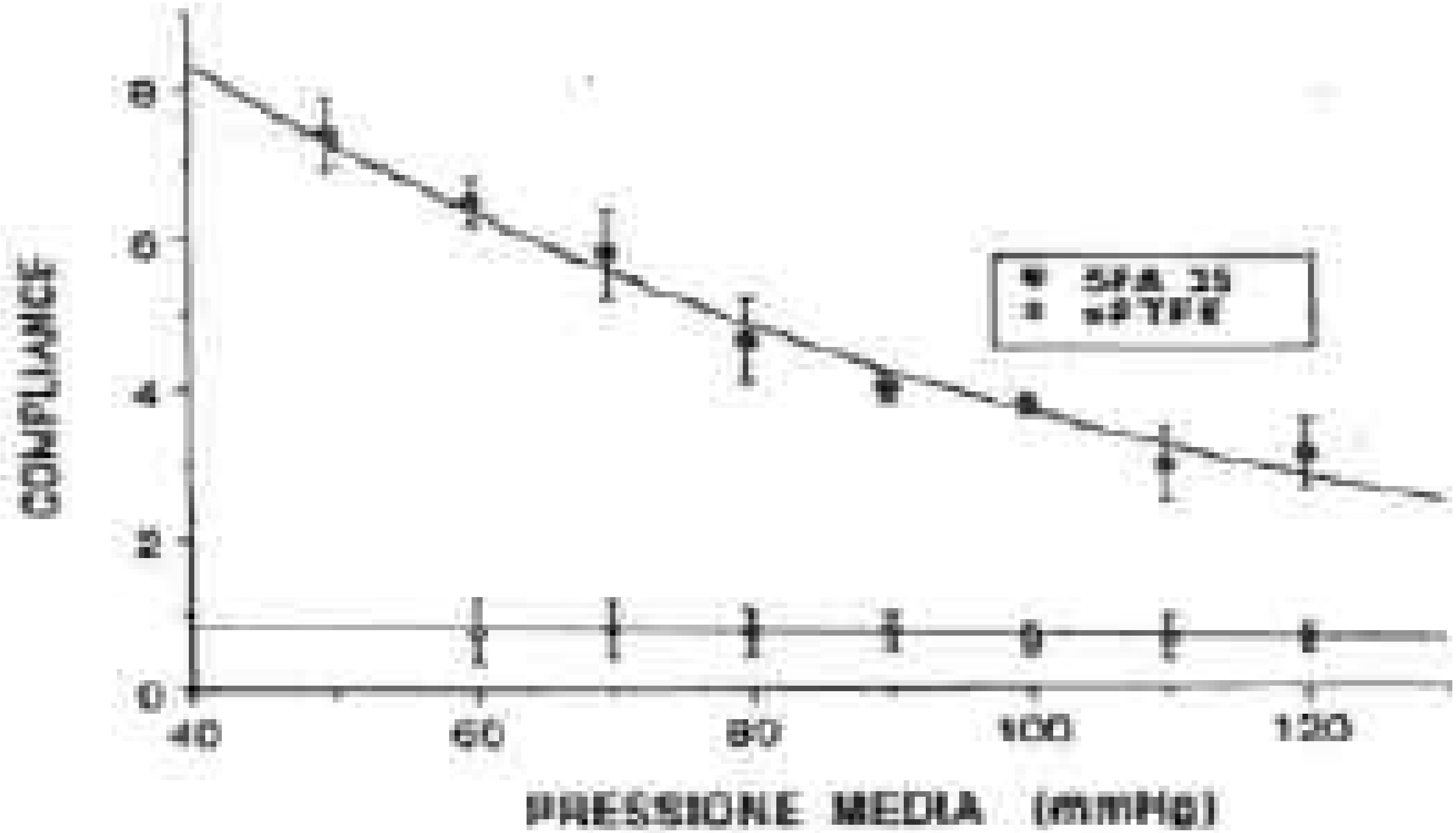
Compliance mismatch at a suture is a major problem in synthetic vessels. It results in:

- Turbulence : no neo intima formed and damage of suture (weakest point)
- Synthetic vessel cannot absorb pressure pulses
- Increase in resistance: heart works harder

Compliance values at 100 mmHg (%*10/100 mmHg)

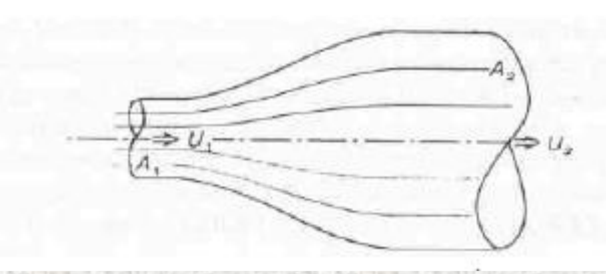
DACRON woven	1.97
DACRON coated with gelatin	0.9
DACRON knitted	0.8
ePTFE standard wall	0.2

Compare with blood vessel



stop

Other aspects to discuss: application of Bernoulli to stenosis and aneurism



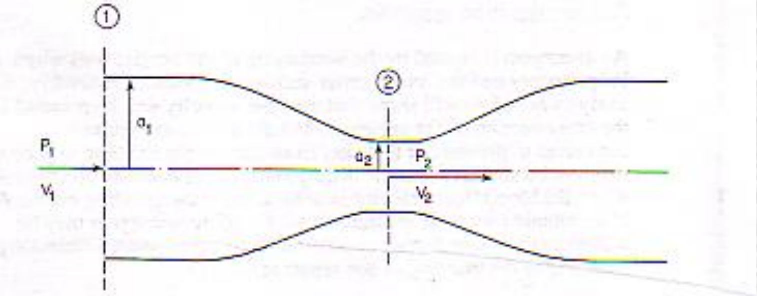
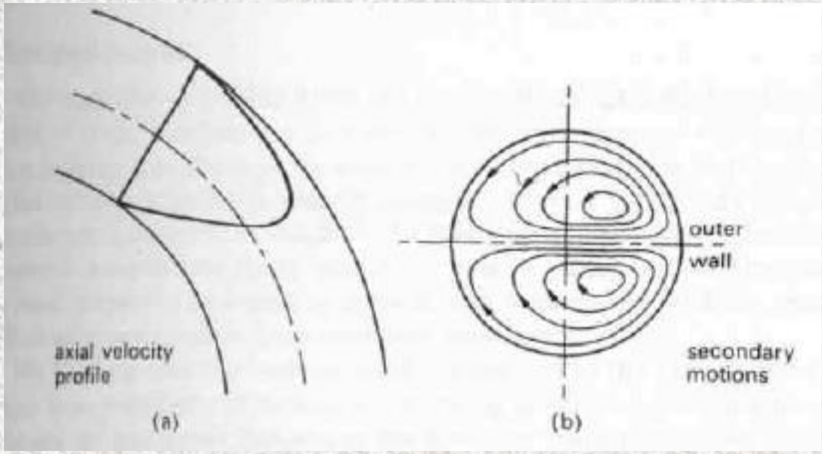
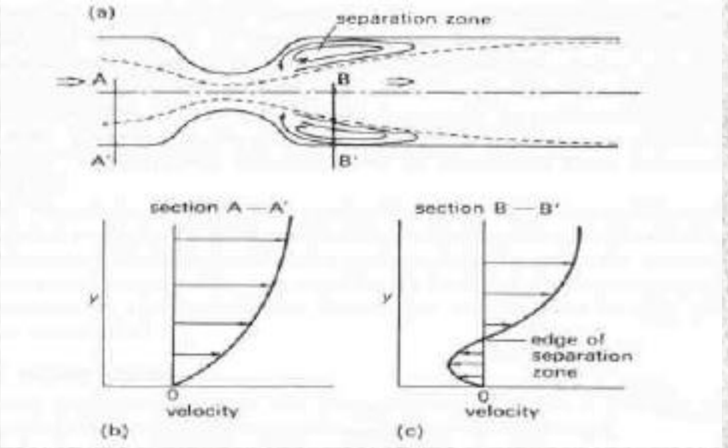
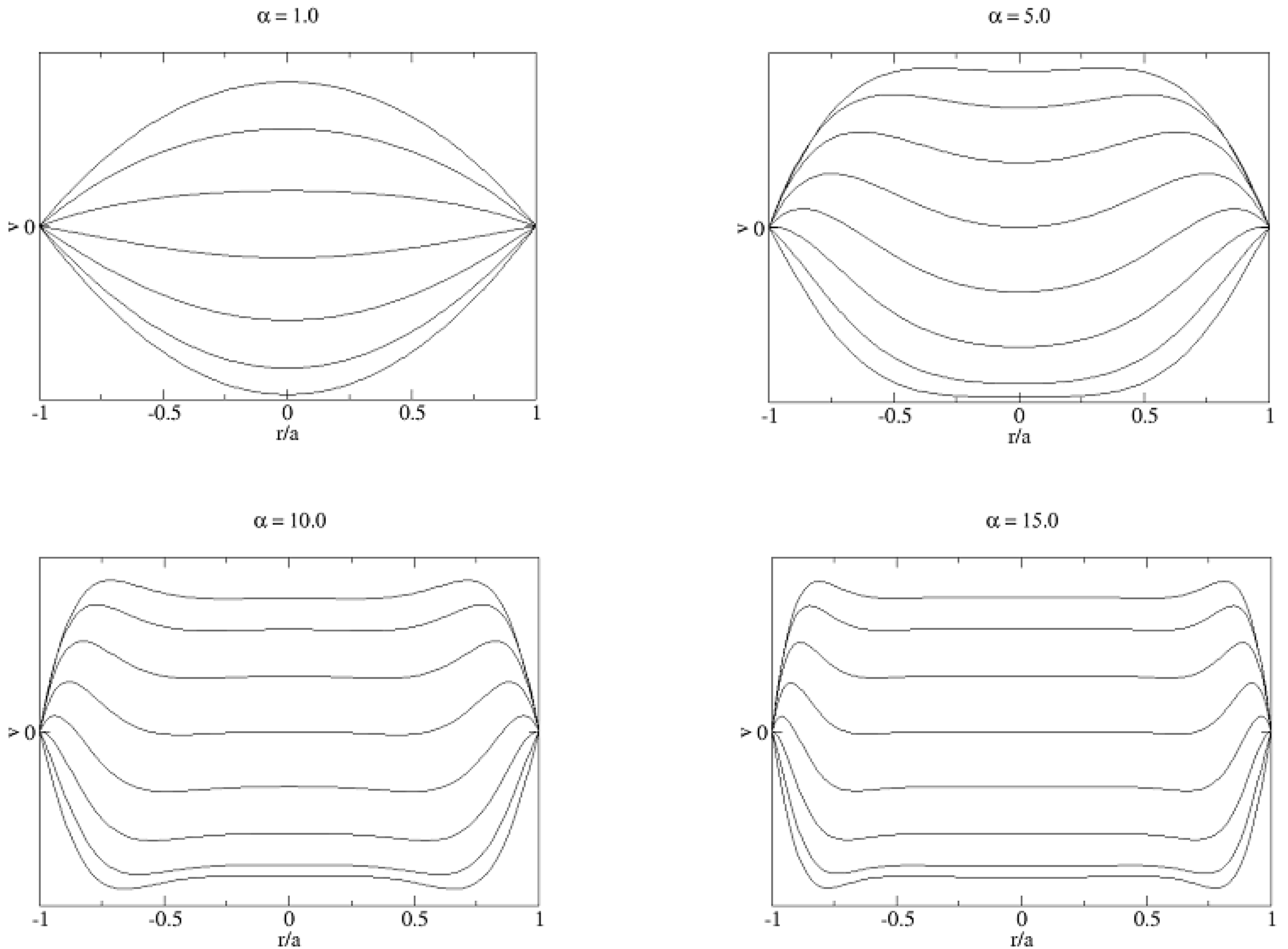


Figure 4.4 Application of Bernoulli equation to an arterial stenosis.

Flow with radius of curvature and flow separation







α = 1.0
α = 5.0
α = 10.0
α = 15.0
v 0
-1
-0.5
0
0.5
1
r/a

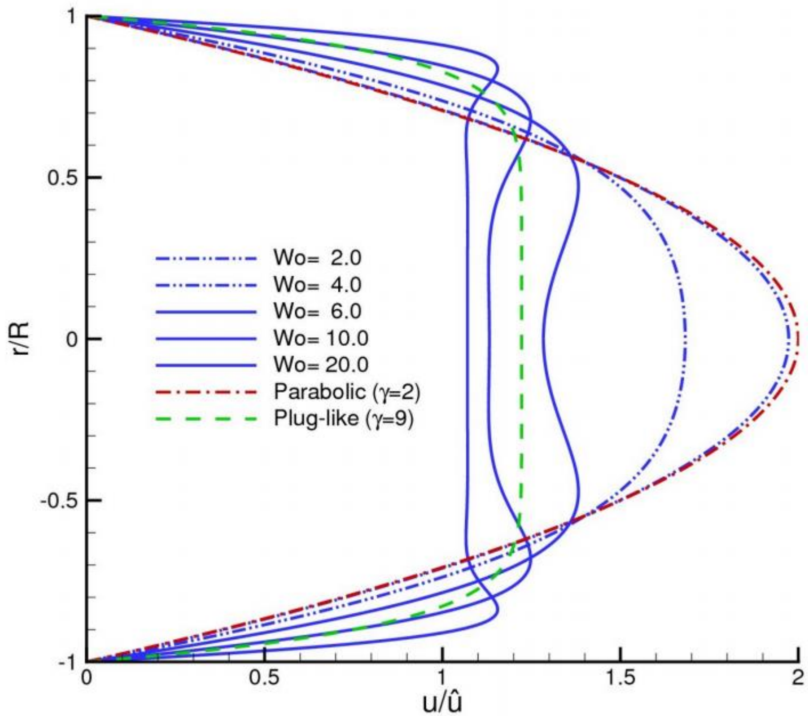
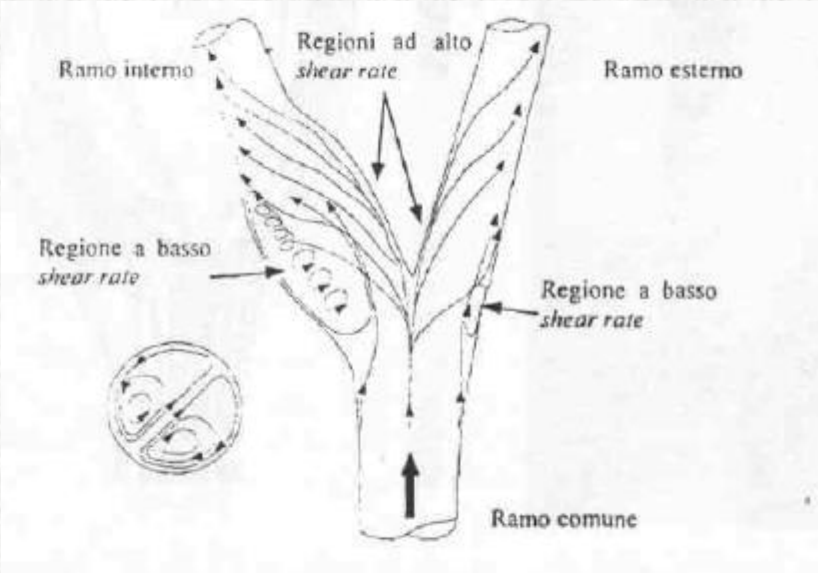
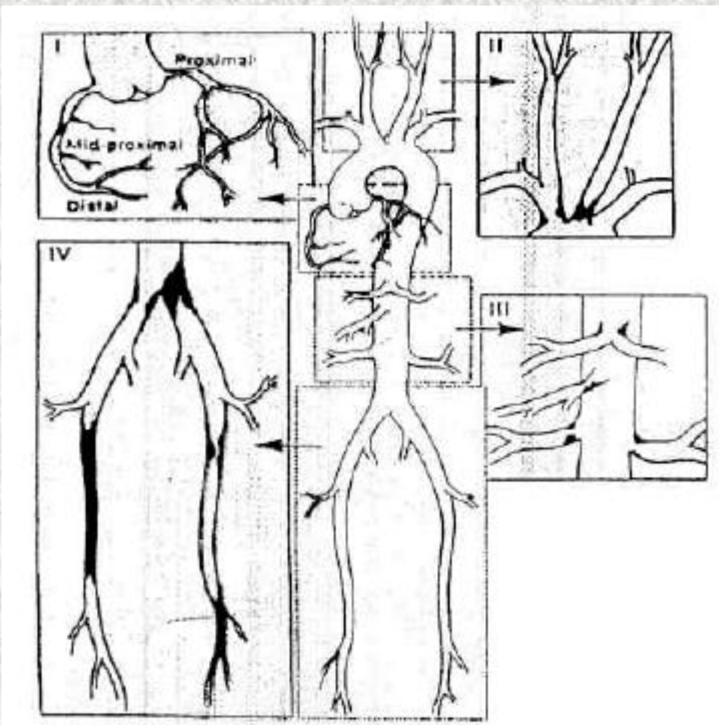


Fig. 1. Steady Hagen-Poiseuille parabolic ($\gamma = 2$) and plug-like($\gamma = 9$) velocity profiles and five representative snapshots of the peak velocity profiles of the transient Womersley flow.

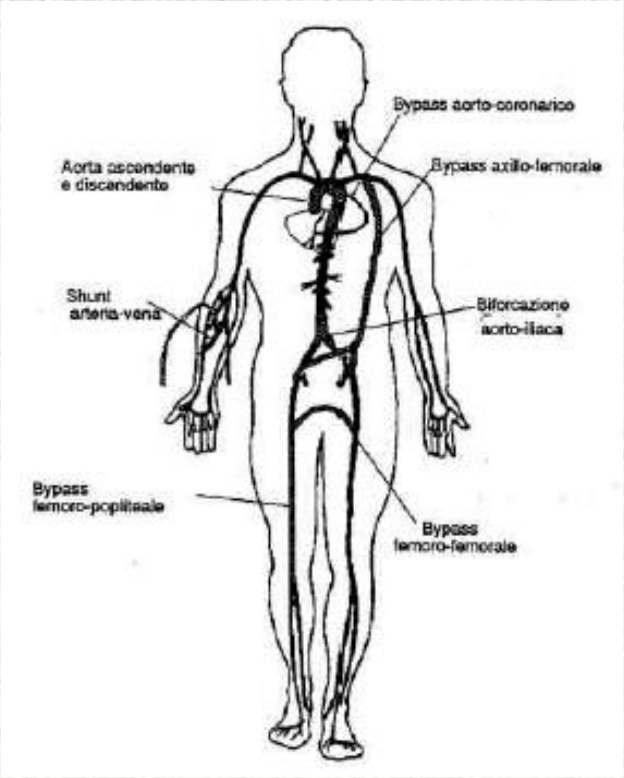


Derivation of entrance length: x=0.03 Re* radius of vessel, calculate this for aorta and discuss

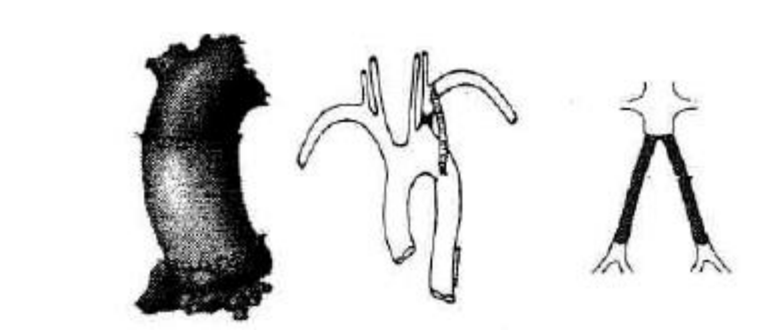
Vascular Prostheses: trauma, pathology



Zones most likely to suffer from plaques

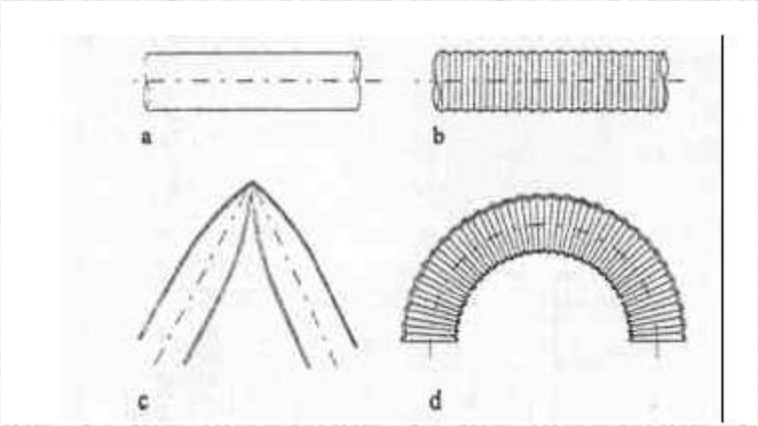


Principal sites for vascular prosthesis



Different types of intervention: substitution, bypass, bifurcation

Problem: synthetic vascular prostheses are limited to a minimum diameter of 6 mm. Why?



Why are prosthese pleated?

	Dacron, weft, no support	Dacron warp	Dacron weft, external suppoprt	ePTFE	Autologus saphenous vein	Internal mammary arterty
Coronary aortic bypass					70%	93%
Aortic bifurcation	99.6%	100%				
Aorta-femoral bypass	98%	100%				
Femoral-femoral bypass	80%	93%				
Axillo-femoral bypass	67%		97%			
Femoral-popliteal bypass	53%		84%		61%	
Femoral-popliteal bypass			63%	49%	76%	

Supponendo che abbiano lo stesso modulo elastico, stimare lo sforzo sulla parete dei seguenti vasi. Spiegare il significato del segno ottenuto.
Dato che la pressione di scoppio dell'aorta e' 1000 mmHg, stimare lo sforzo di rottura del vaso.

Vaso	Diametro interno	Diametro esterno	Pressione
Aorta		3.2 cm	120 mmHg
Arteriola	1 mm	1.1mm	39 mmHg
Vena	1 cm	1.1 cm	3 mmHg