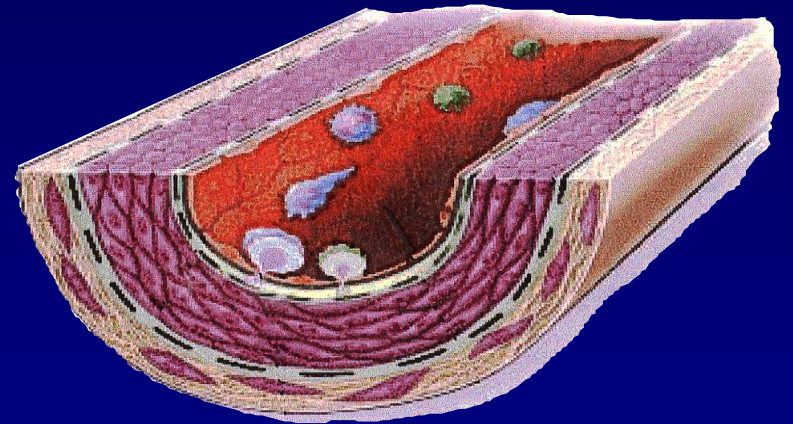
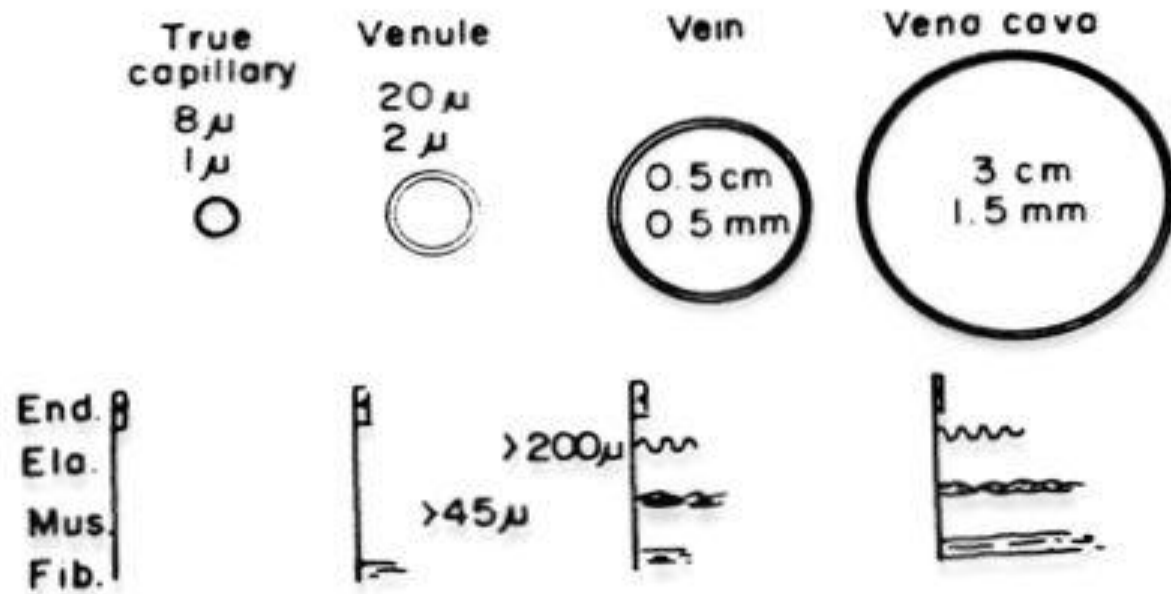
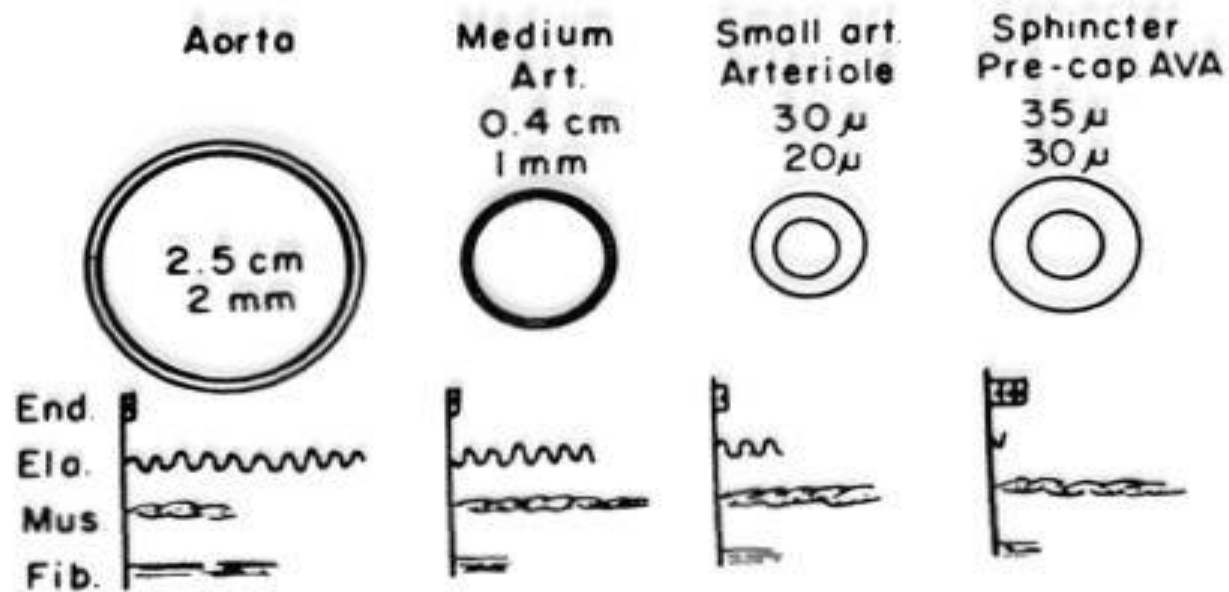


Le système cardiovasculaire: macro et microcirculation

Bernard LEVY
INSERM
Hôpital Lariboisière
Paris





	n	D	h	CSA (cm ²)
Aorta	1	25 mm	2mm	2.8
Arteries	40-110000	20 - 0.5 mm	1 - 0.1mm	40
Arterioles	3×10^6	500-20 μm	100 - 10 μm	55
Capillaries	3×10^9	15 - 5 μm	0.5 μm	1350

3cm²

40

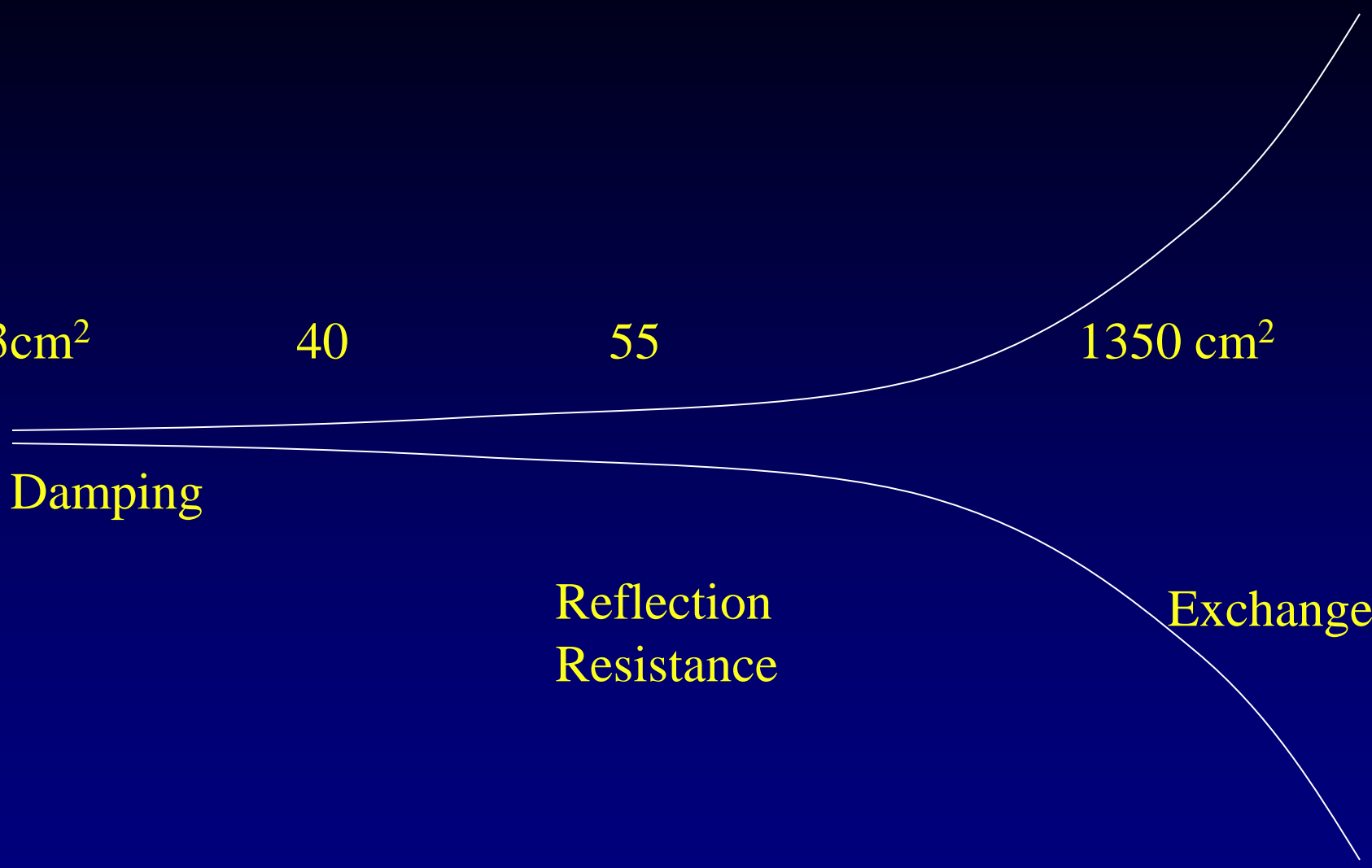
55

1350 cm²

Damping

Reflection
Resistance

Exchanges



Few elastic arteries

Thousands of muscular arteries

Millions of arterioles

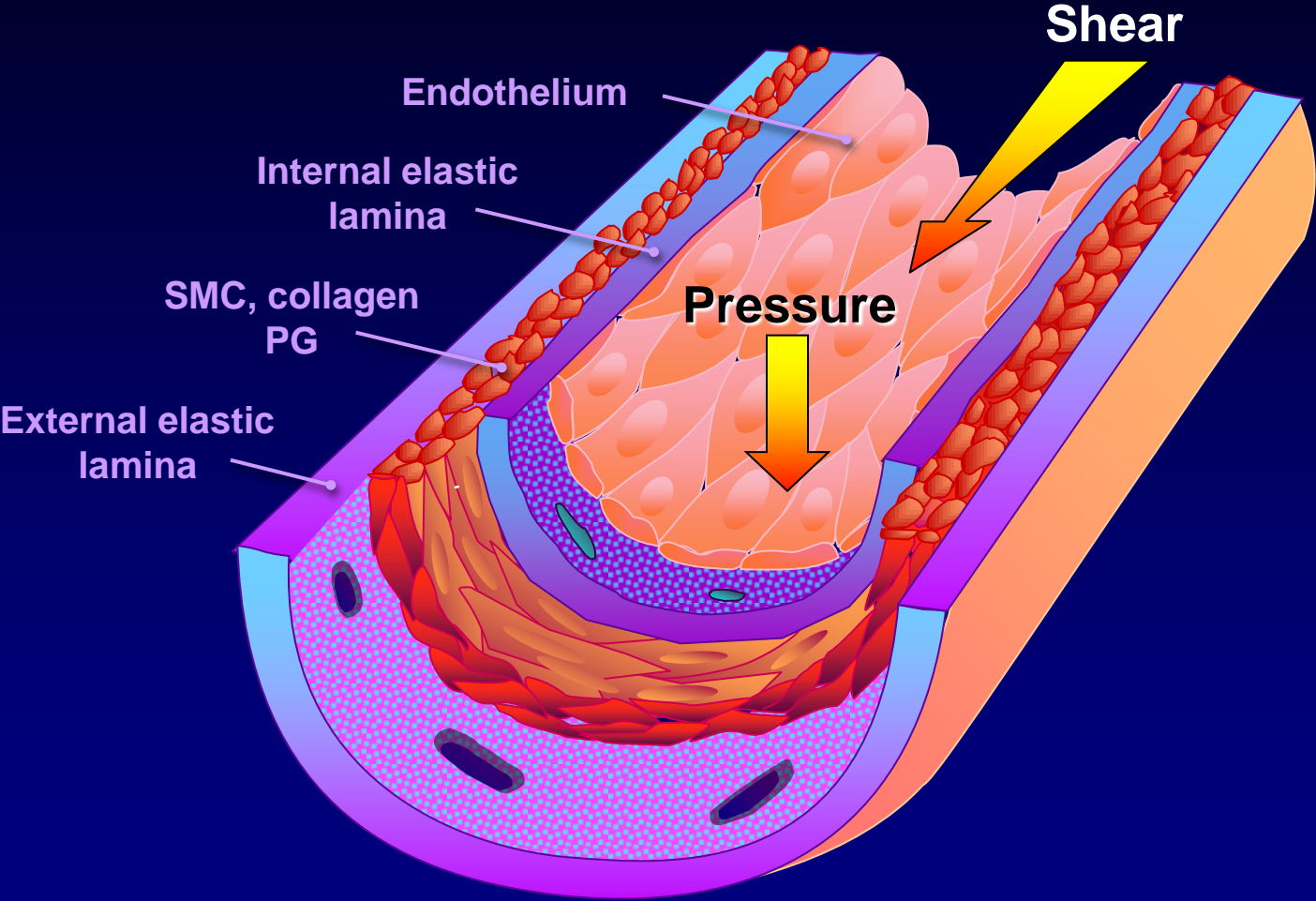
Billions of capillaries

distribution and damping

resistance & reflection

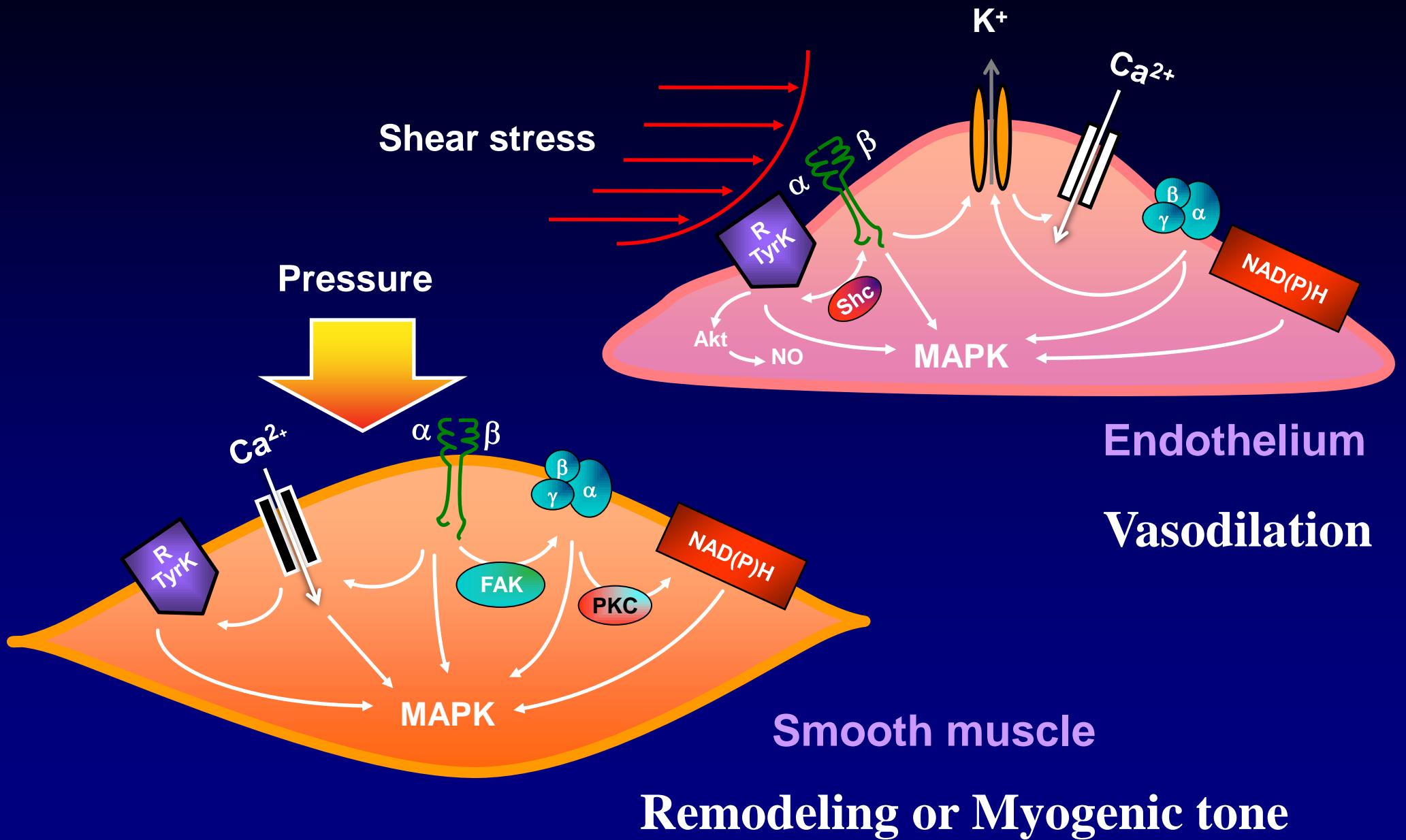
diffusion and exchanges

Mechanical forces in the vascular wall

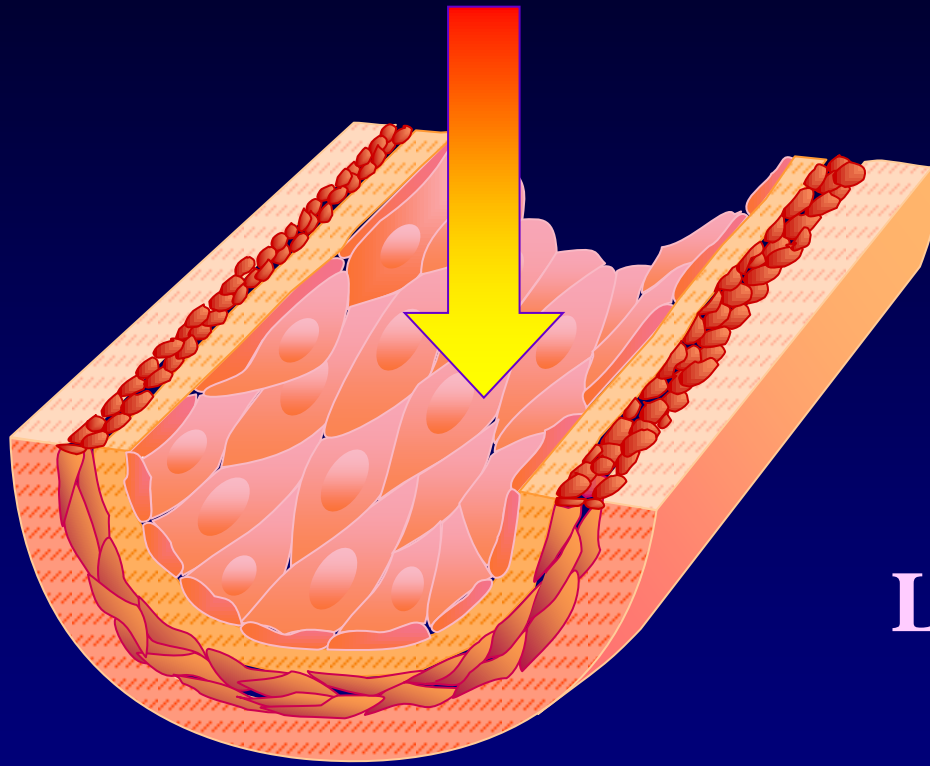


$$\text{Shear Stress} = 4 \mu Q / \pi r^3 = 4 \mu (\pi r^2 V) / \pi r^3 = 4 \mu V / r$$

$$\text{Tensile stress} = P r / h$$



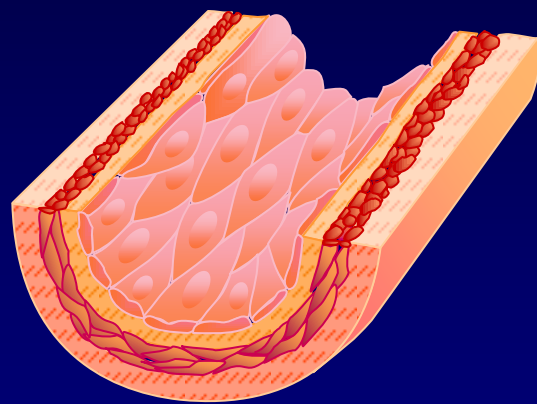
Tensile stress



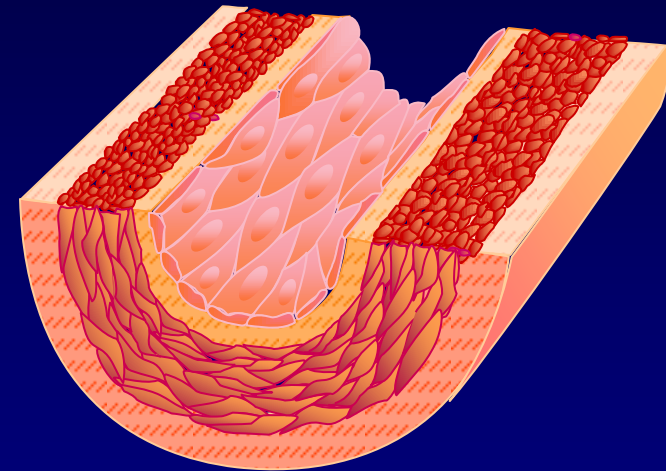
Laplace law

$$\frac{P \cdot r}{h}$$

Pressure-induced vascular remodelling



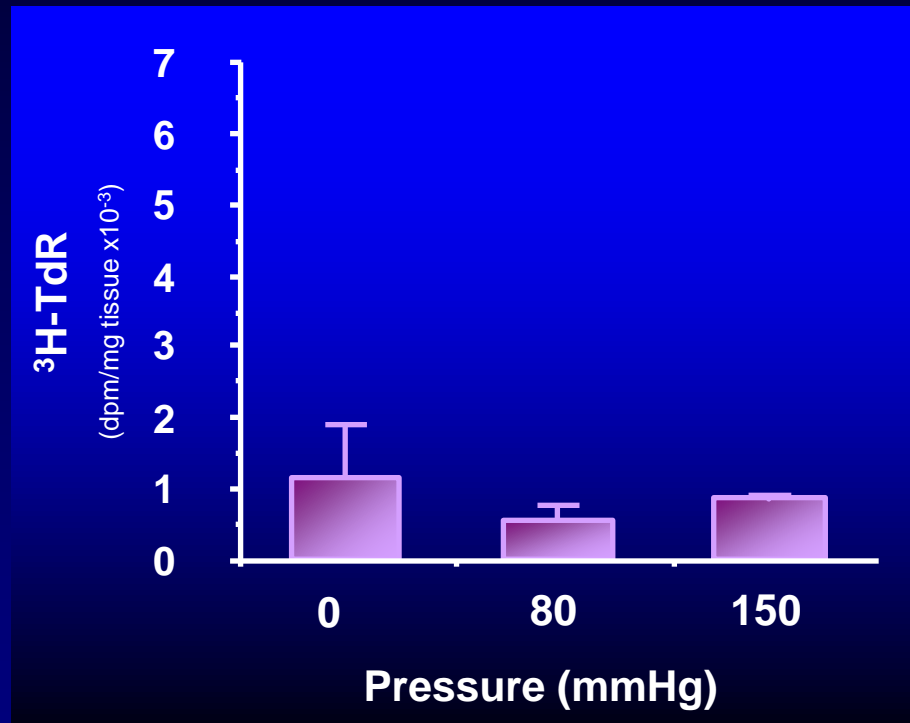
Hypertension



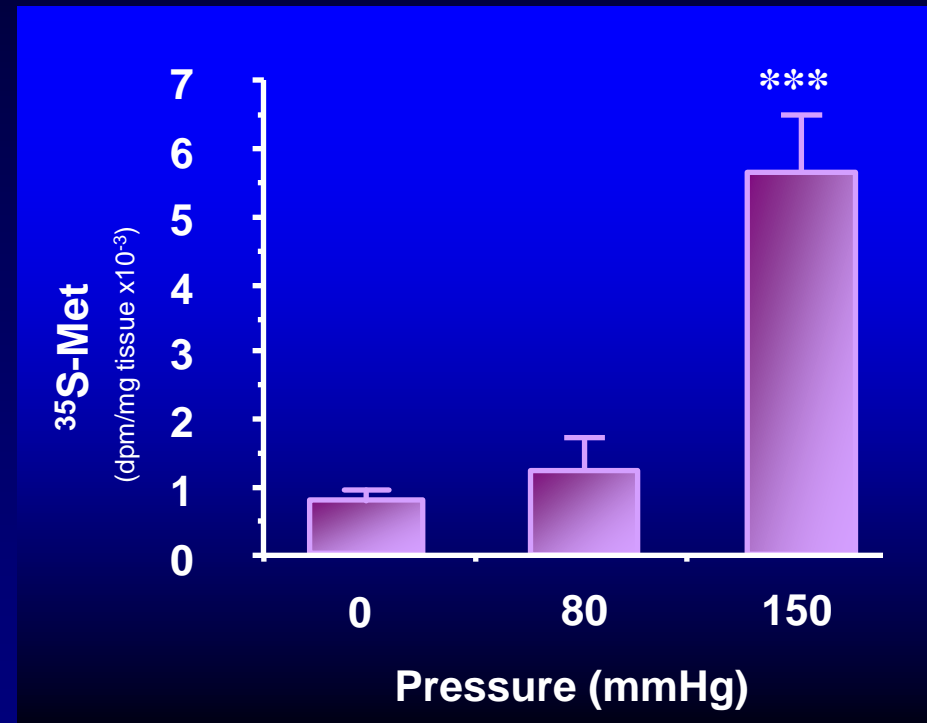
ECM synthesis/degradation
VSMC hypertrophy/hyperplasia

Pressure-induced changes in DNA and protein synthesis

DNA synthesis

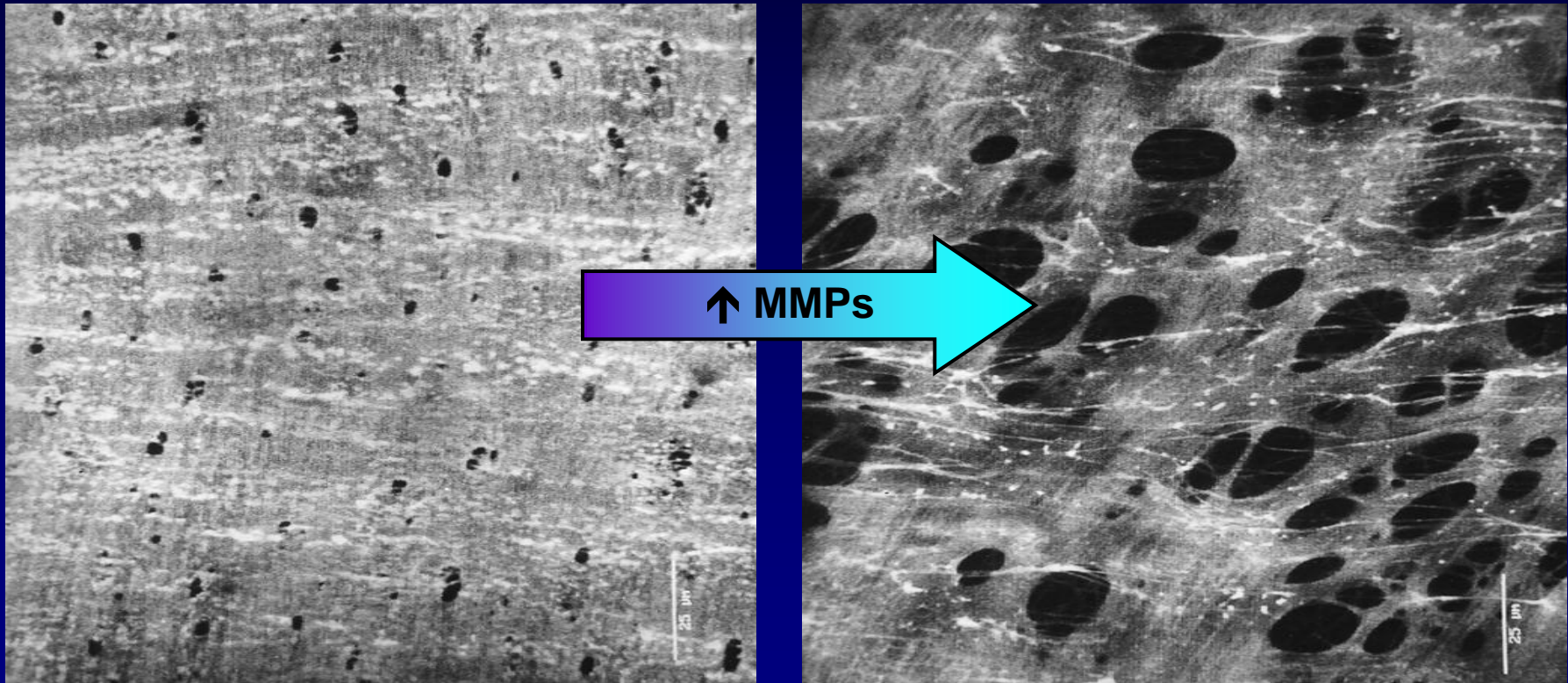


Protein synthesis

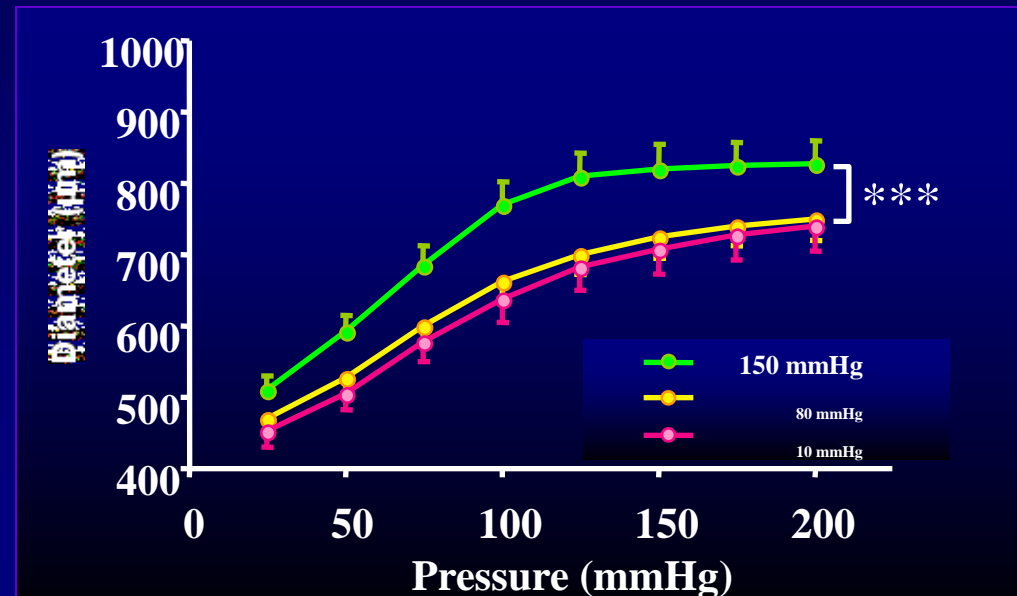
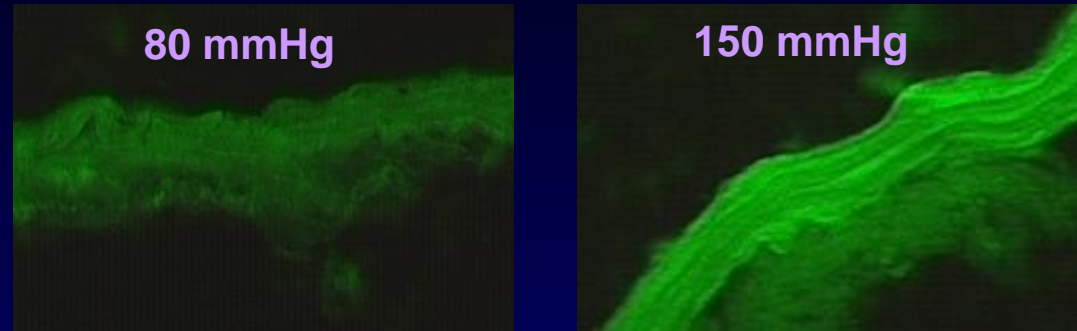
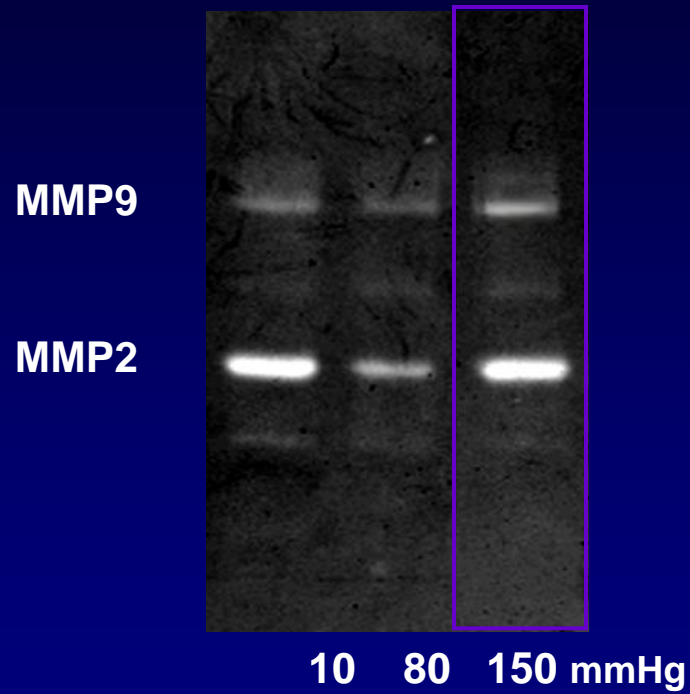


Role of MMPs in vessel remodelling

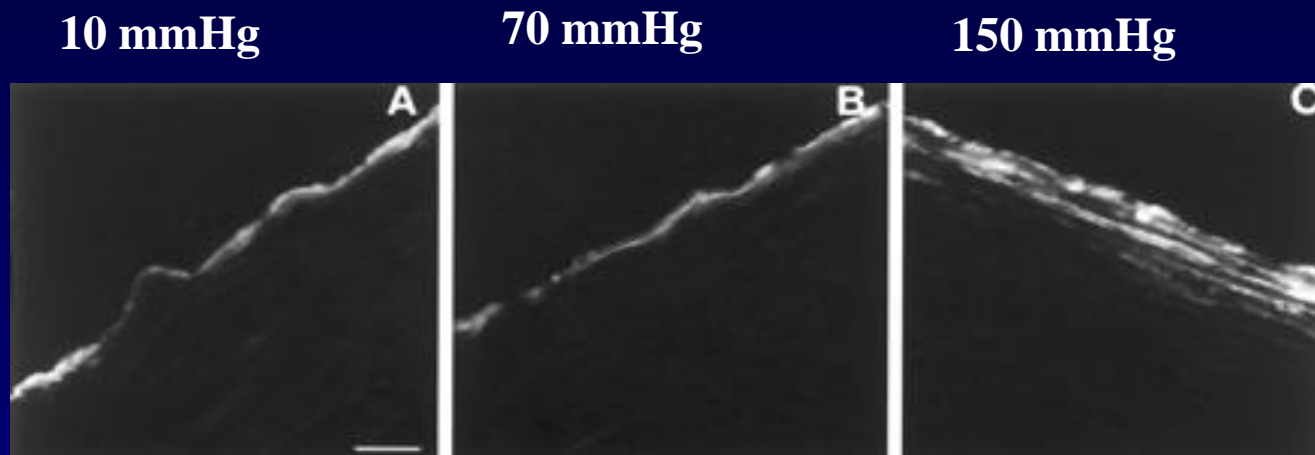
Photomicrographs of the internal elastic lamina (IEL) from right common carotid arteries



Role of MMPs in vascular remodelling



Strain-induced fibronectin expression in whole aorta

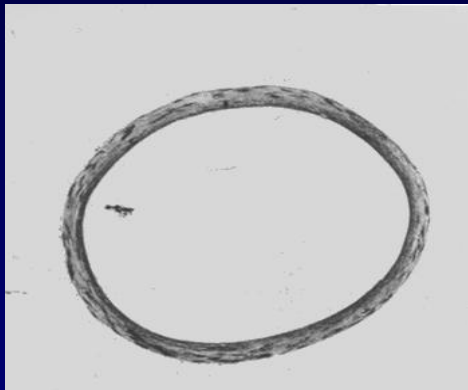


Bardy et al. Circ Res, 1996

Mechanical factors & physiological remodeling

Thoracic
aorta

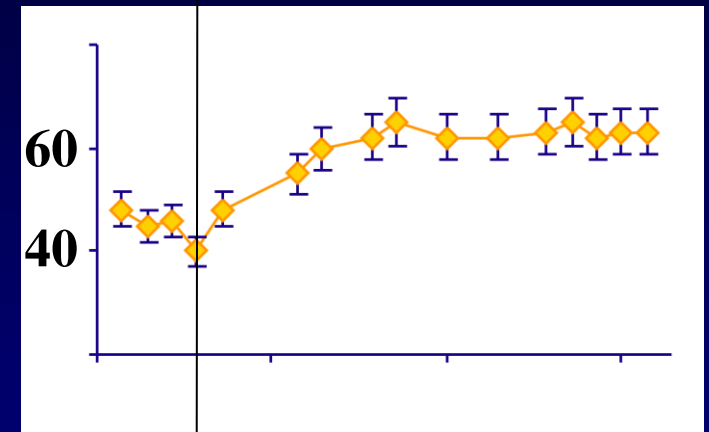
Fetal



Post-partum

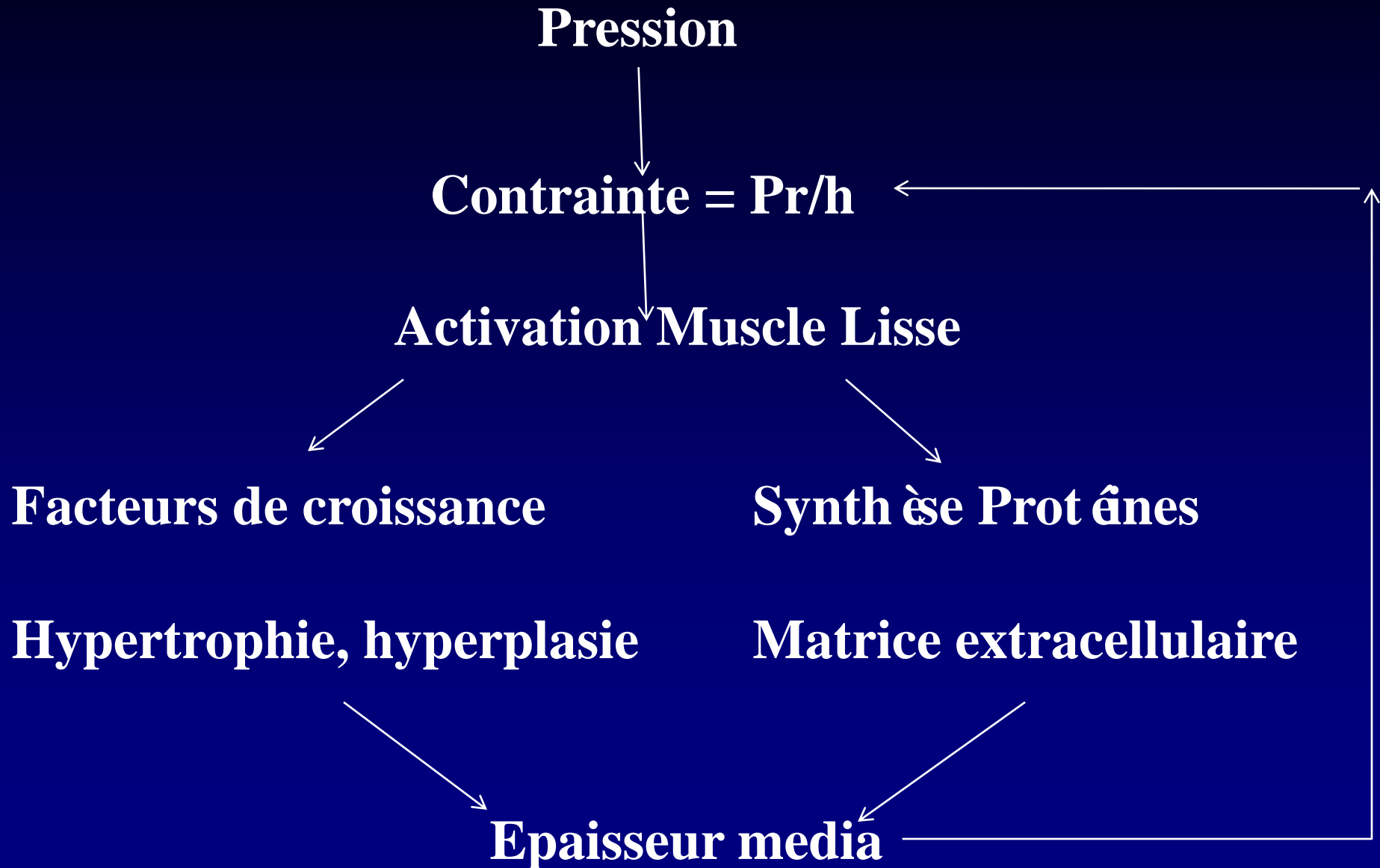


Arterial pressure (mmHg)

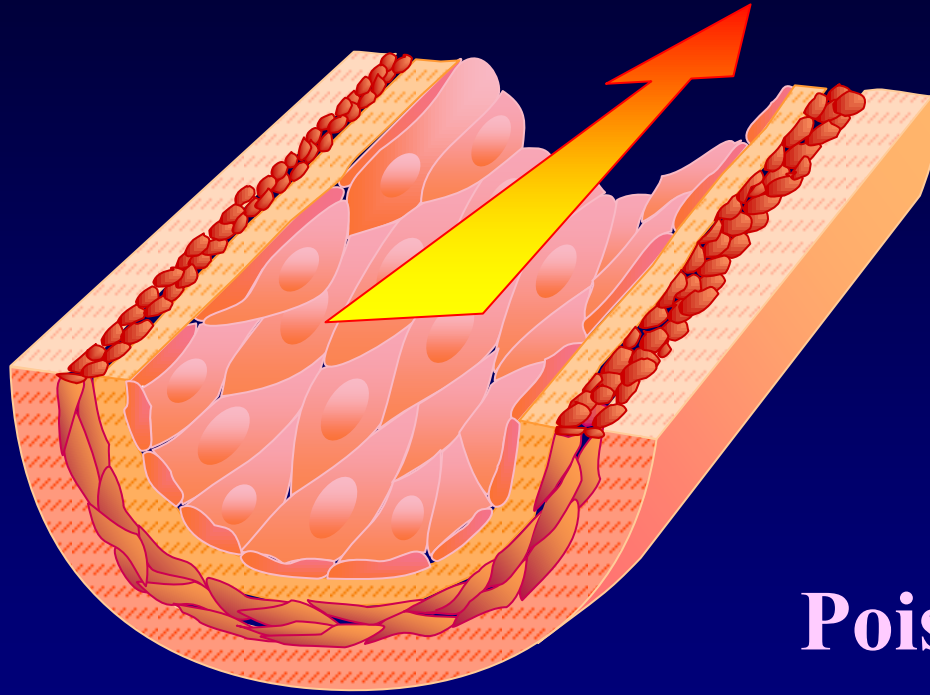


Langille et al. Am J Physiol.1990

Remodelage par contrainte pariétale (Pression)



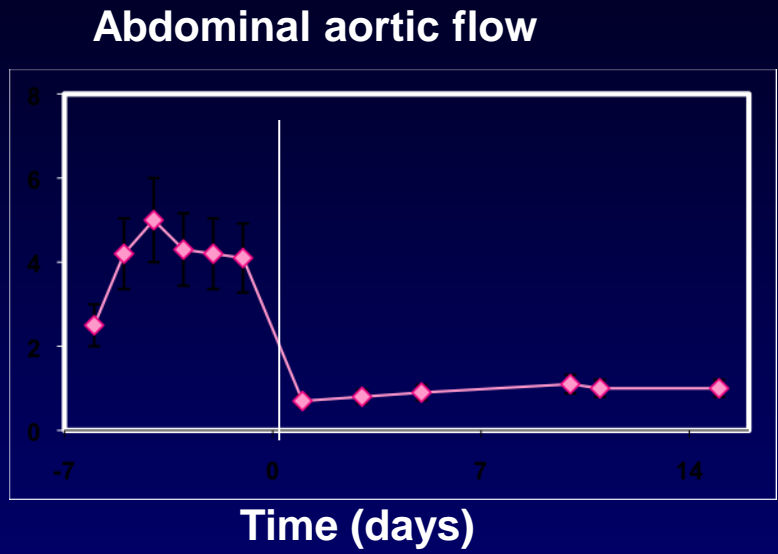
Shear stress



Poiseuille's law

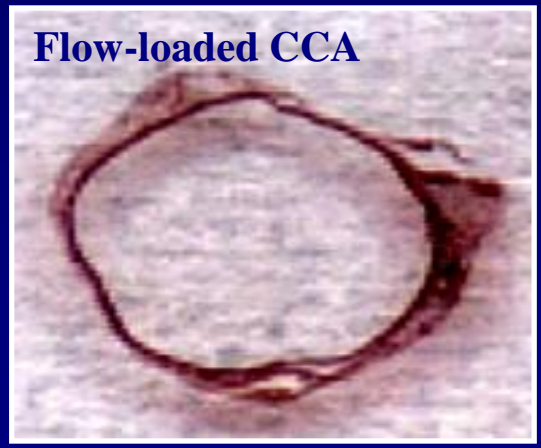
$$\tau = \frac{4 \mu \cdot Q}{\pi \cdot r^3}$$

Shear stress and physiological vascular remodelling

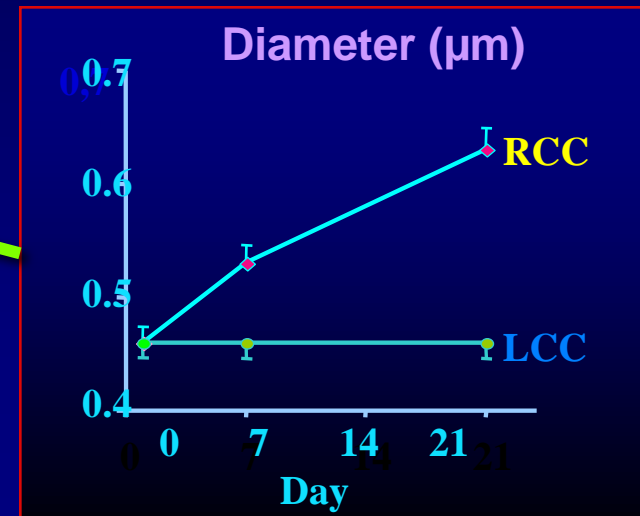
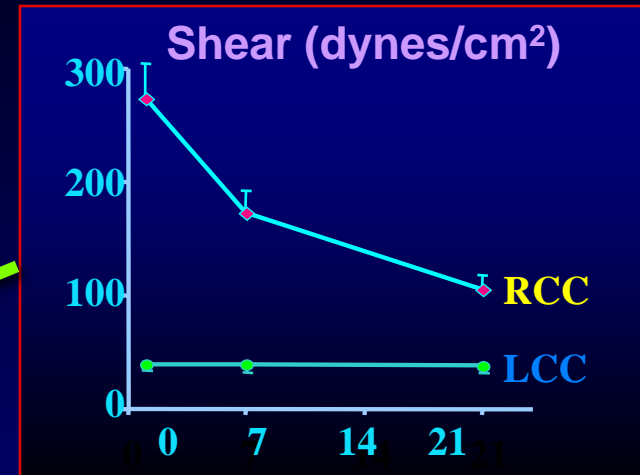
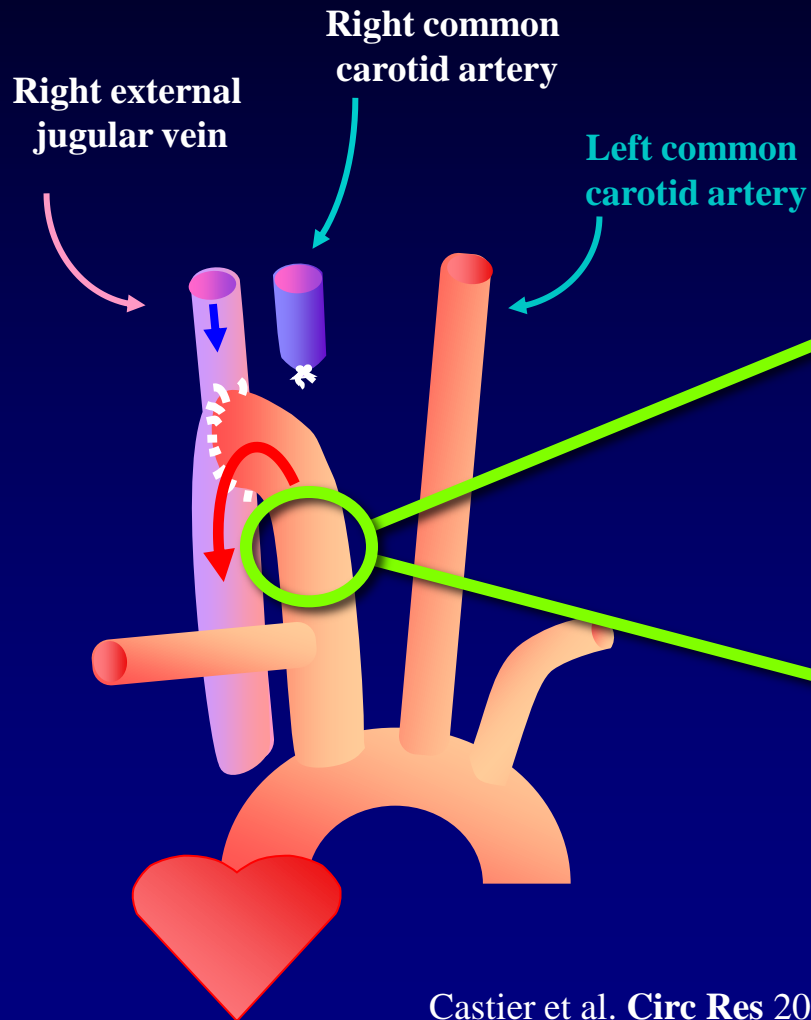


Langille et al. Am J Physiol.1990

Arteriovenous fistula

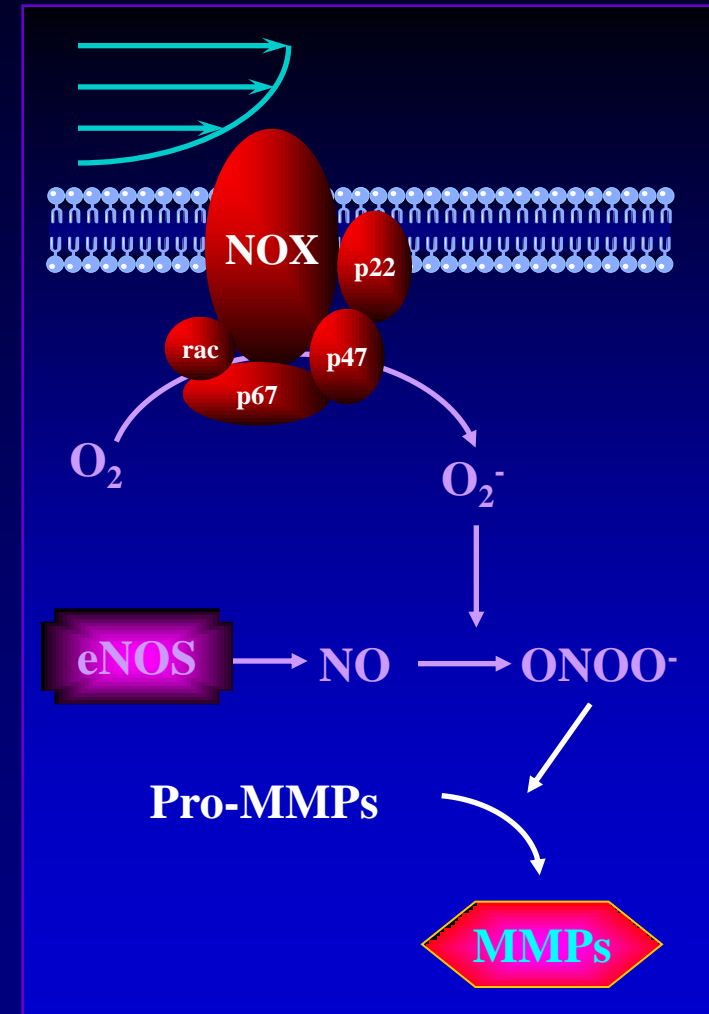
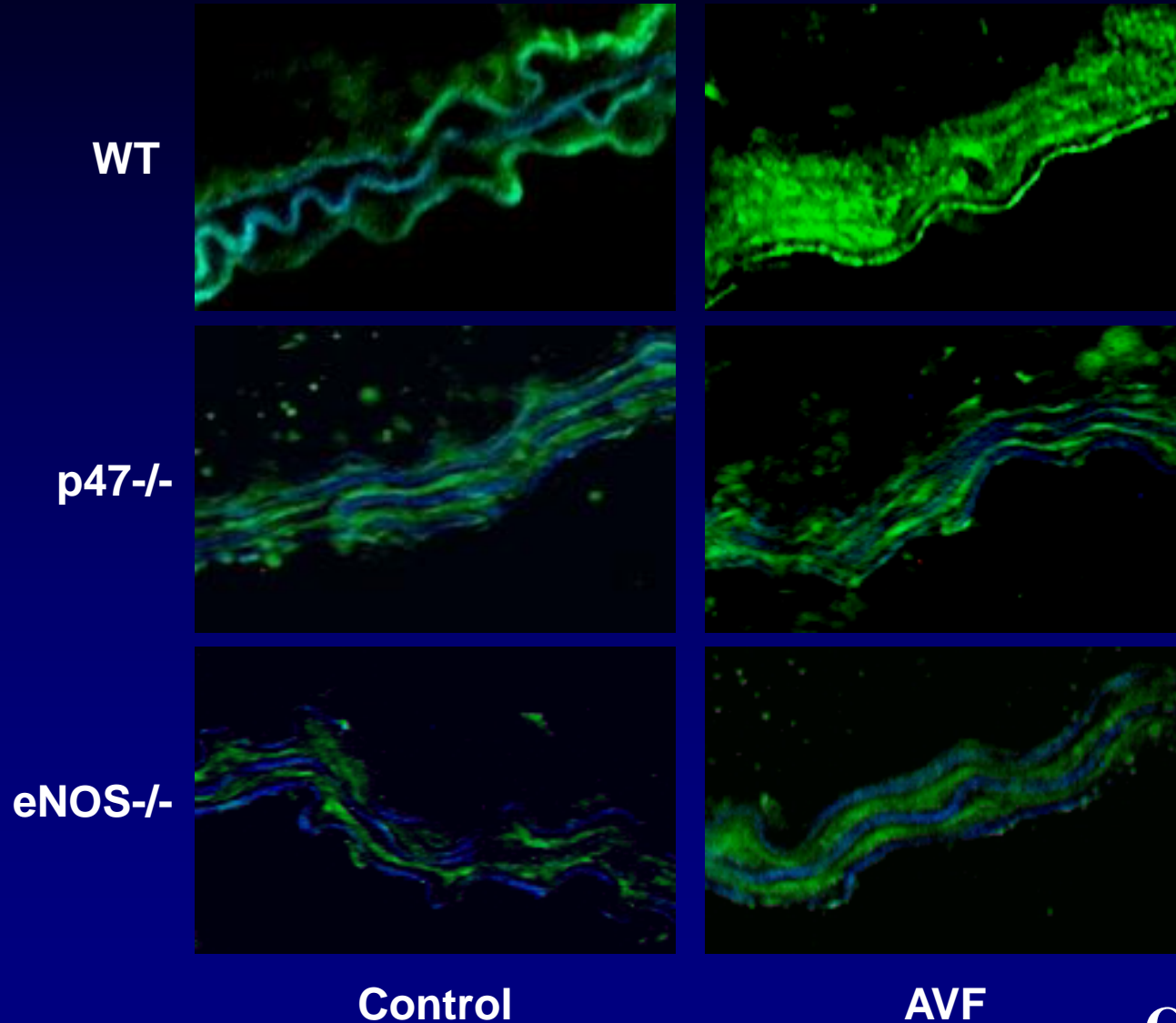


Model of arteriovenous fistula

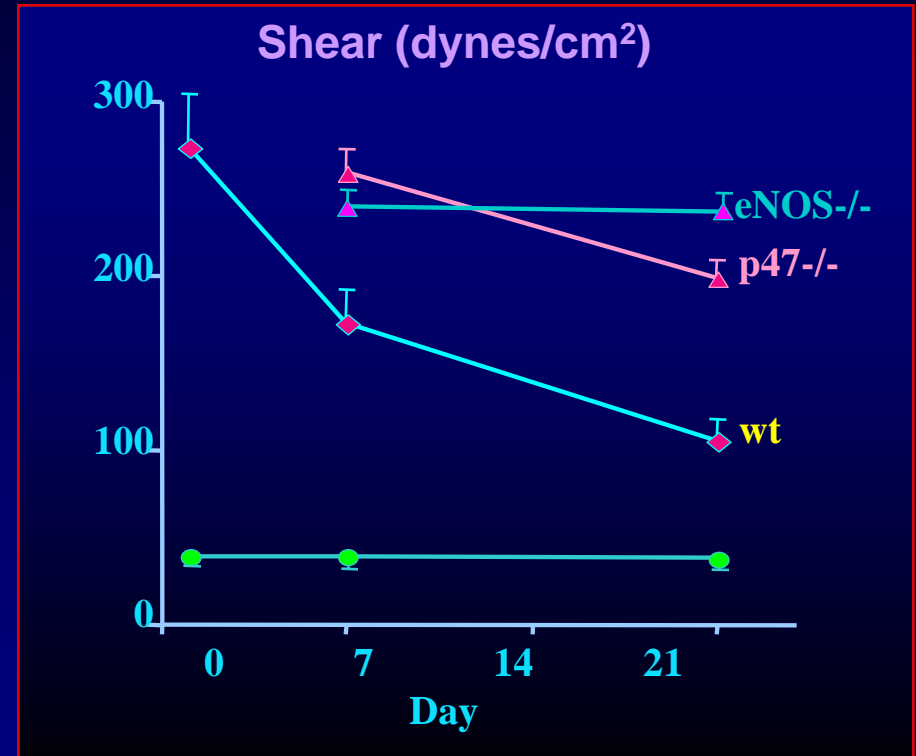
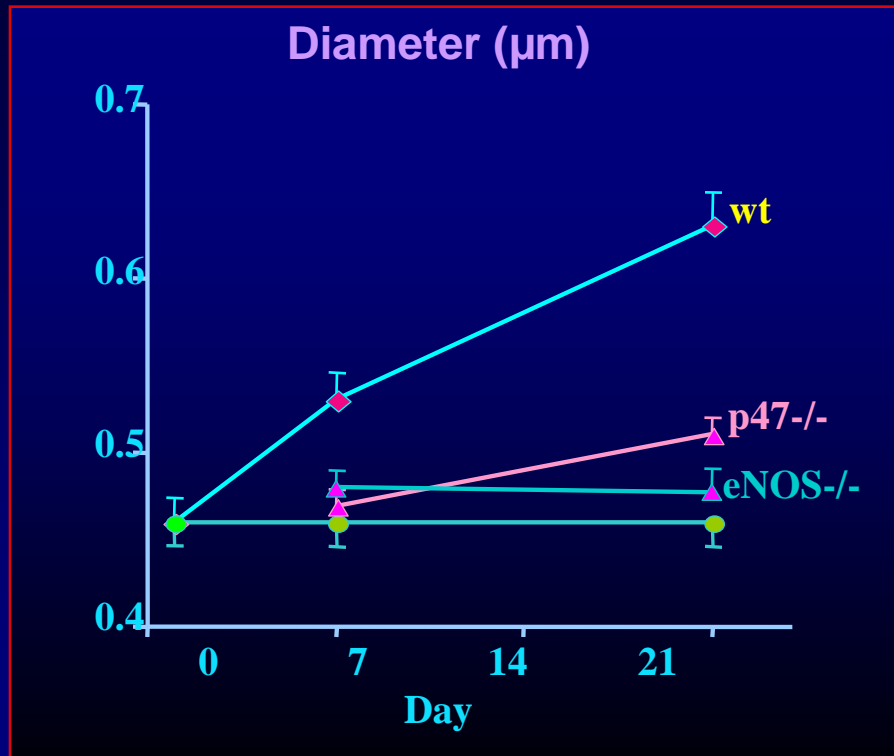


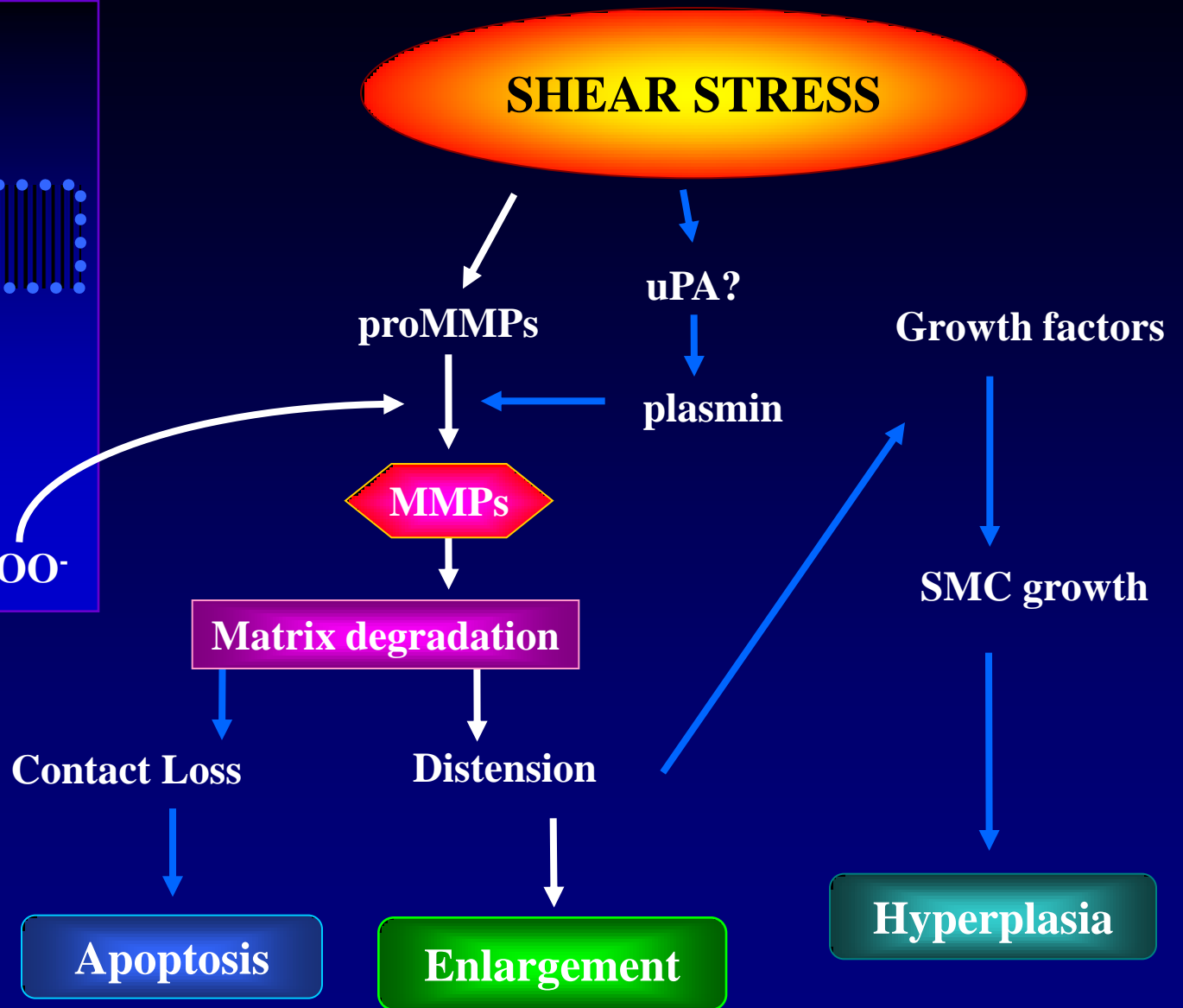
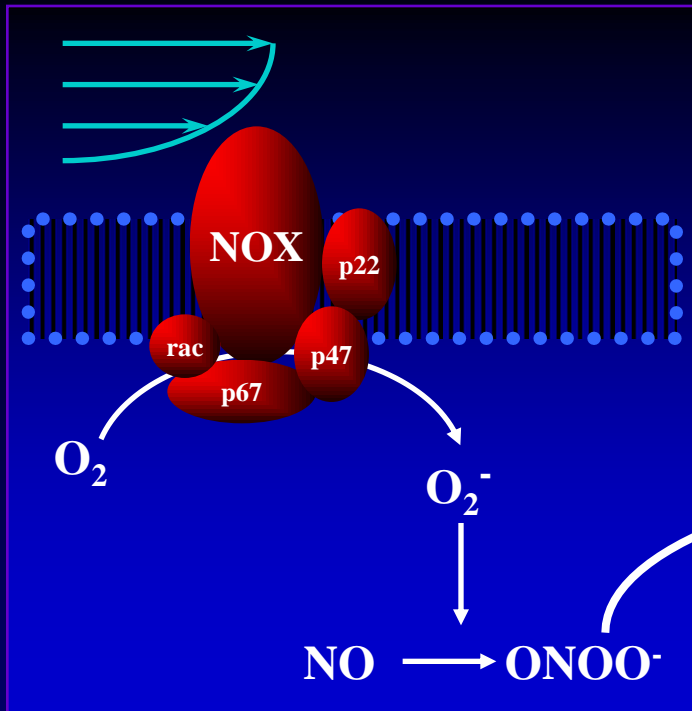
Castier et al. *Circ Res* 2005

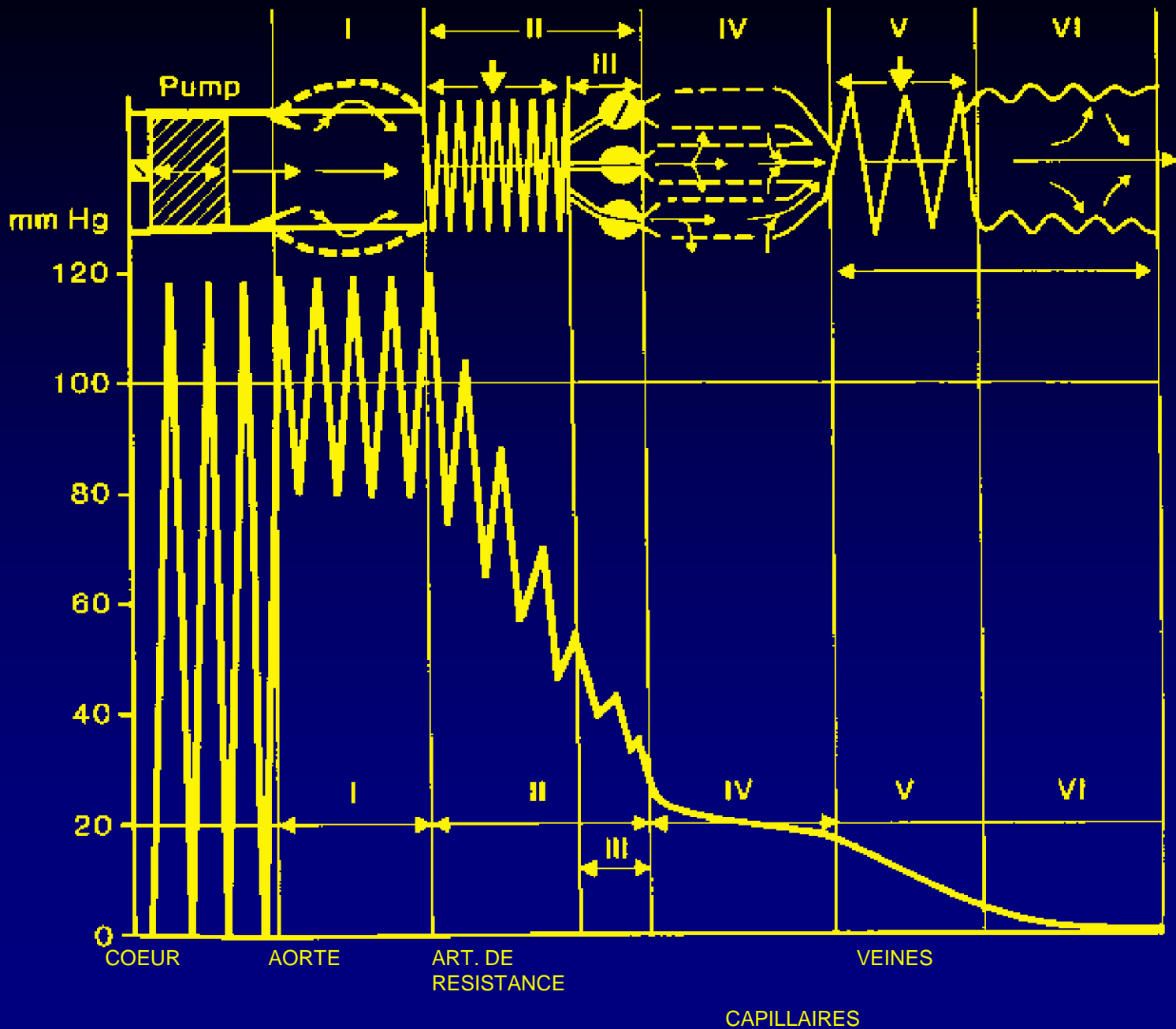
High shear stress induces ROS production in arteries of wild-type but not p47^{-/-} mice



Role of ROS in vascular adaptation to blood flow

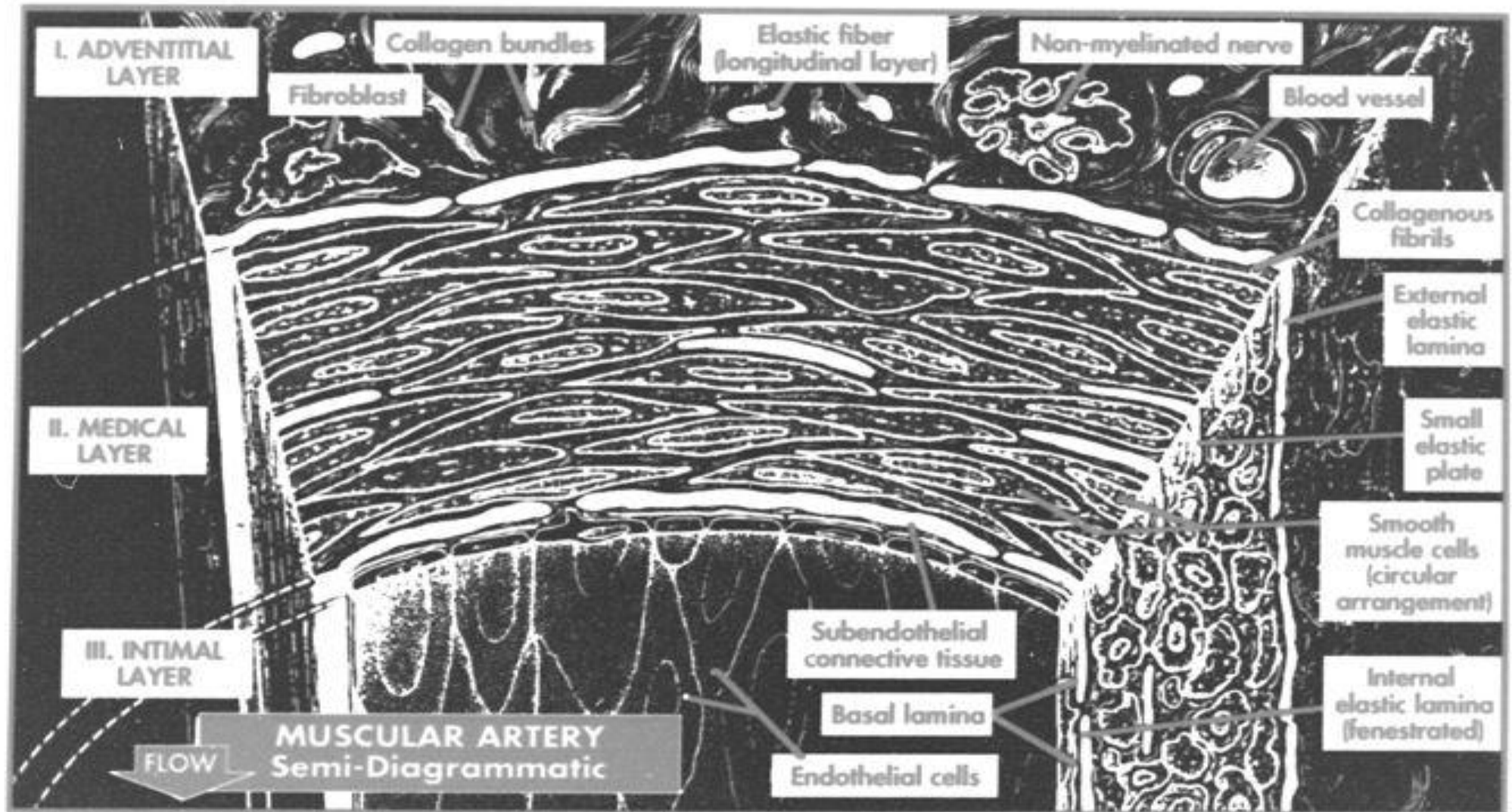


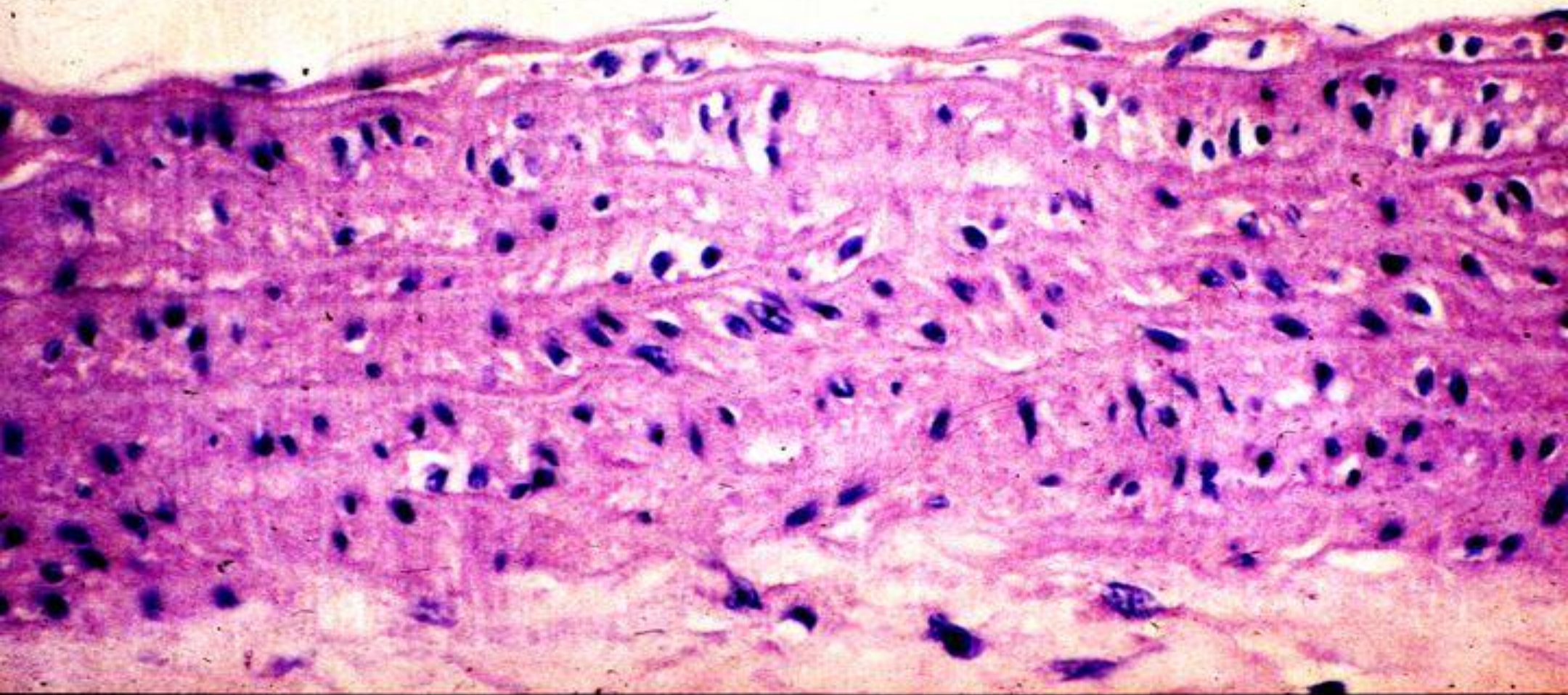




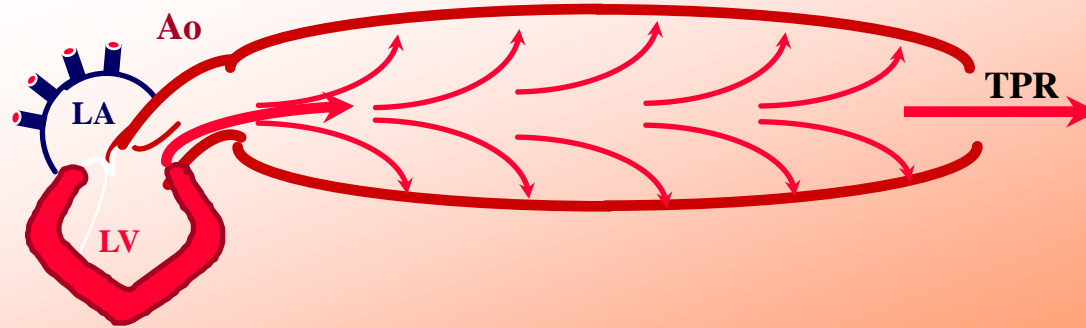
Système à Haute Pression

MUSCULAR ARTERY SEMI-DIAGRAMMATIC

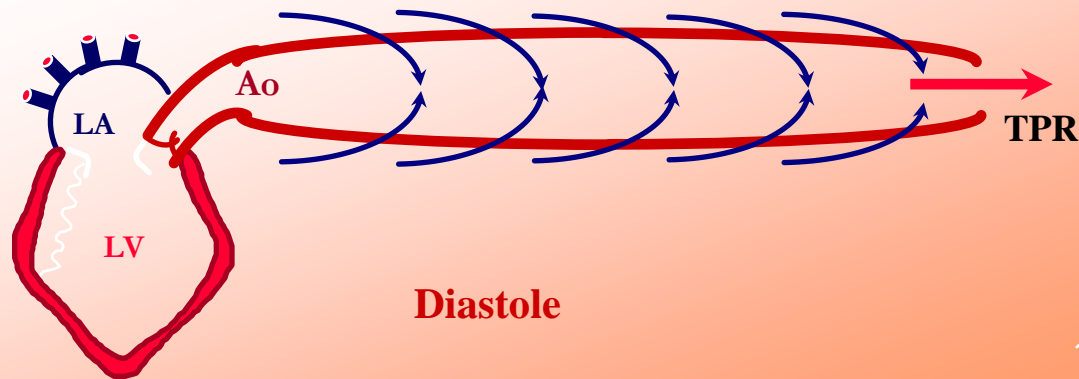




Damping of pressure and flow



Systole

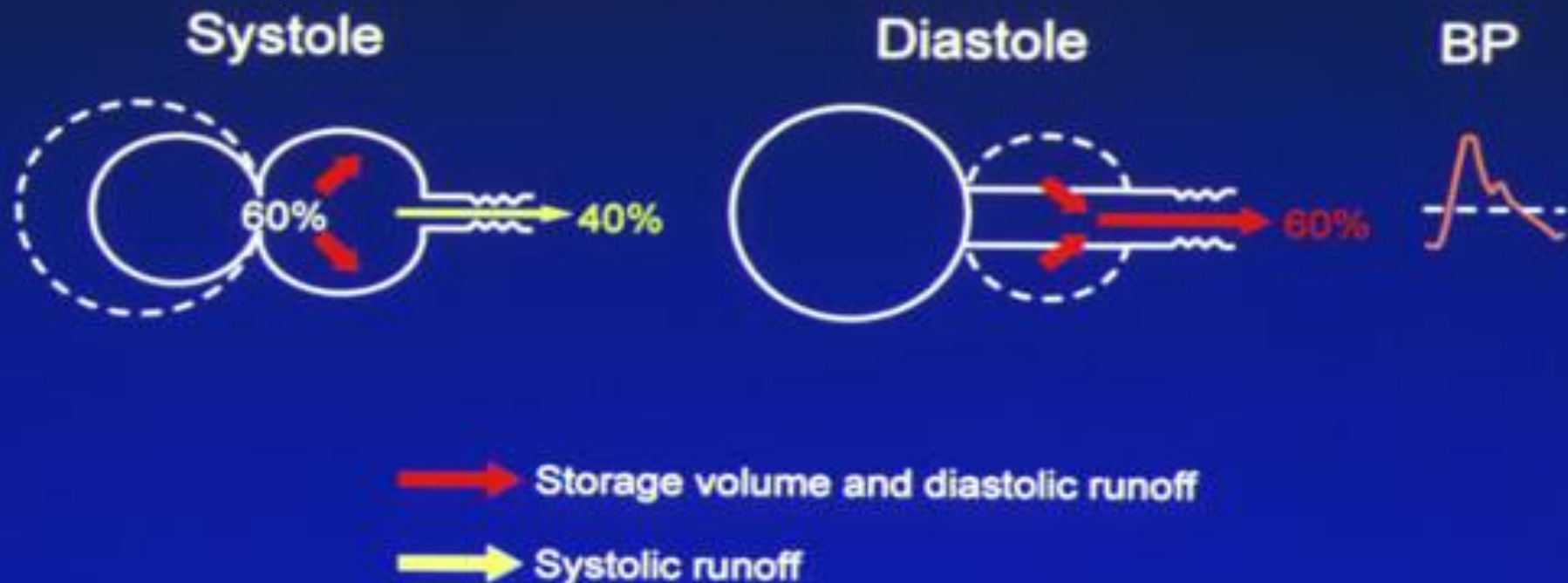


Diastole

F&B

ARTERIES AS CUSHIONS

Normal conditions



Large arteries in hypertension:

Remodeling

Hypertrophy

Fibrosis

Stiffening

ARTERIES AS CUSHIONS

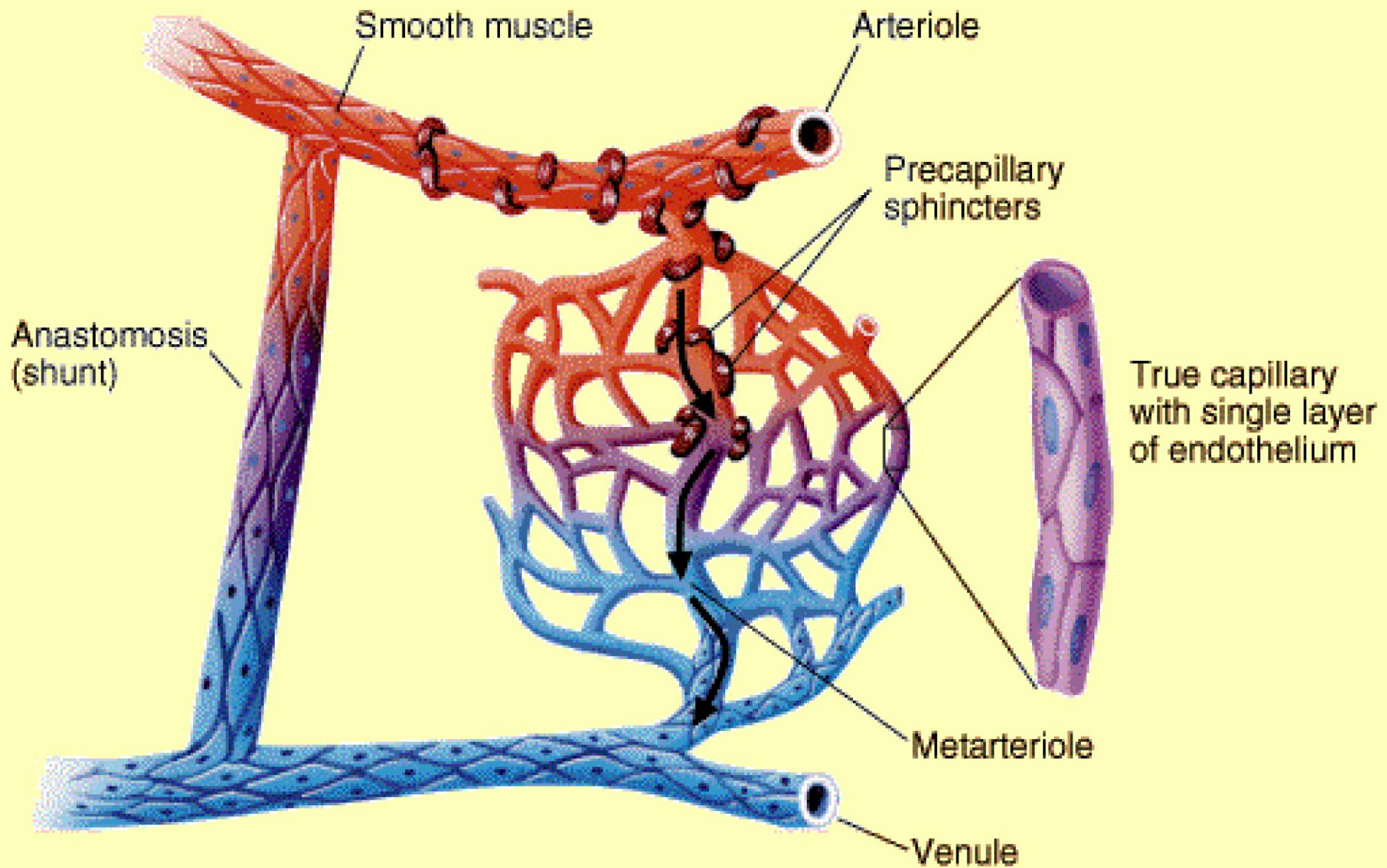
Increased TPR



Decreased distensibility

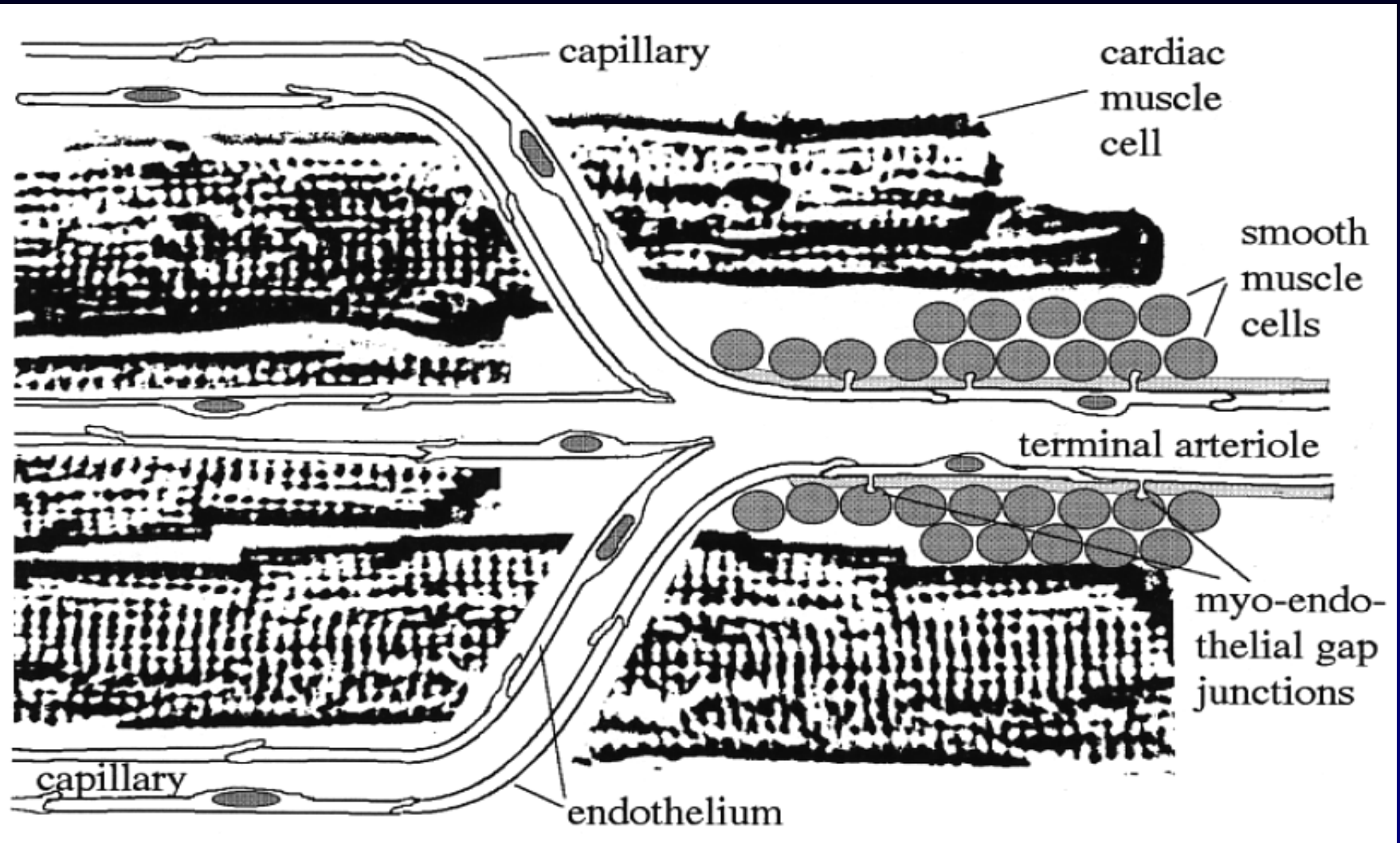


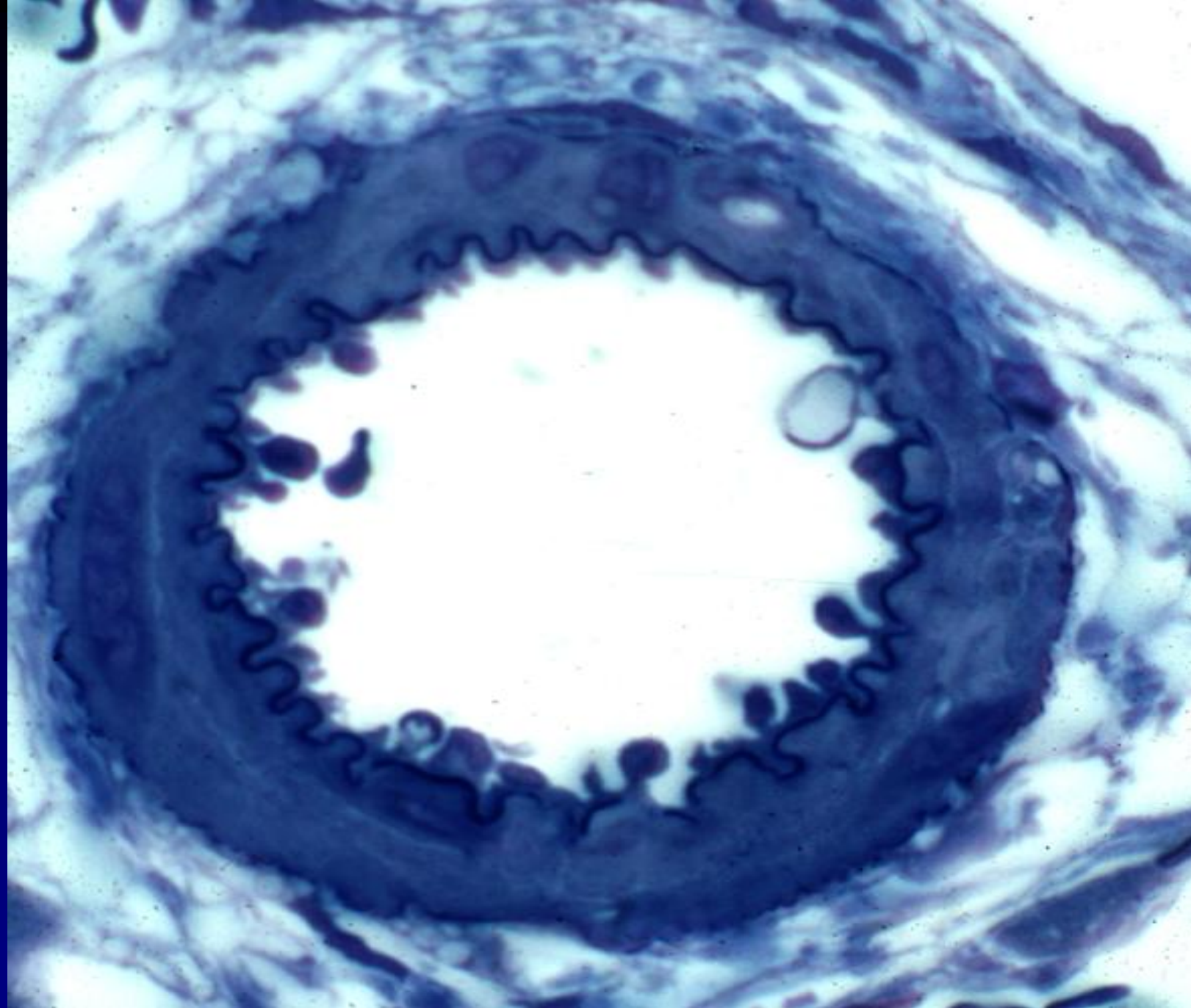
→ Systolic runoff → Storage volume and diastolic runoff



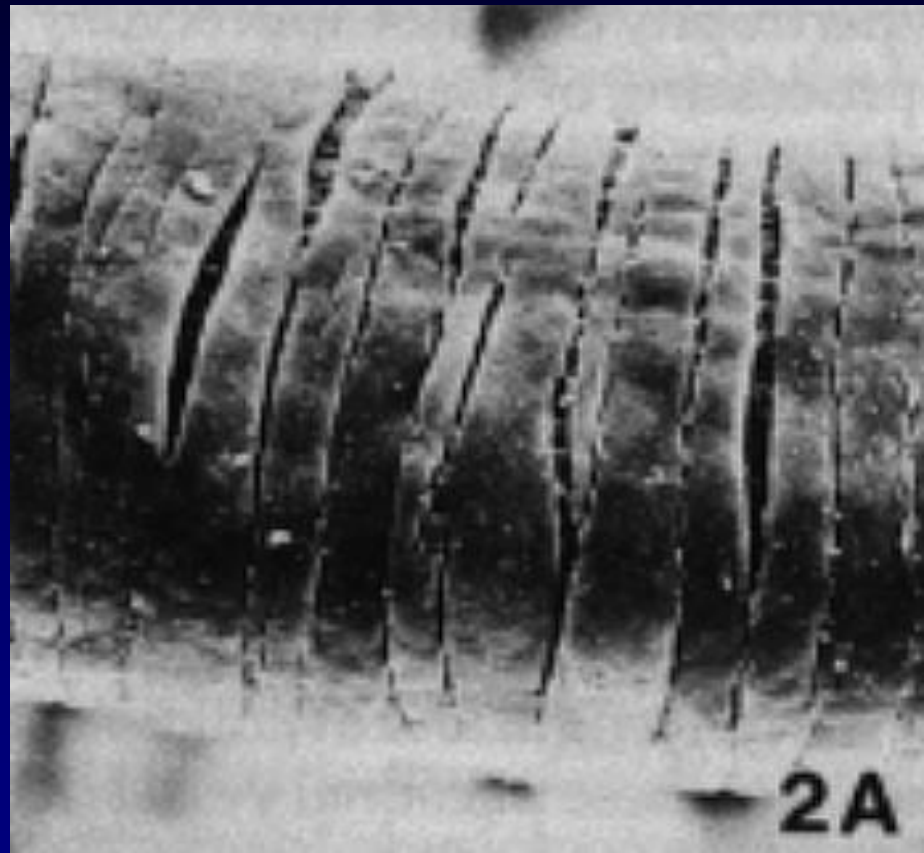
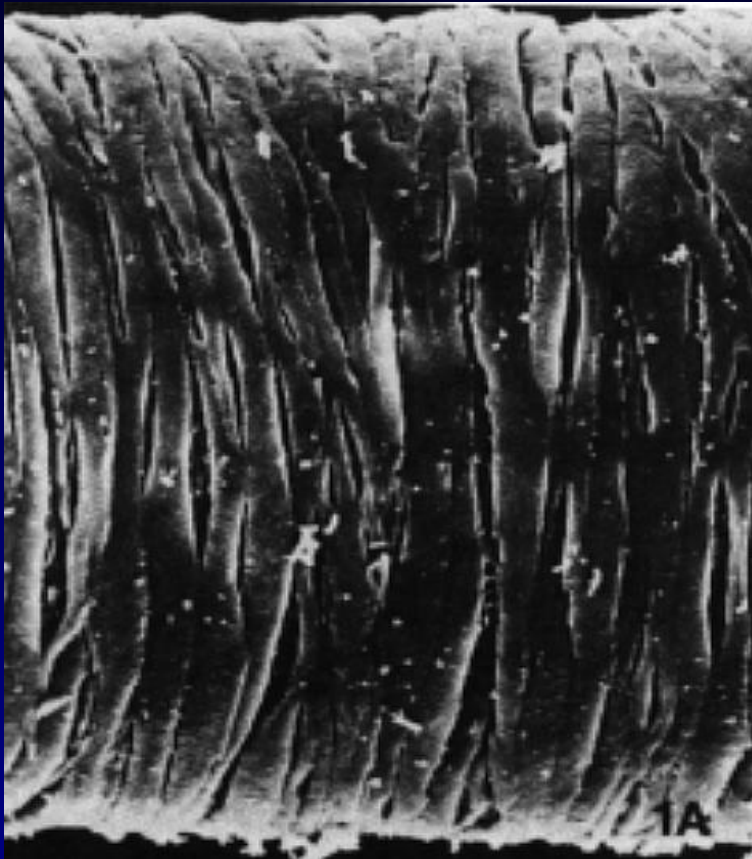
Resistance arteries:

- Arteries with significant MT and then Resistance (Diameter $< 300 \mu\text{m}$):
Intraluminal pressure $<$ Aortic pressure
- The most important in quantity

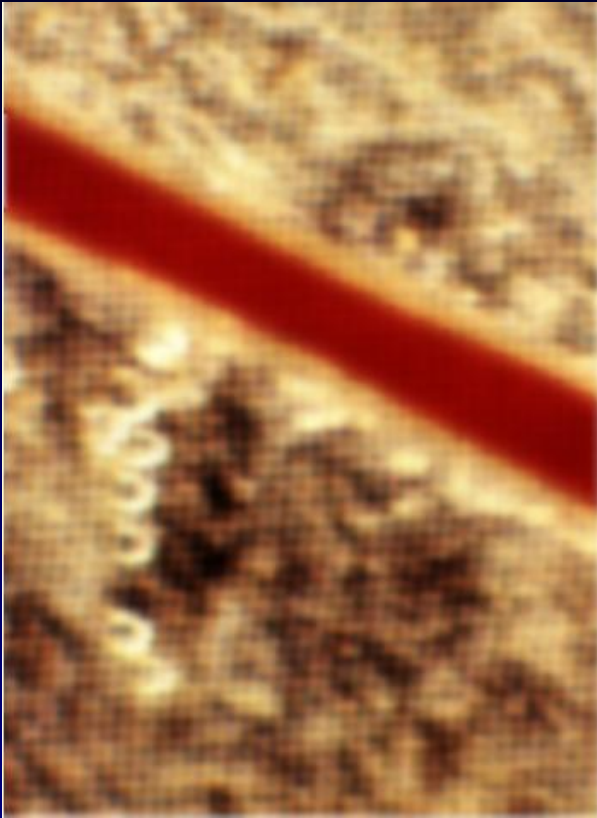




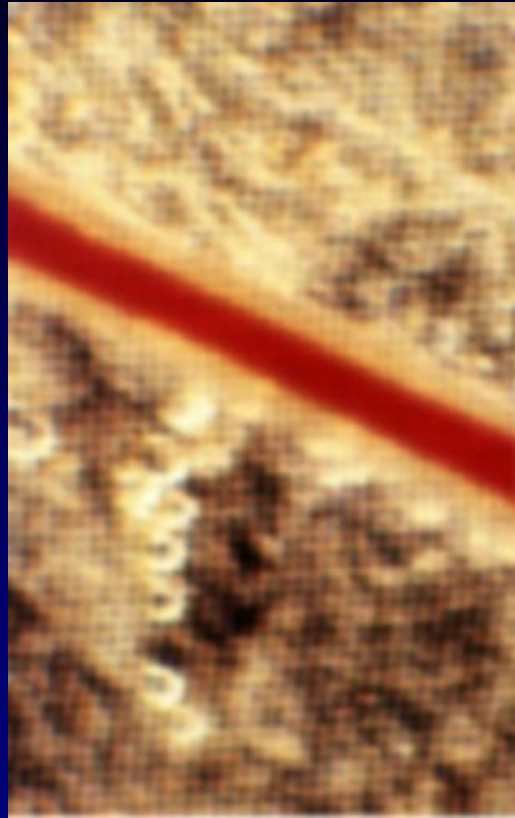
Organization of Smooth Muscle Cells: vasomotor tone



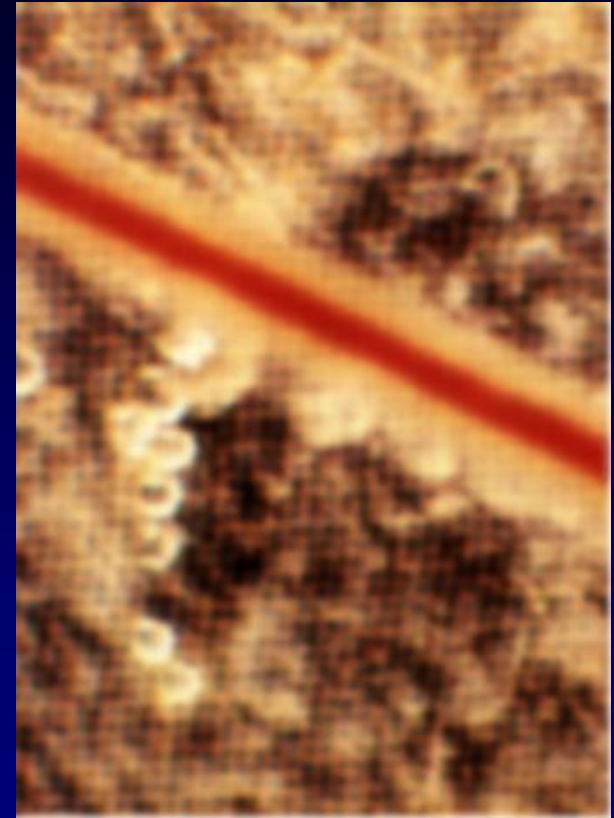
3rd and 4th arteriole generation



CONTROL



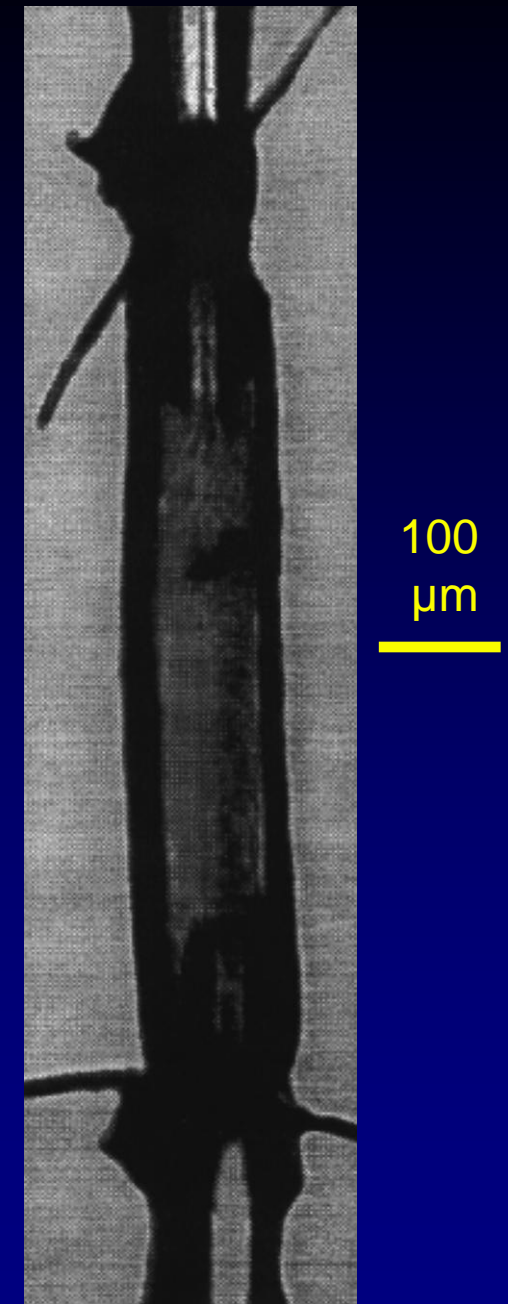
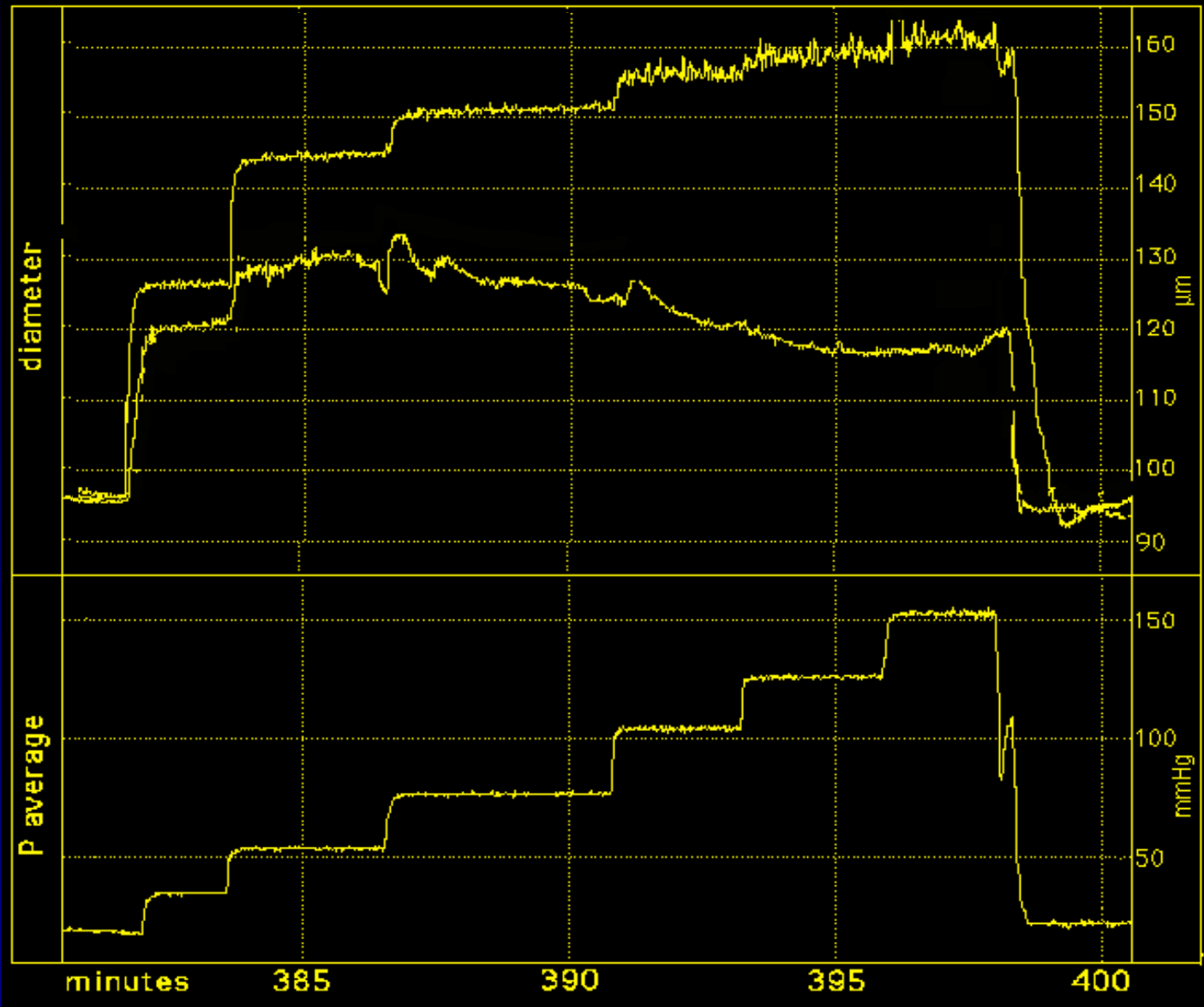
INTRALUMINAL



EXTRALUMINAL

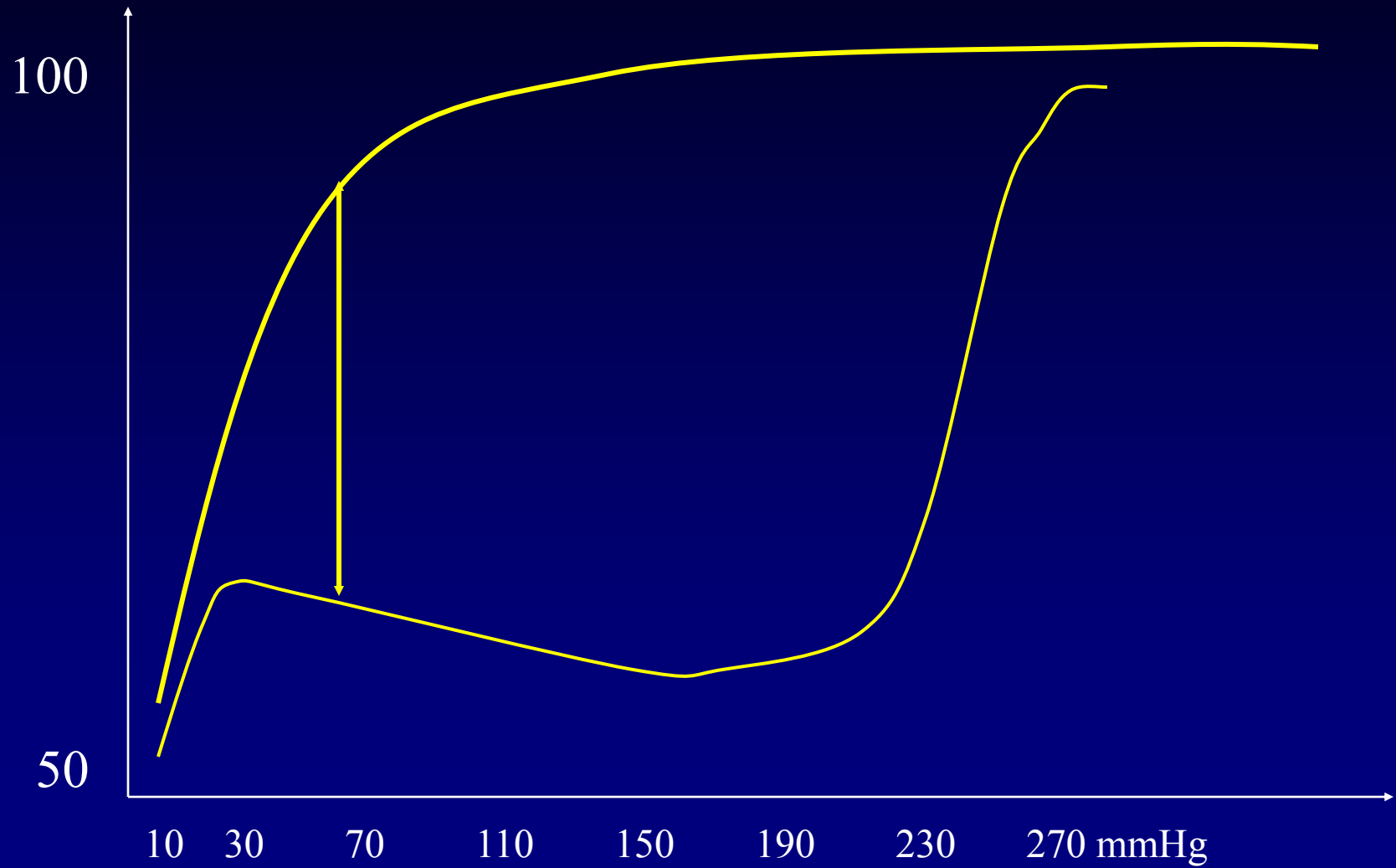


ANGIOTENSINE II



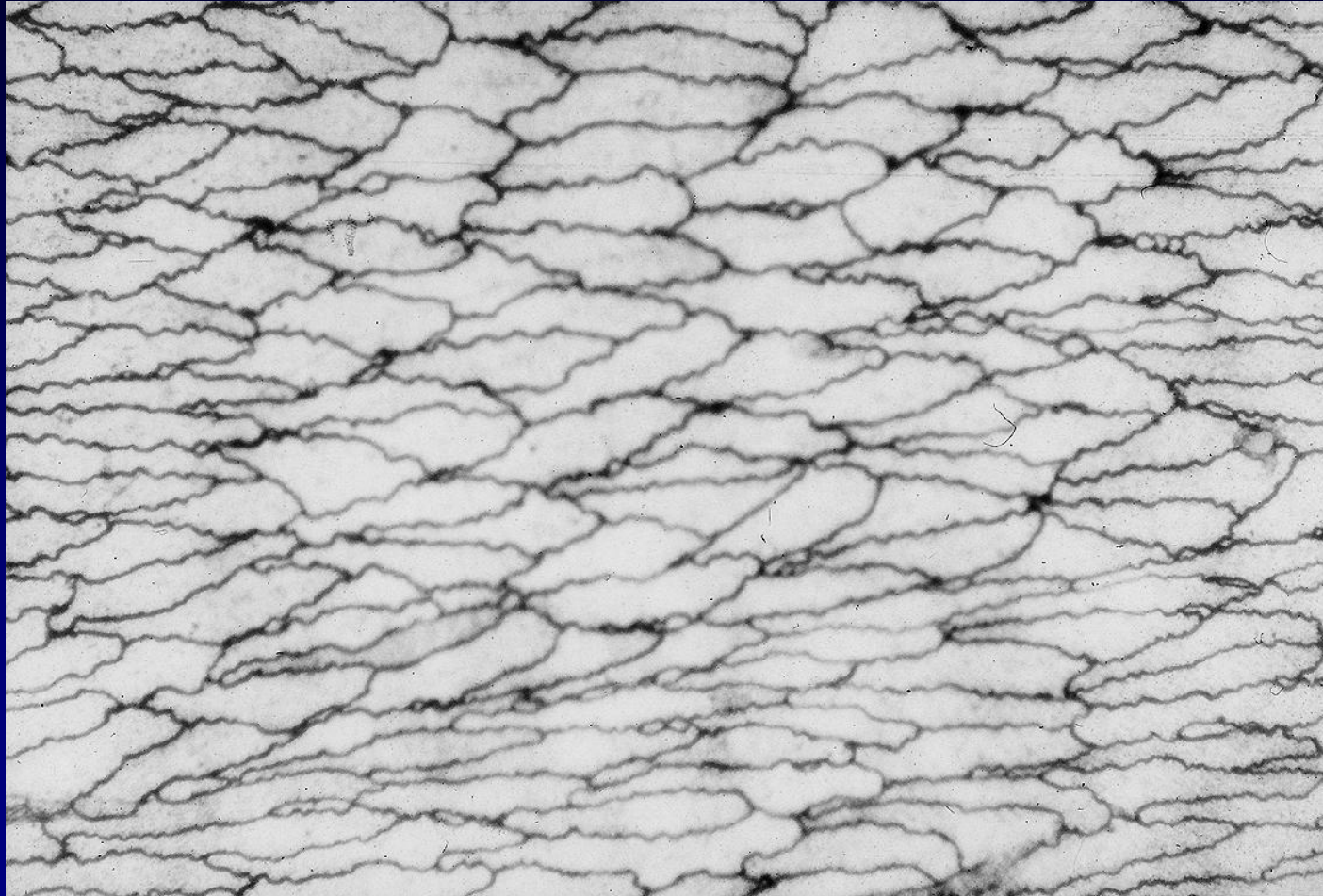
Henrion D et al. J Clin Invest. 1997; 100: 2909-2914.

Percentage of passive diameter at 100 mmHg



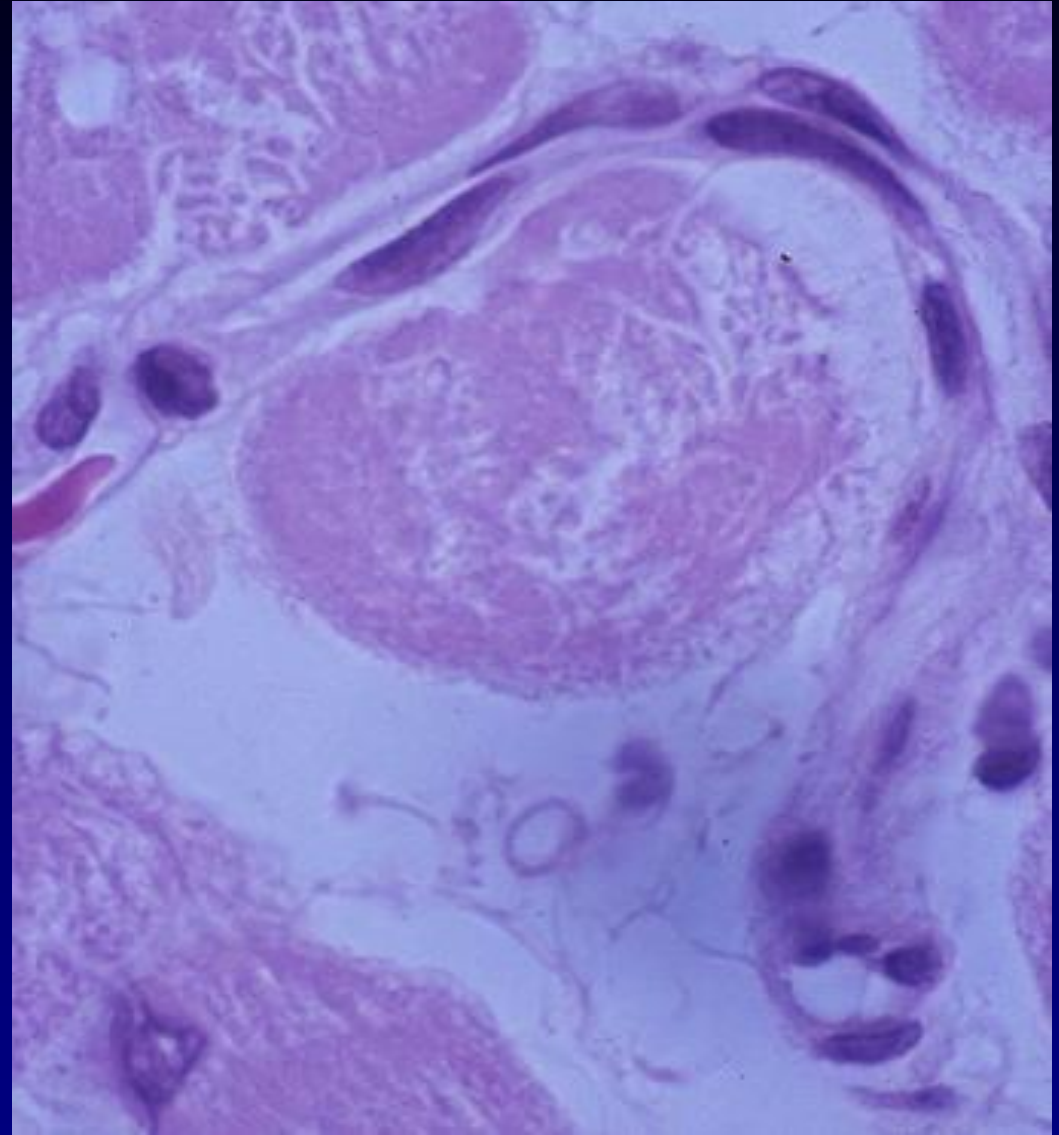
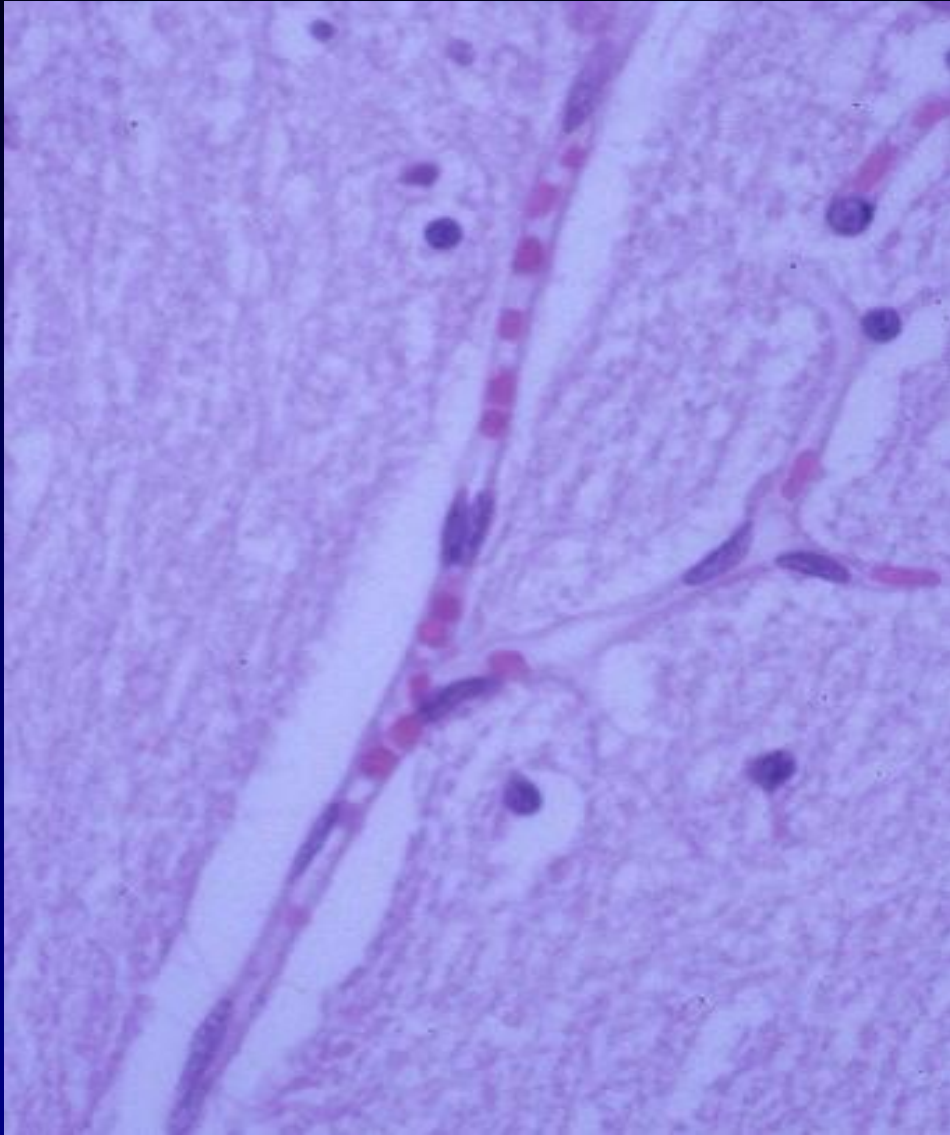
Endothélium et filtration endothéliale

In vivo Shear Oriented Endothelial Cells

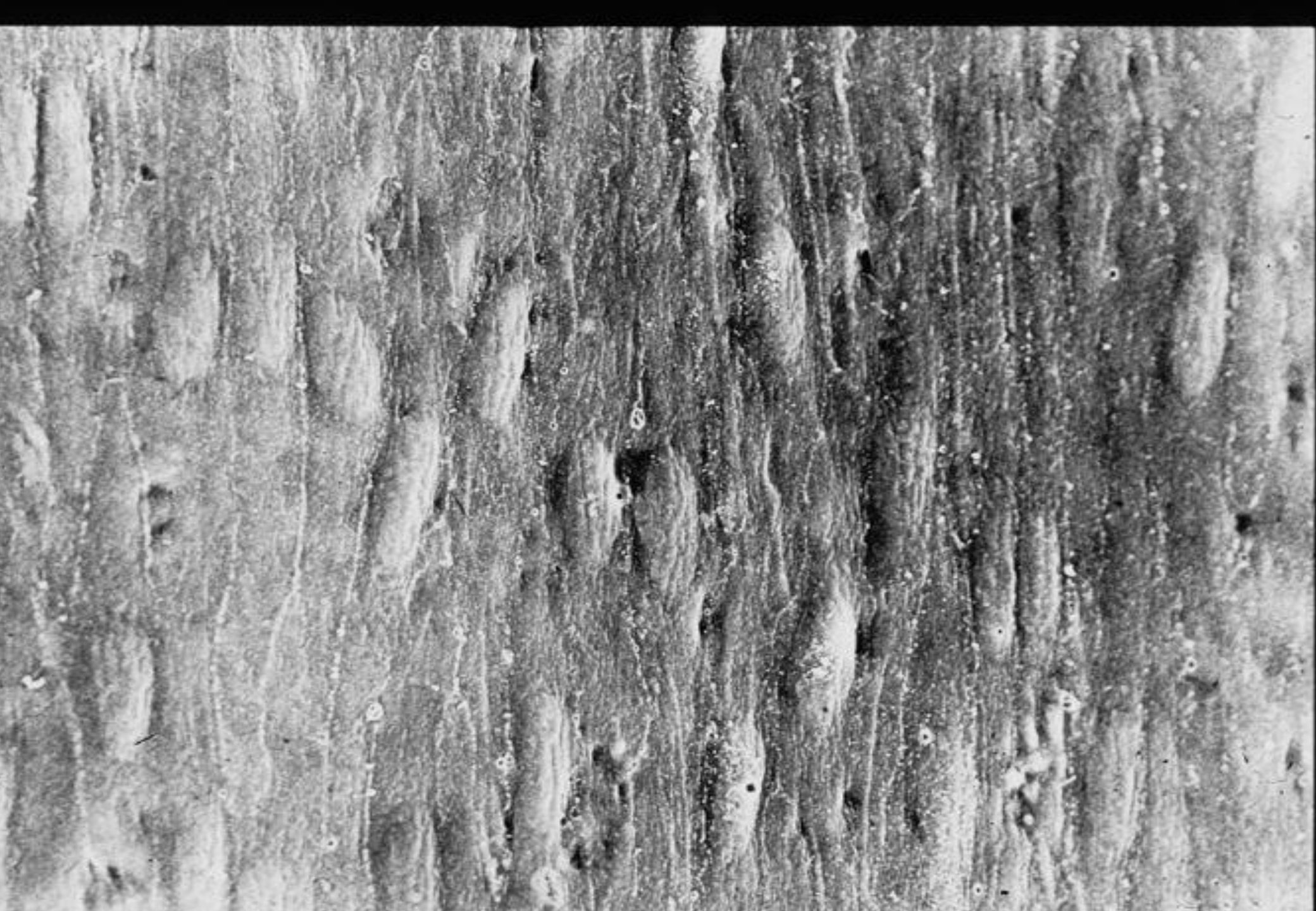




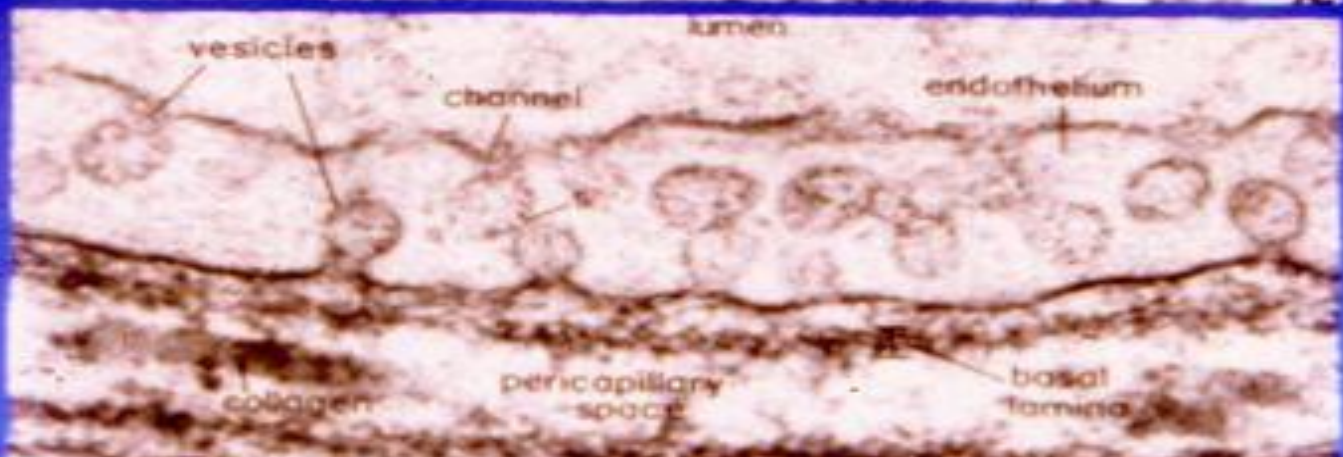
thin ($<1\mu\text{m}$) and fragile capillary wall

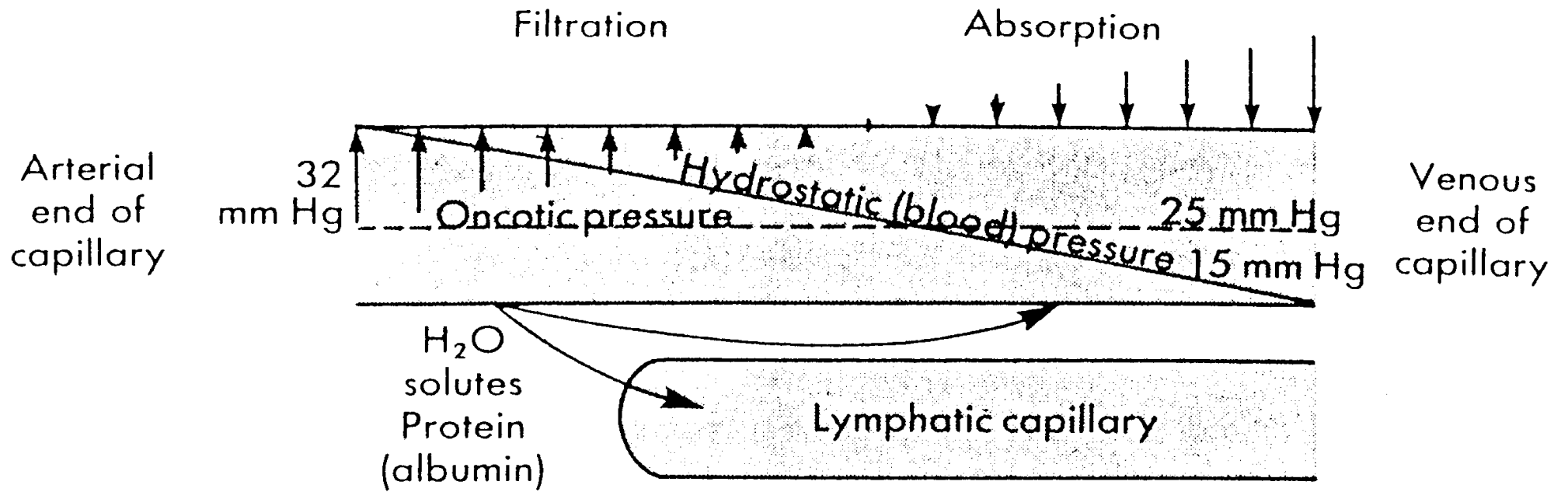


P. Bruneval



Trois types d'endothélium vasculaire





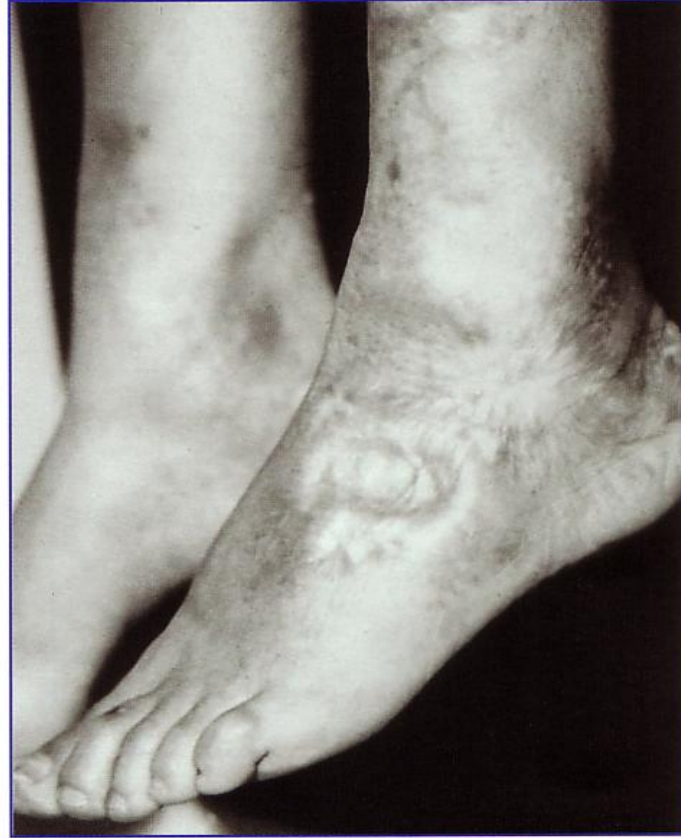
Tissue pressure = ca 0

Figure 19. Stade I du lymphœdème. La pression du doigt provoque le signe du godet.

A



B





Œdème des membres inférieurs lors du stade précoce d'une insuffisance veineuse chronique (IVC).



Photo: Dr P. Blanchemaison

Œdème lors des stades tardifs de l'IVC, avec participation du système lymphatique.



Œdème et télangiectasies, lors des stades tardifs de l'IVC.



Photo: Dr P. Blanchemaison

Œdème et varices lors d'une IVC sévère.



Figure 28. Éléphantiasis lymphostatique avec aspect verruqueux du tégument.





Figure 29. Lymphœdème primaire congénital avec signe de Stemmer positif : œdème du dos des pieds.



Figure 33. Lymphoedème associé à une obésité, une insuffisance cardiorespiratoire et un syndrome post-thrombotique bilatéral.