Cardiovascular Center Aalst

Regulation of Coronary Blood Flow

… A Glossary for Interventionalists

Bernard De Bruyne
Cardiovascular Center Aalst
Belgium

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ABC of Coronary Physiology for the Interventionalist

1. General concepts
2. Epicardial vs microvascular compartments
3. Flow-function relationship
4. Coronary autoregulation

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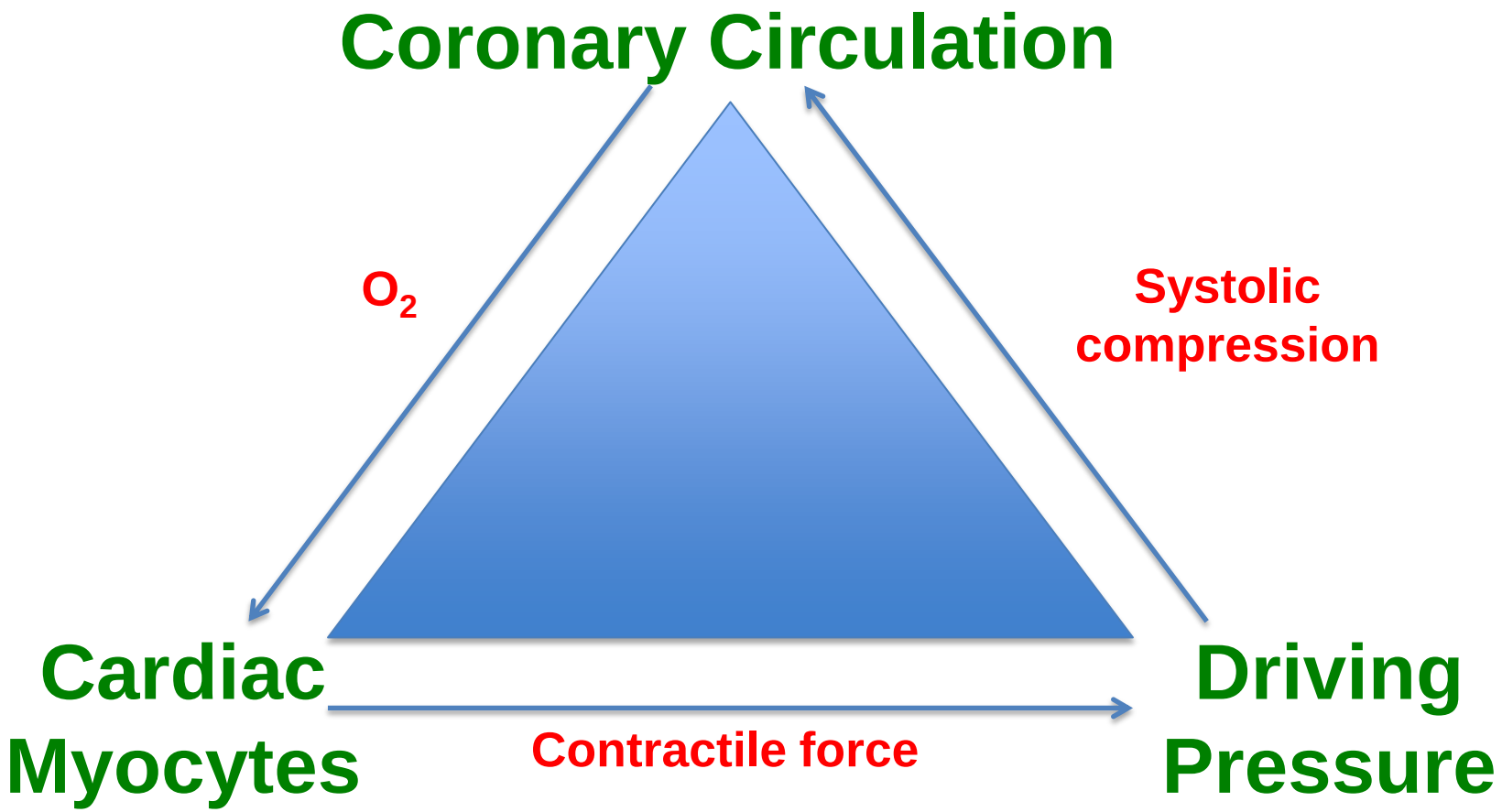
Uniqueness of the Coronary Circulation



No other circulation is so dependent on the function of the organ it perfuses

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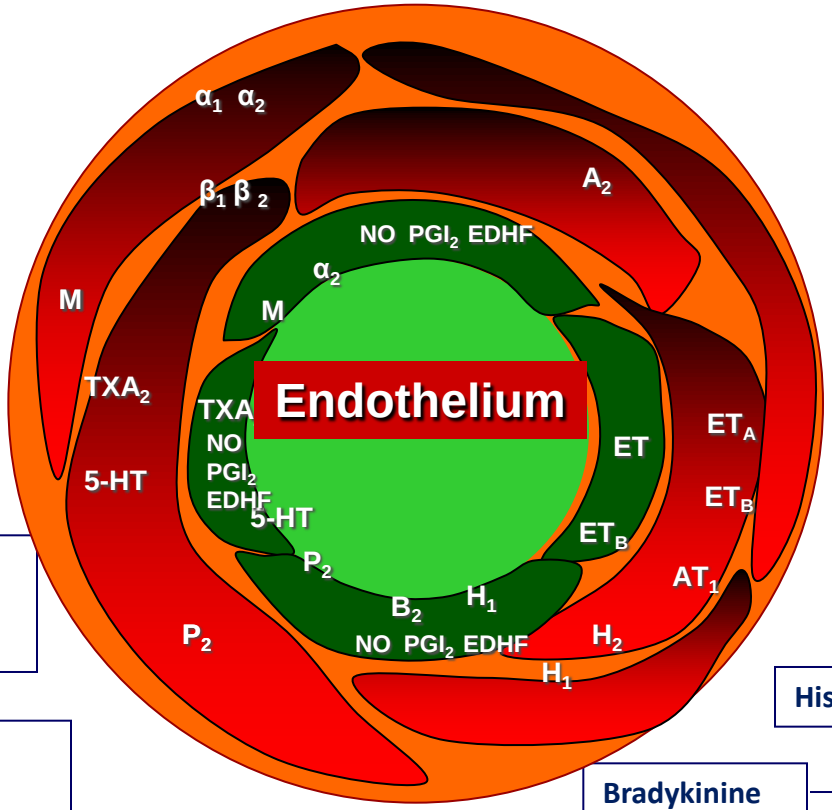
The Control of Myocardial Blood Flow



Neuro-humoral factors

- Noradrenaline
  Adrenaline
- Acethylcholine

Metabolic factors

- adenosine
- PO_2
- PCO_2, H^+, K^+

Physical factors

- Arterial Pressure
  Coronary pressure
  RAP, LVDP and $P_{f=0}$
- Systolic compression
  Diastolic compression

Endo- and paracrine factors

- Angiotensine II
- Histamine
- Bradykinine

Adapted from D.J.G.M. Duncker and Bache R Physiol Rev 2008

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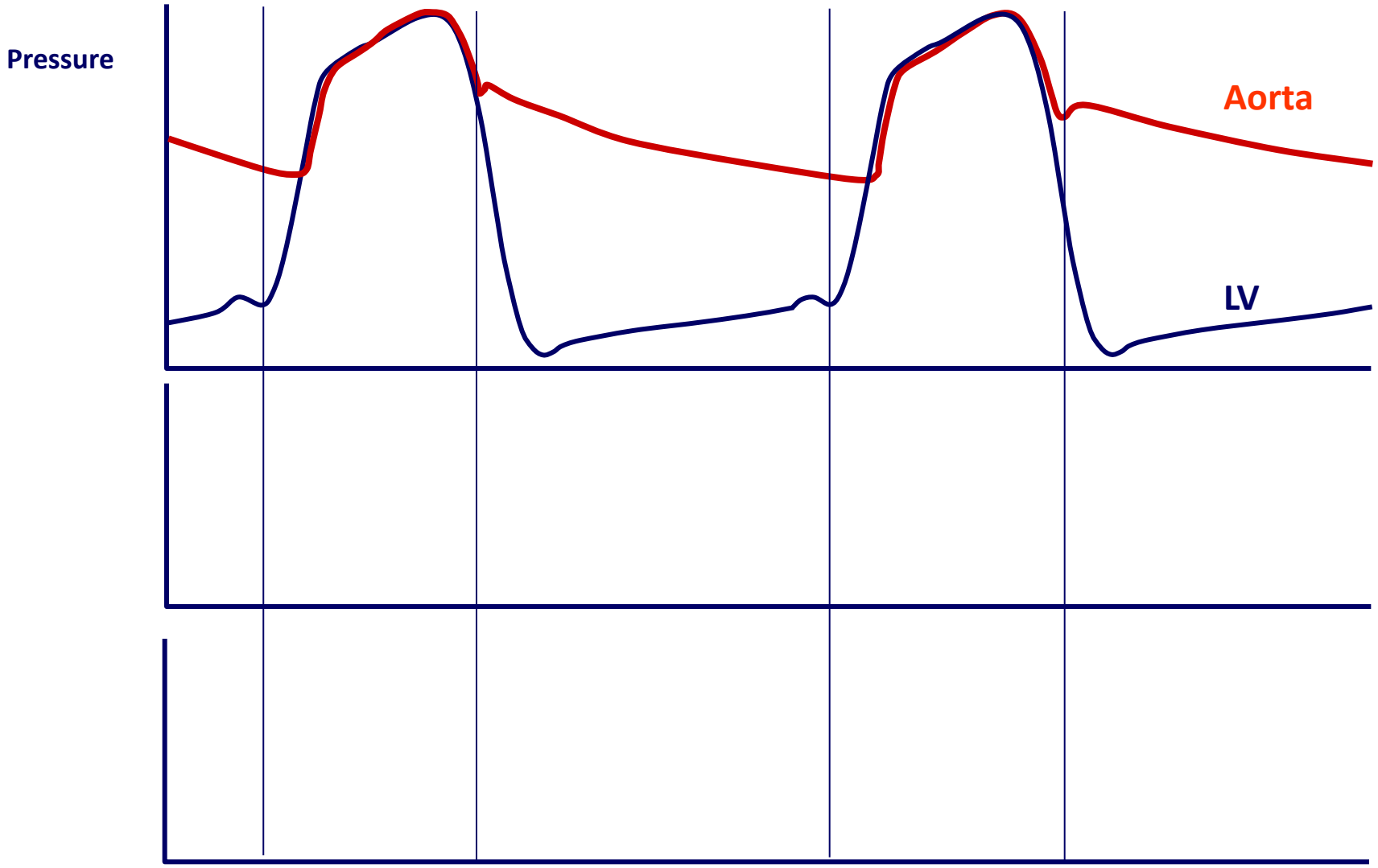
Extravascular Compressive Forces



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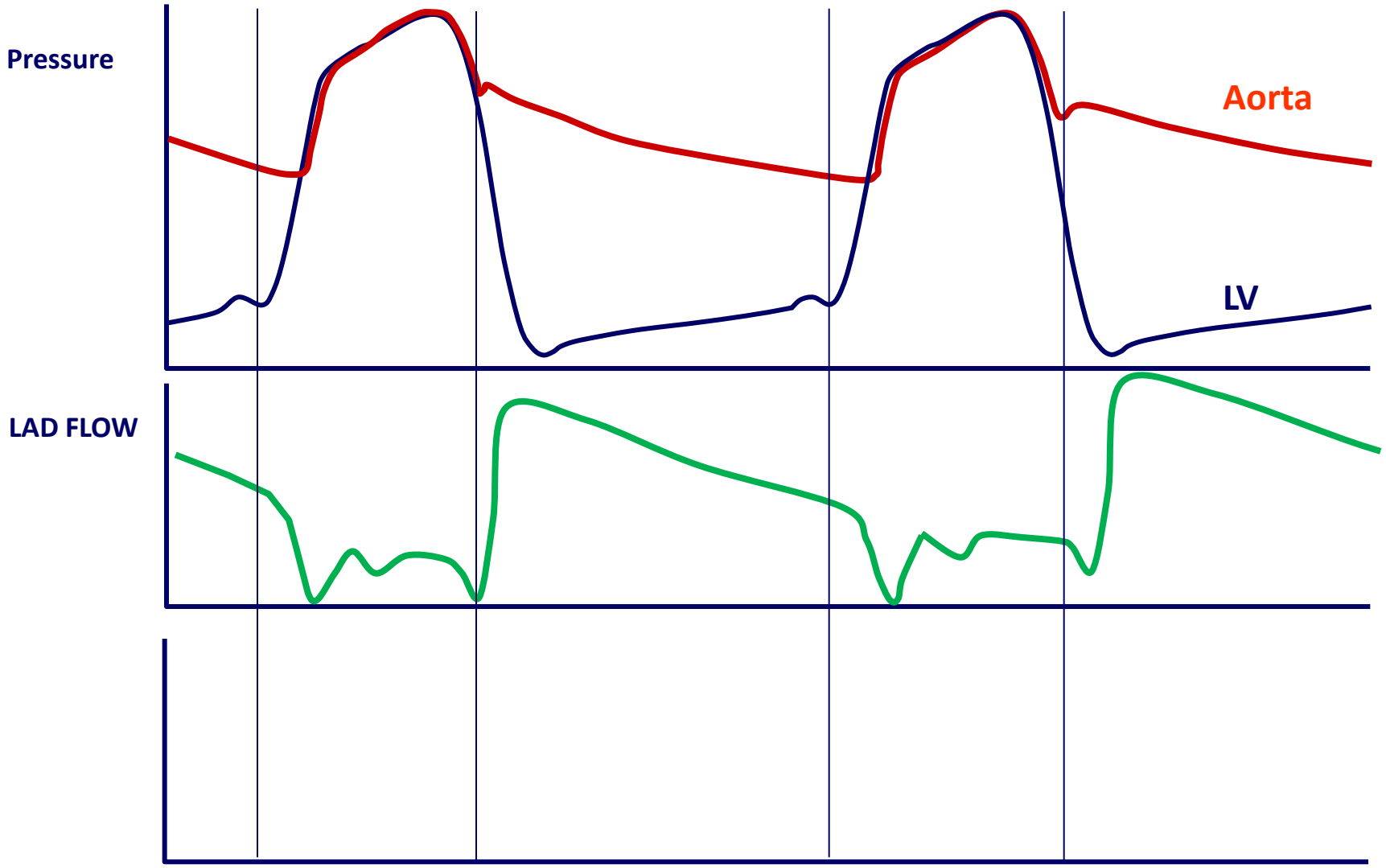

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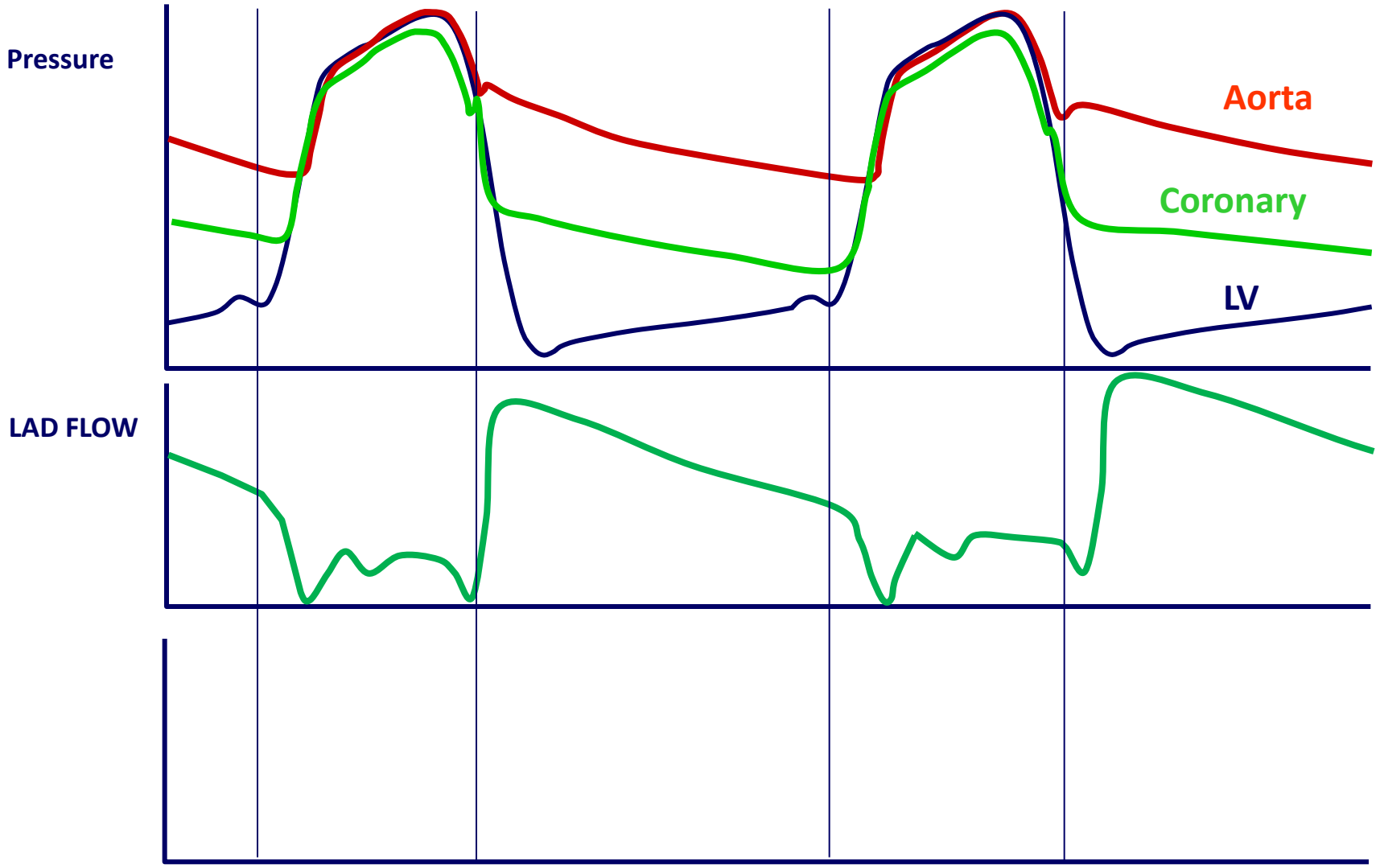

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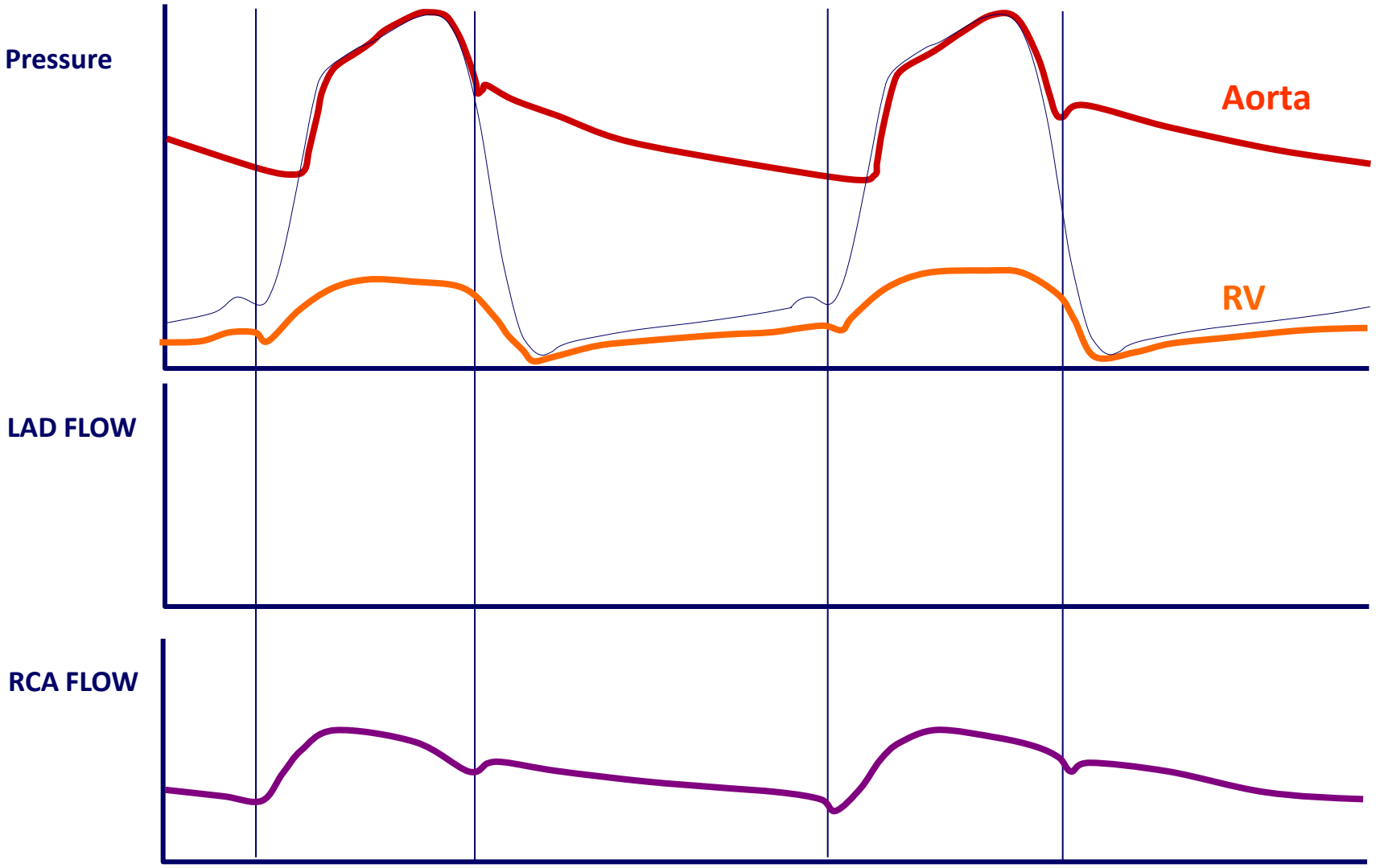
Extravascular Compressive Forces



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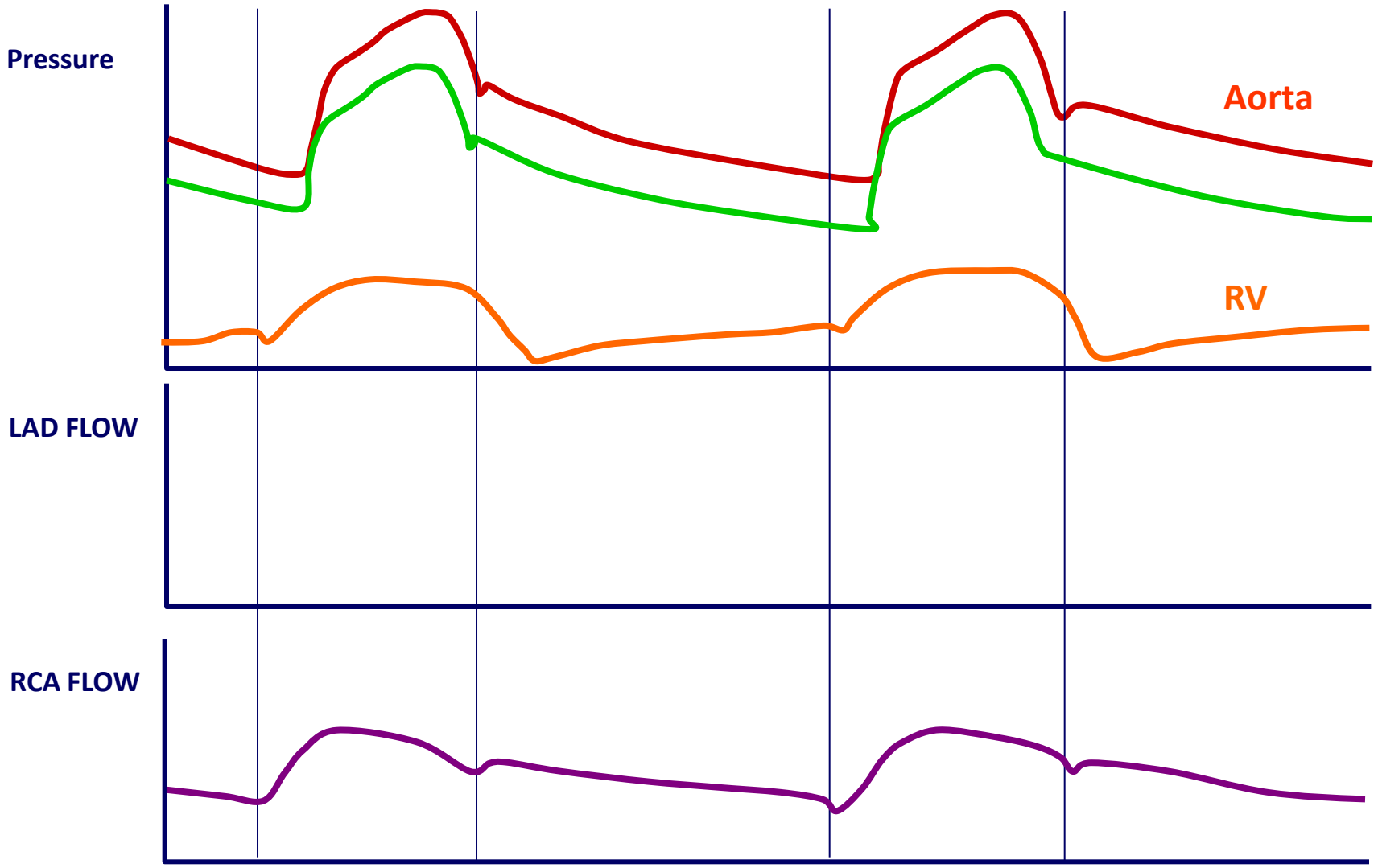
Extravascular Compressive Forces



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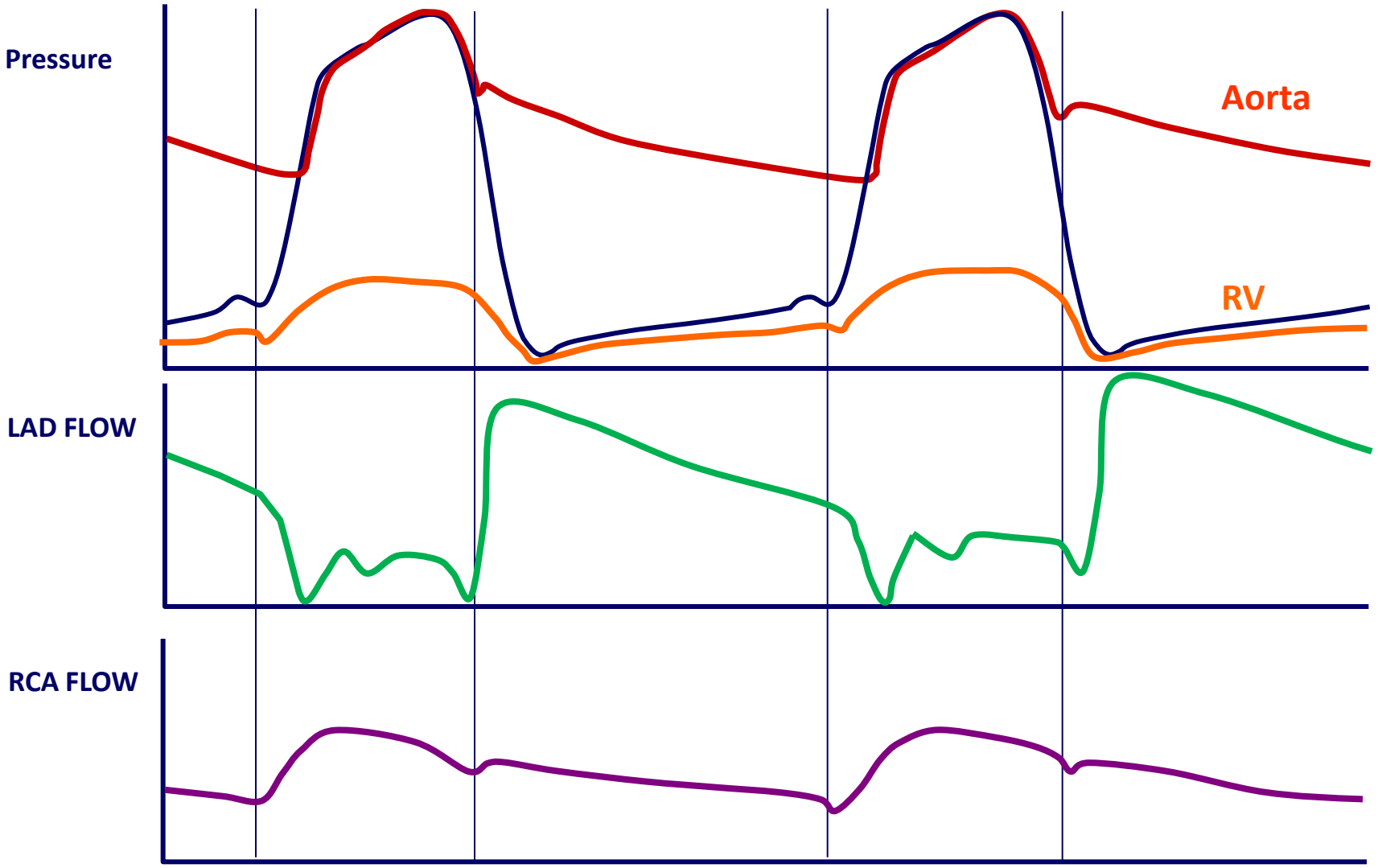
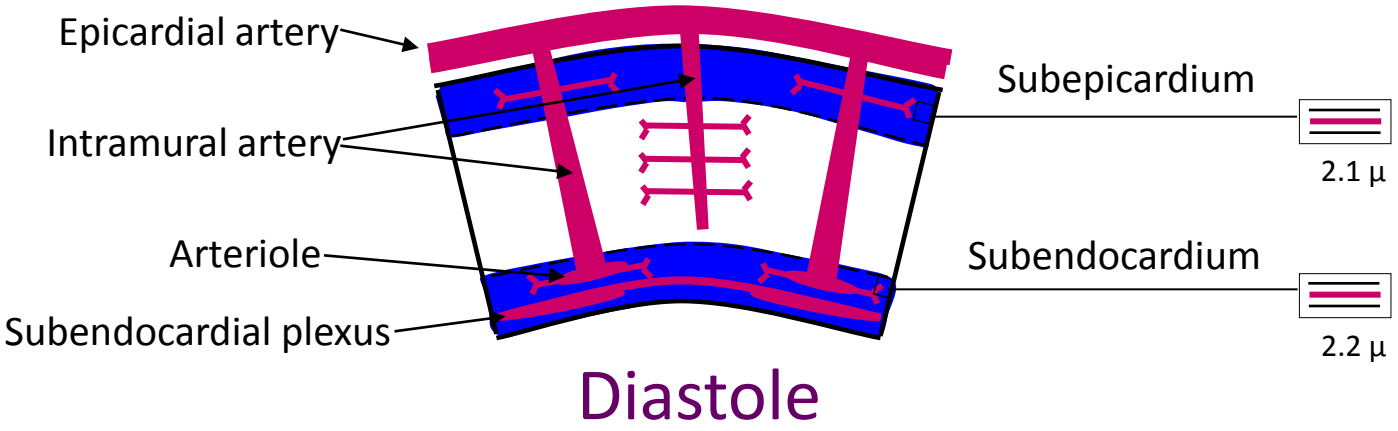
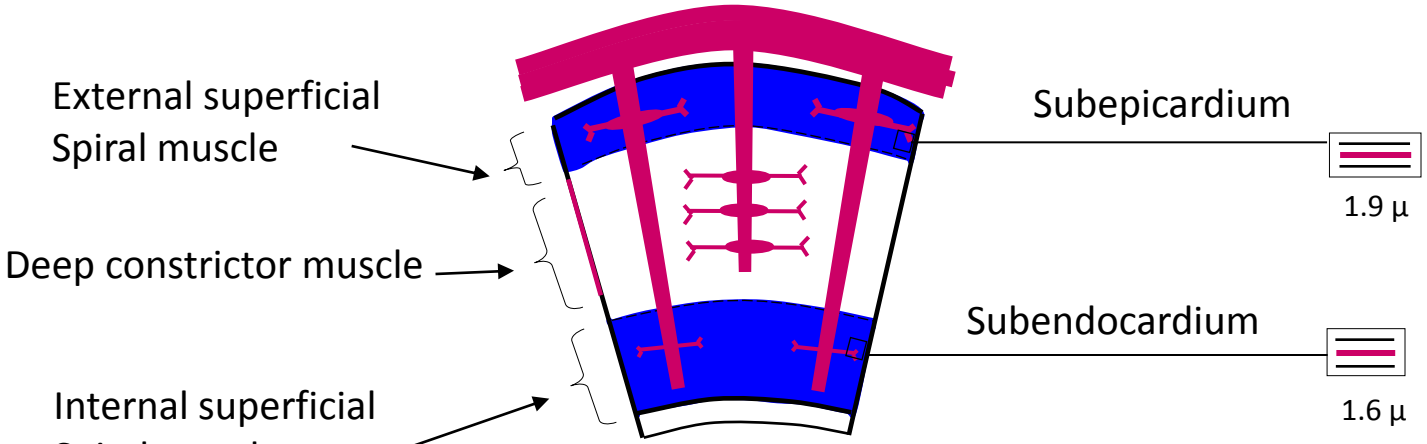
Extravascular Compressive Forces



Systolic Compression



Diastole



Systole

Endo/Epi flow : 1.2

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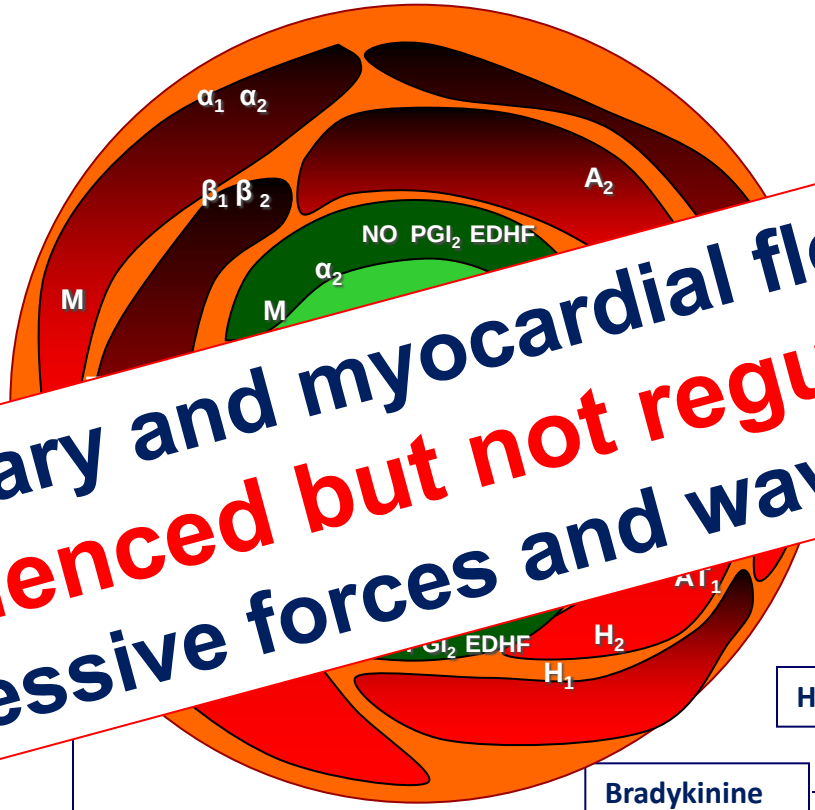
The Control of Myocardial Blood Flow

Neuro-humoral factors

- Noradrenaline
  Adrenaline
- Acethylcholine

Metabolic factors



Coronary and myocardial flow are influenced but not regulated by compressive forces and wave mechanics

Physical factors

- …mpression

Endo- and paracrine factors

- Angiotensine II
- Histamine
- Bradykinine

Adapted from D.J.G.M. Duncker and Bache R Physiol Rev 2008

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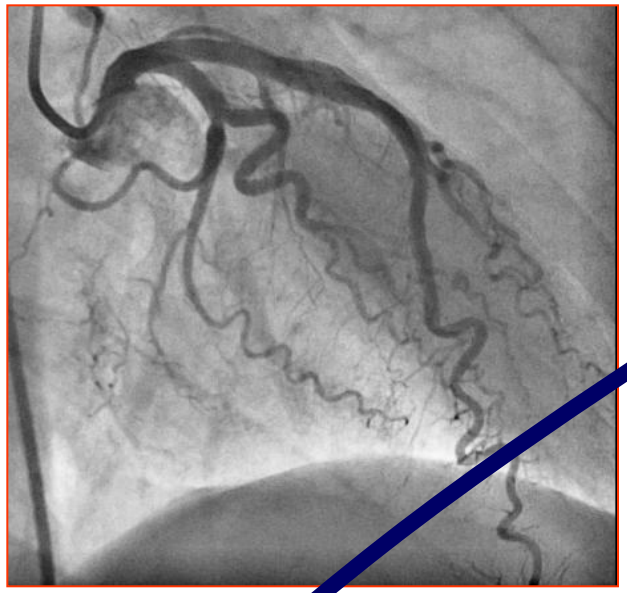
Relation between Vessel Size and Myocardial Mass



C. Seiler et al Circulation 1992

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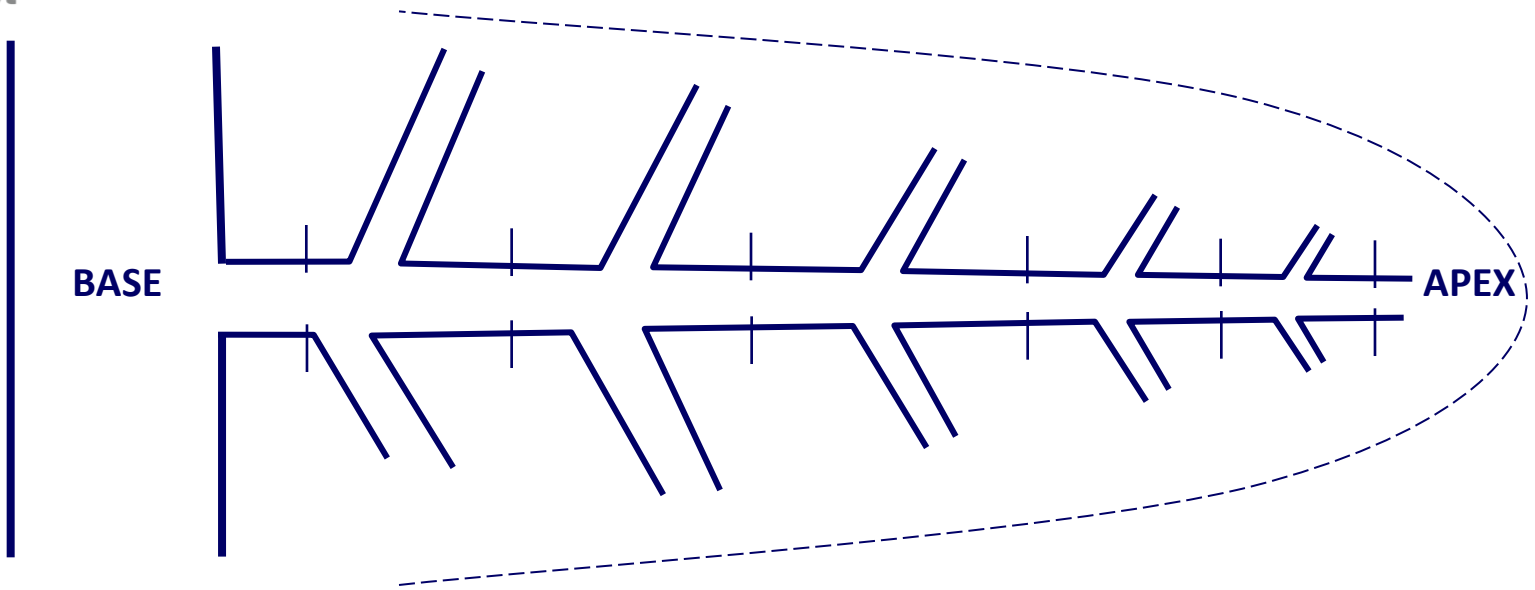
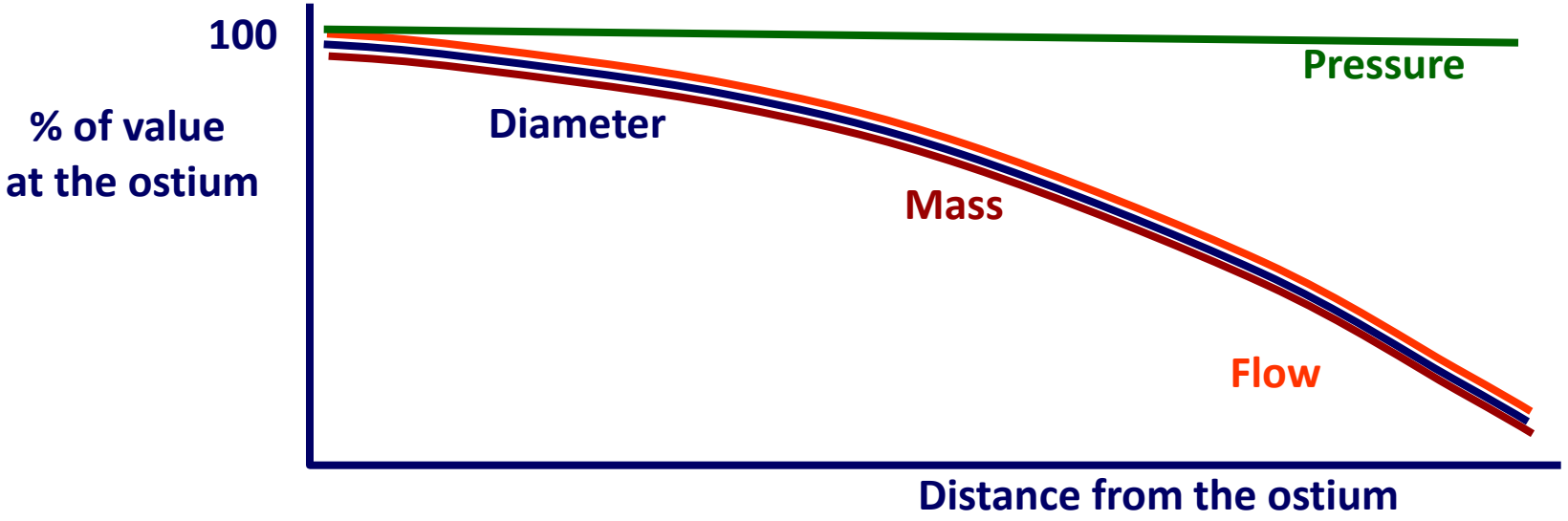
About Pressure, Flow, Resistance, and Vessel Size





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About Pressure, Flow, Resistance, and Vessel Size

	Tree Shrew	Human	Blue Whale
Body Mass [kg]	0.005	70	100,000
Heart Weight [kg] (~M^1)	$3.3x10^{-5}$	0.46	660
Stroke Volume [ml] (~M^1)	0.0033	46	66,000
Heart Rate[s^{-1}] (~$M^{-1/4}$)	11 (>600 bpm)	1	0.16 (<10 bpm)
Cardiac Output [L/min] (~$M^{3/4}$)	0.003	5	1000
Radius of Aorta [cm] (~$M^{3/8}$)	0.02	1	15
Mean Aortic Velocity [cm/sec] (~M^0)	10	10	10
Mean Aortic Pressure [mmHg] (~M^0)	100	100	100
Mean Aortic Reynold's No. (~$M^{3/8}$)	15	530	8080 (turbulent!)
Mean Aortic Shear Stress [dynes/cm^2] (~$M^{-3/8}$)	180	5	0.3

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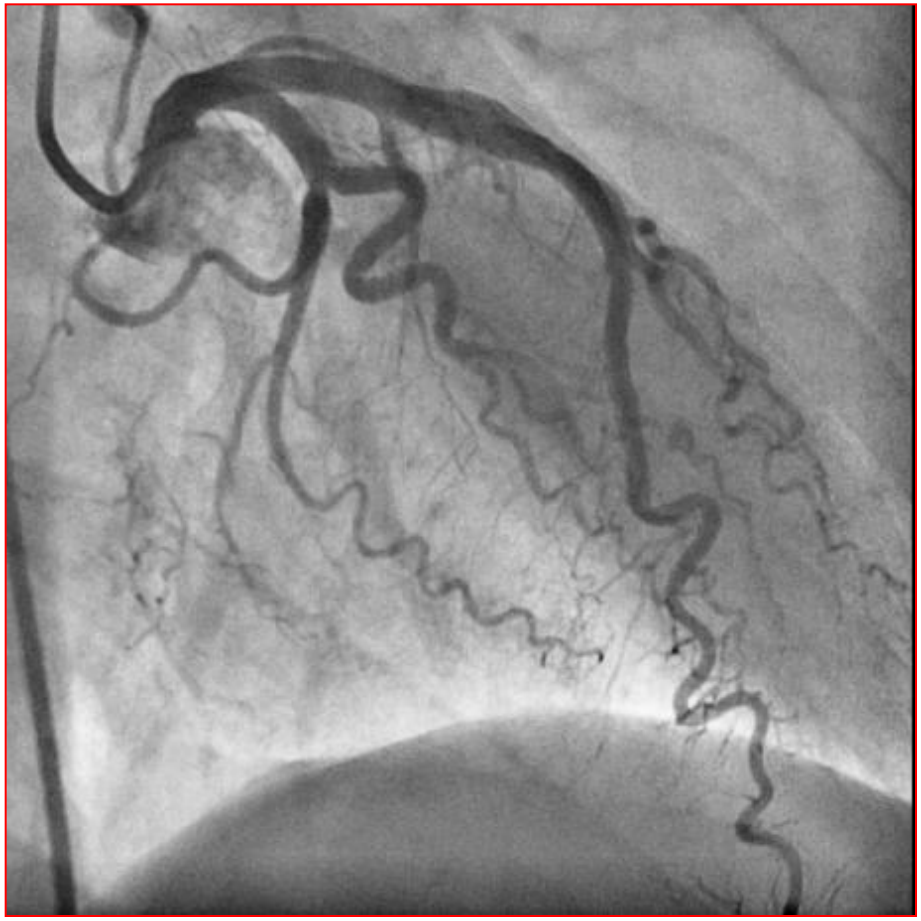
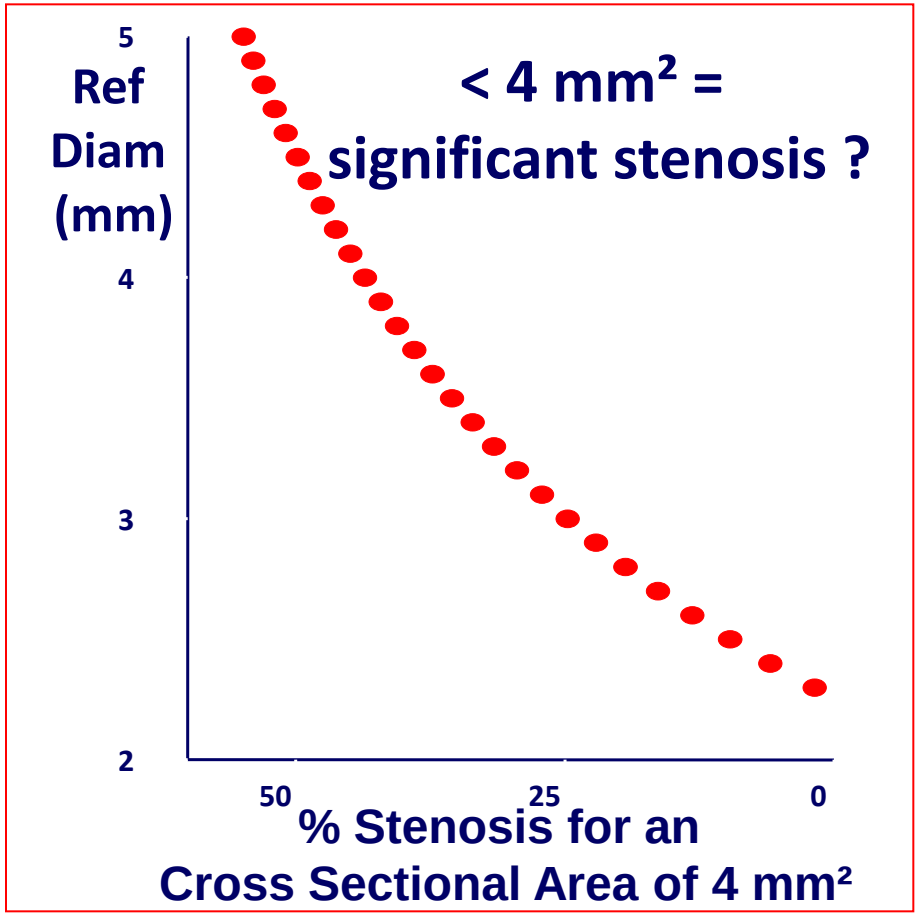
About Pressure, Flow, Resistance, and Vessel Size





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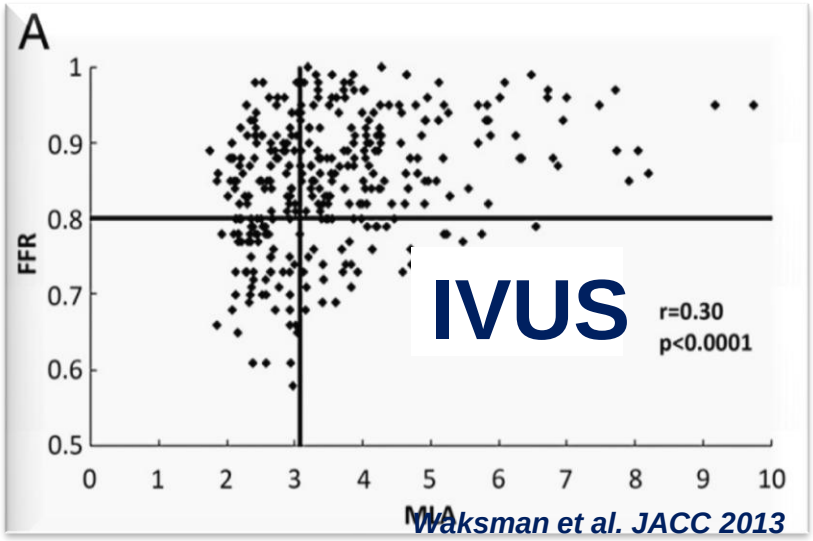
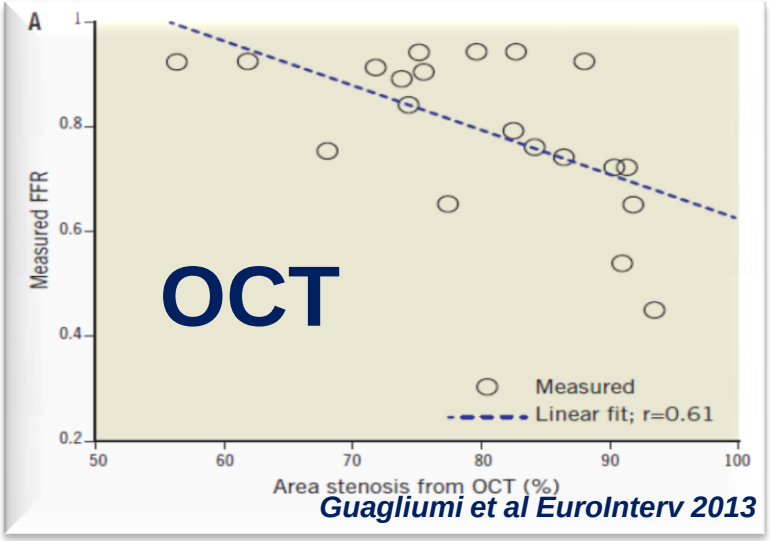
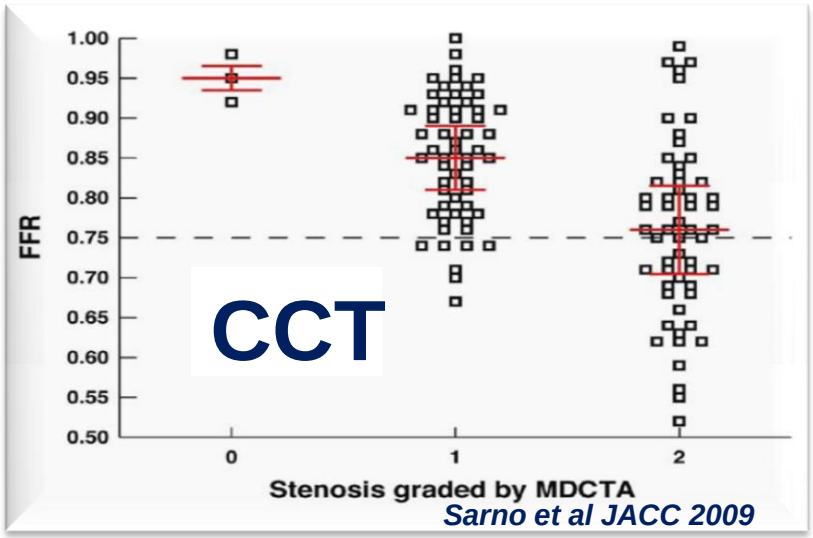
Anatomy vs Physiology: the Chimeric Link



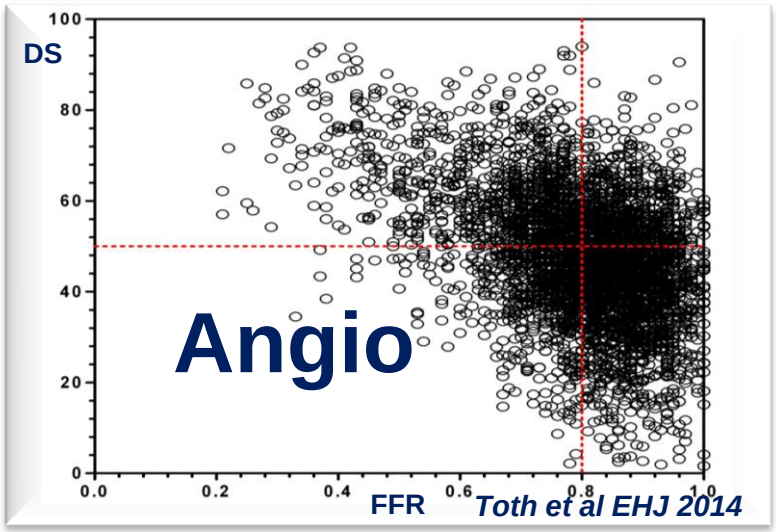
Waksman et al. JACC 2013



Guagliumi et al EuroInterv 2013



Sarno et al JACC 2009



Toth et al EHJ 2014

Statistical (mechanistic) relation but little clinical relation

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ABC of Coronary Physiology
For the Interventionalist

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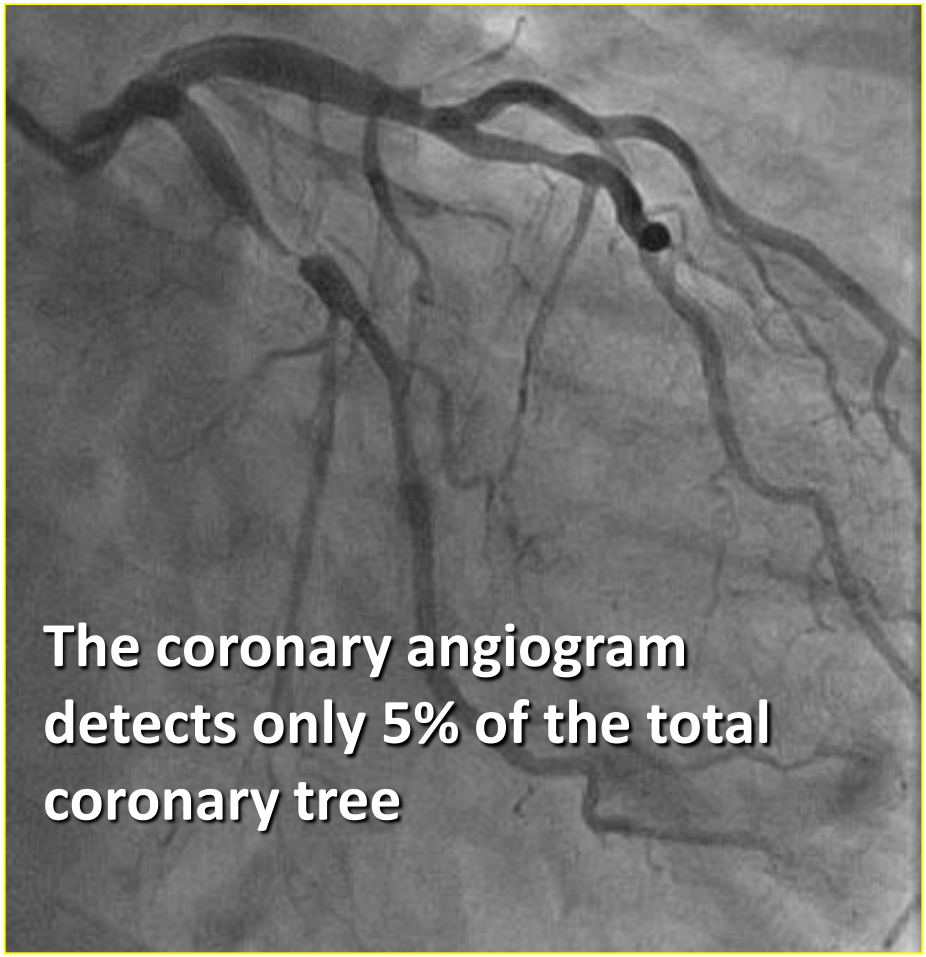
Two-Compartment Model of the Coronary Circulation



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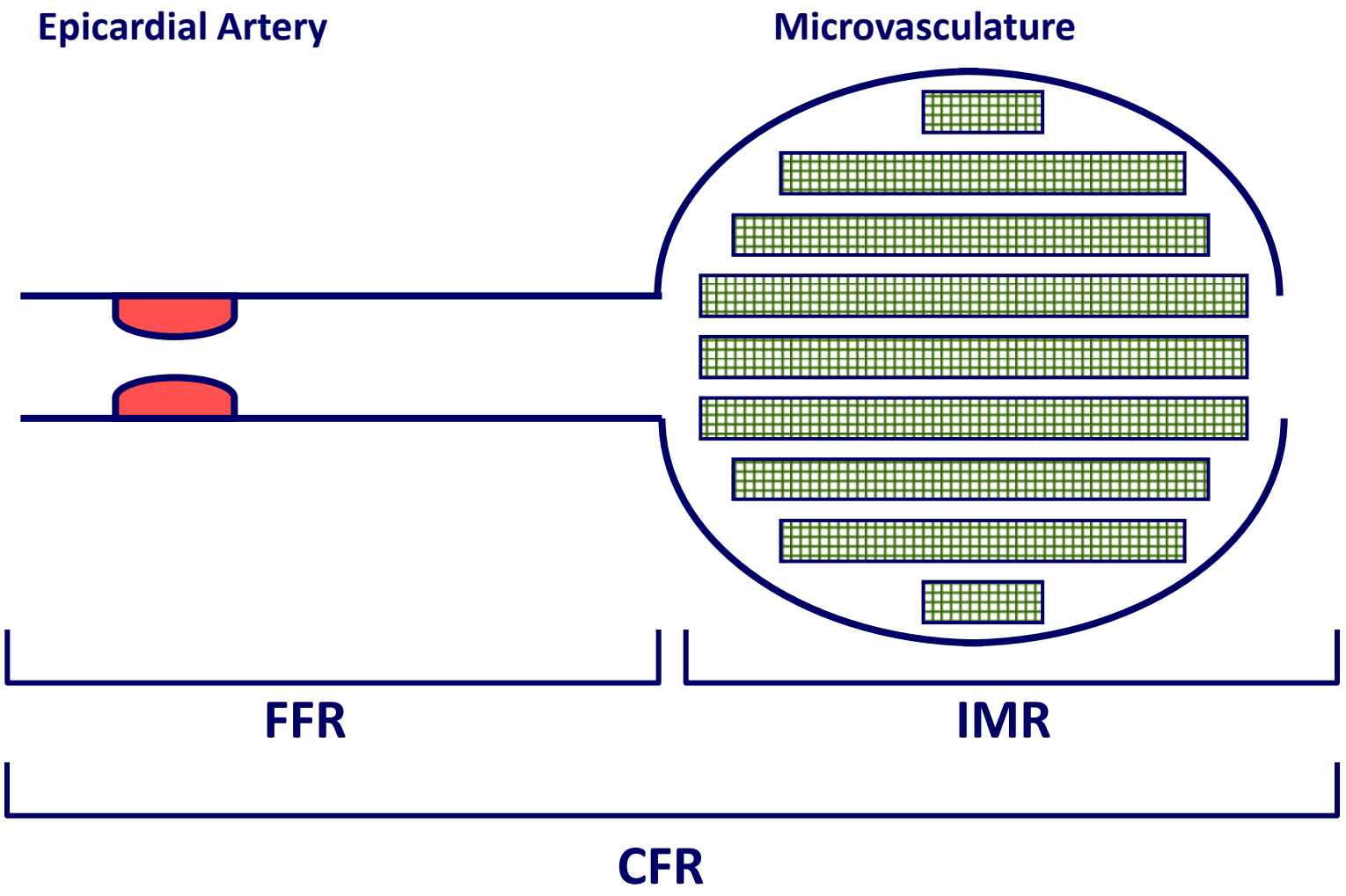

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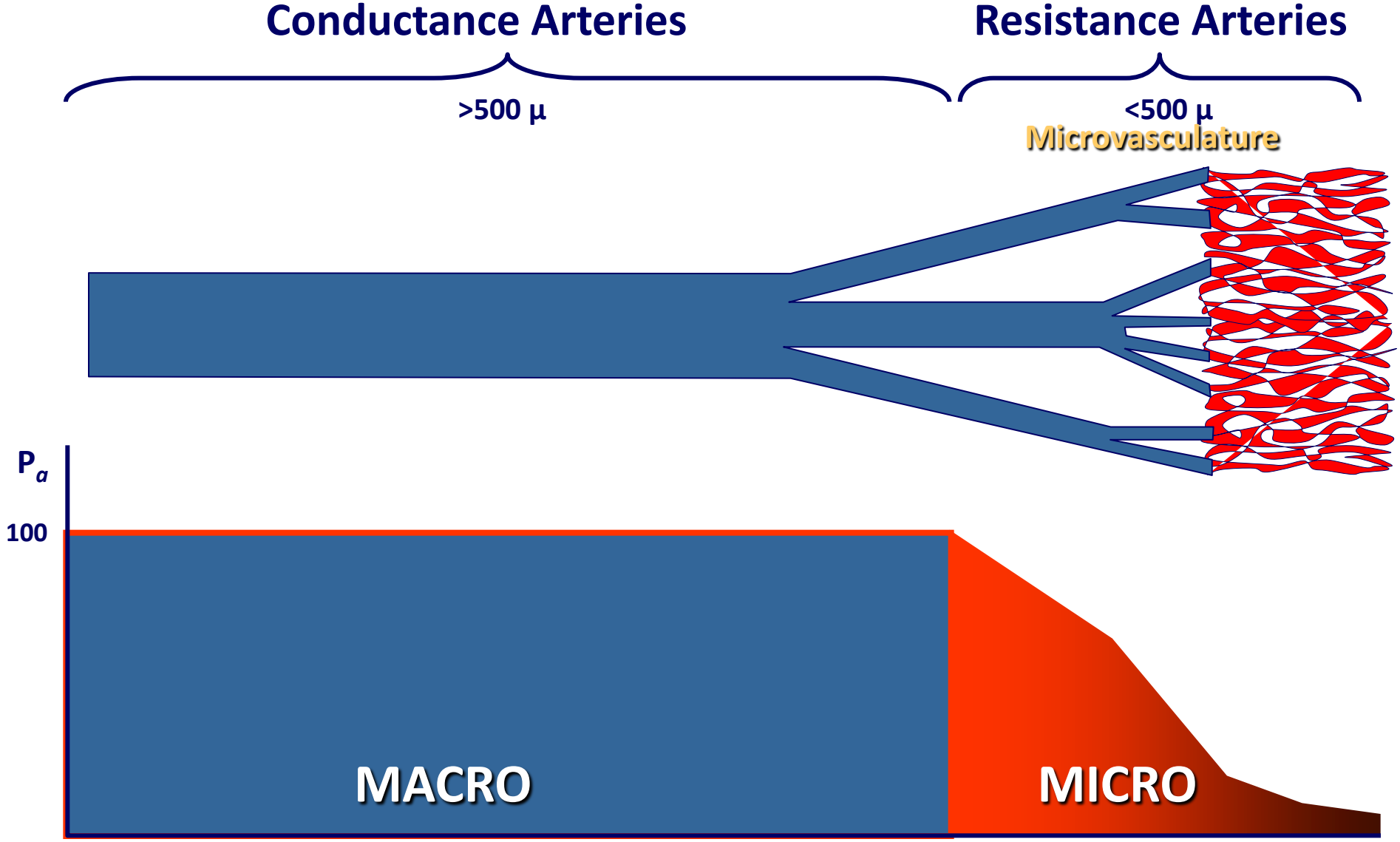

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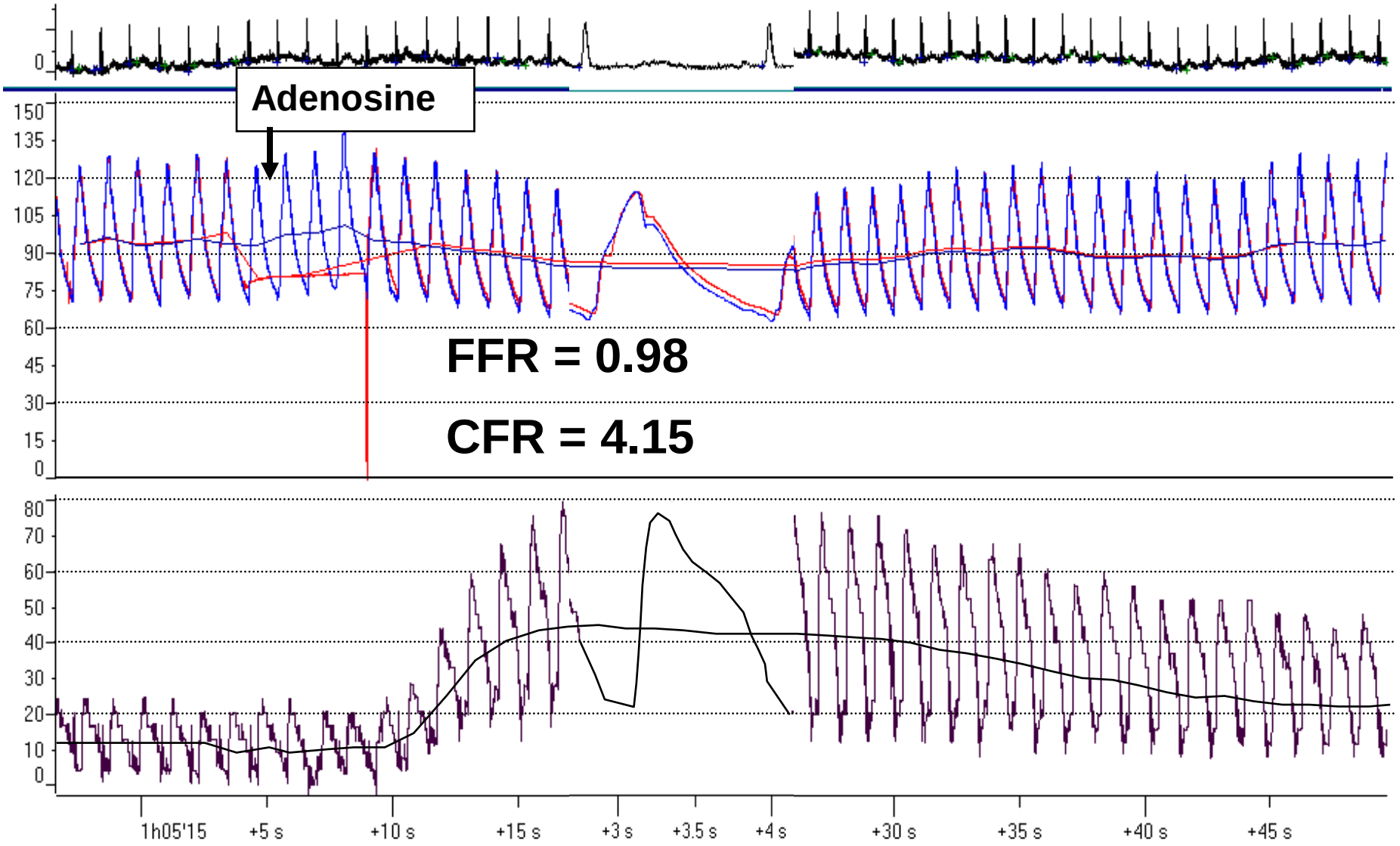
Pressure and Flow Velocity in Normal Coronary Arteries



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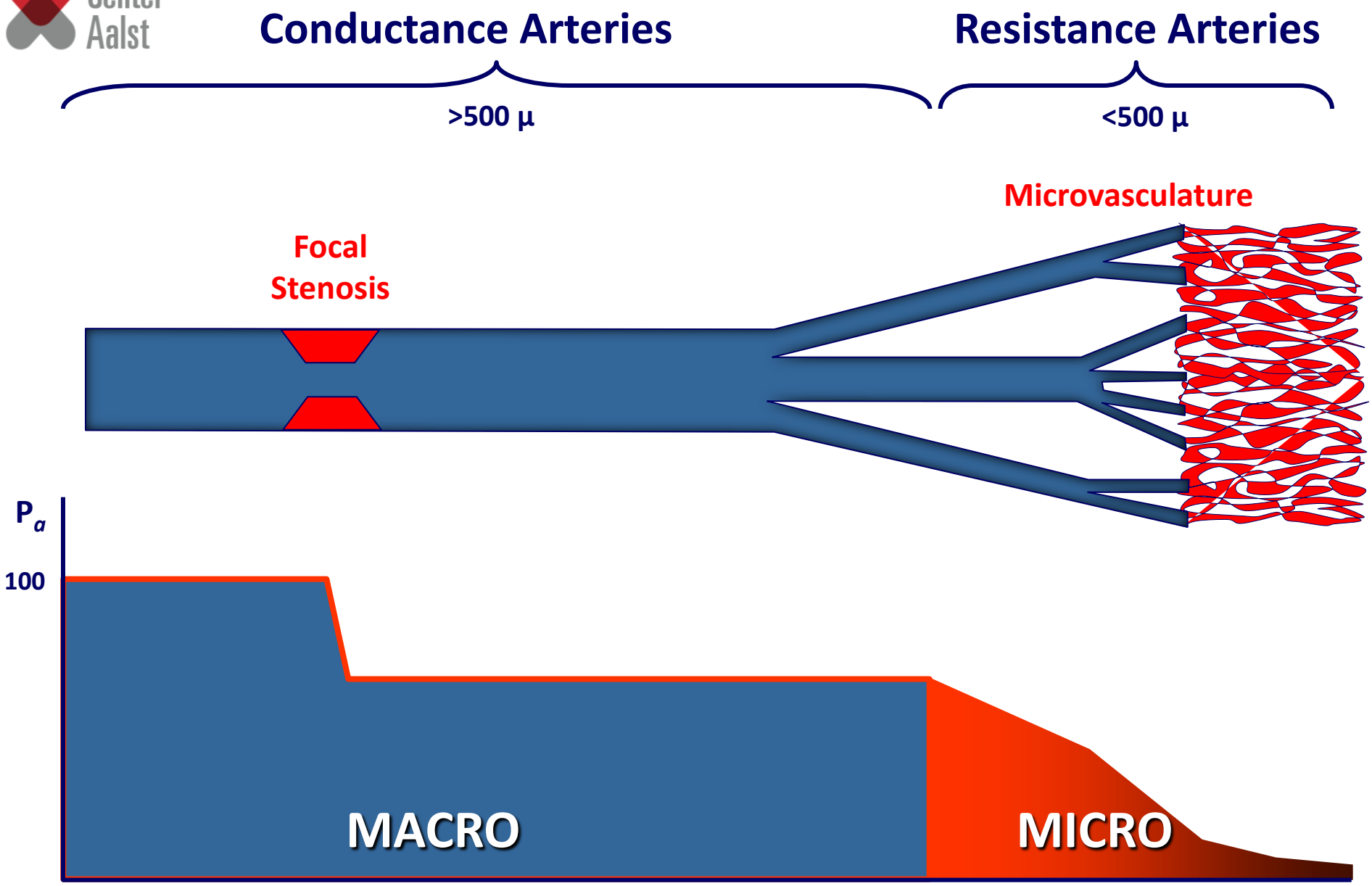

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Conductance Arteries

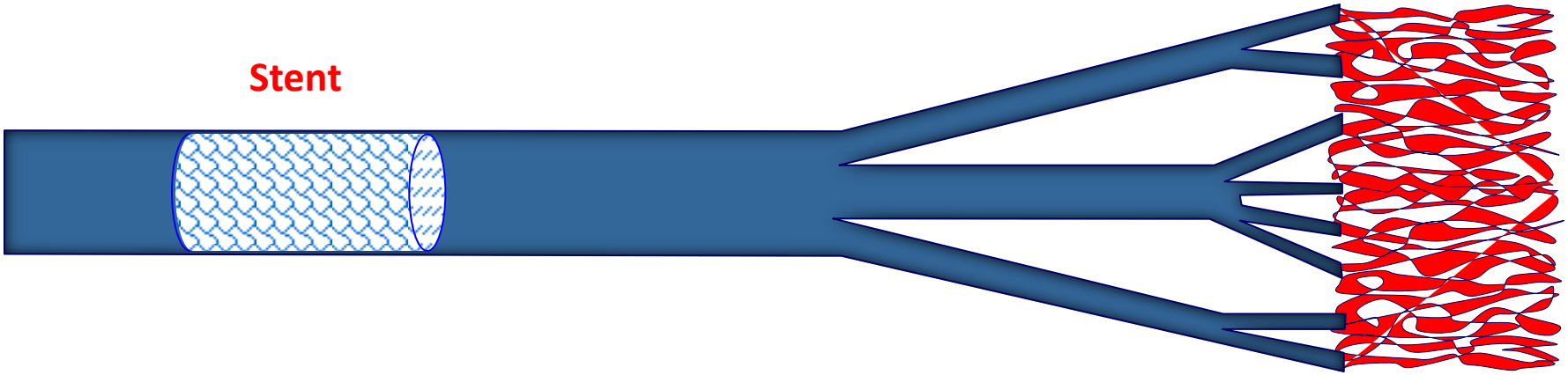
Resistance Arteries

>500 µ

<500 µ

Microvasculature

Stent



P_a

100

MACRO

MICRO

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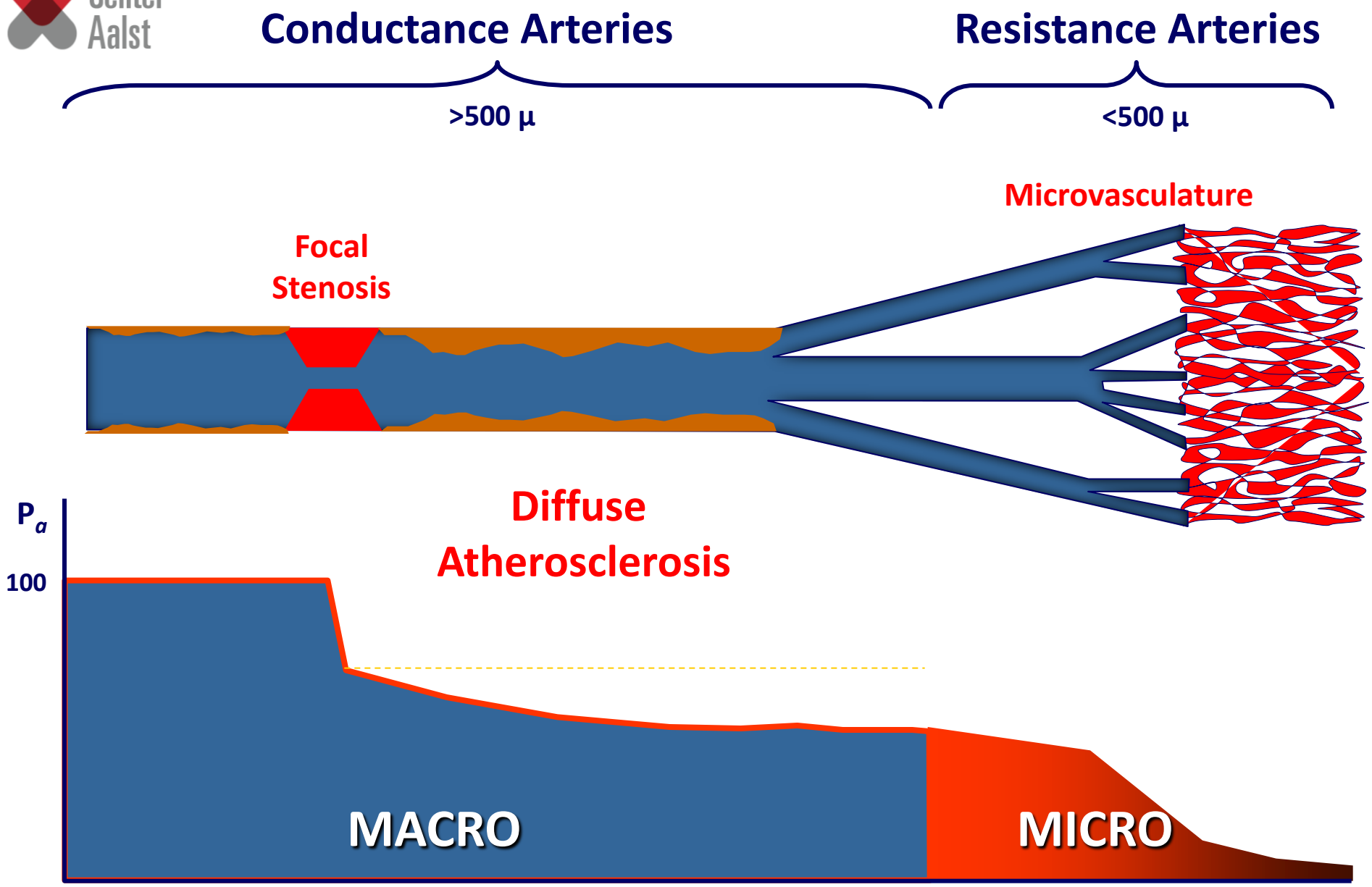

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Conductance Arteries

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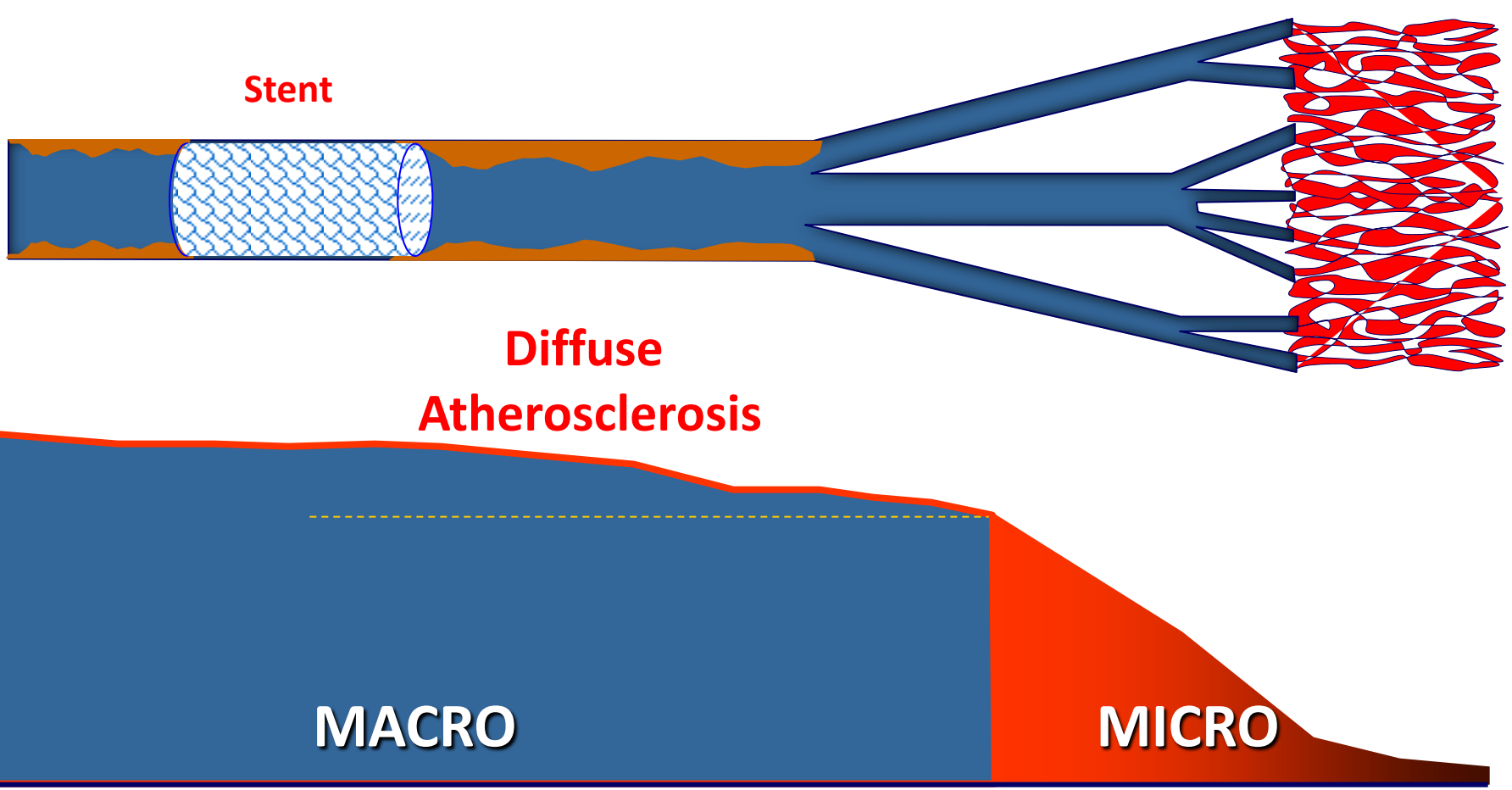

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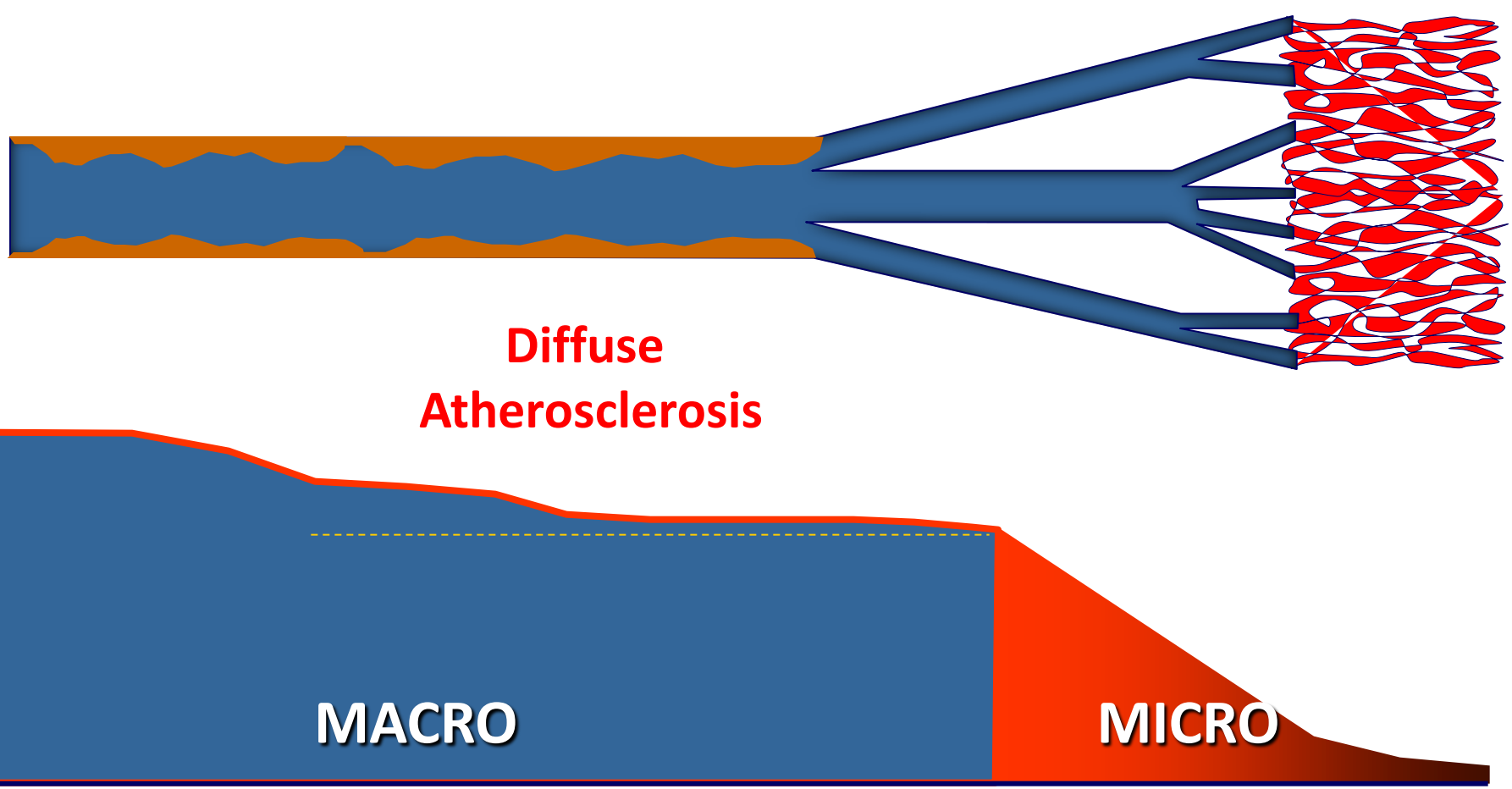

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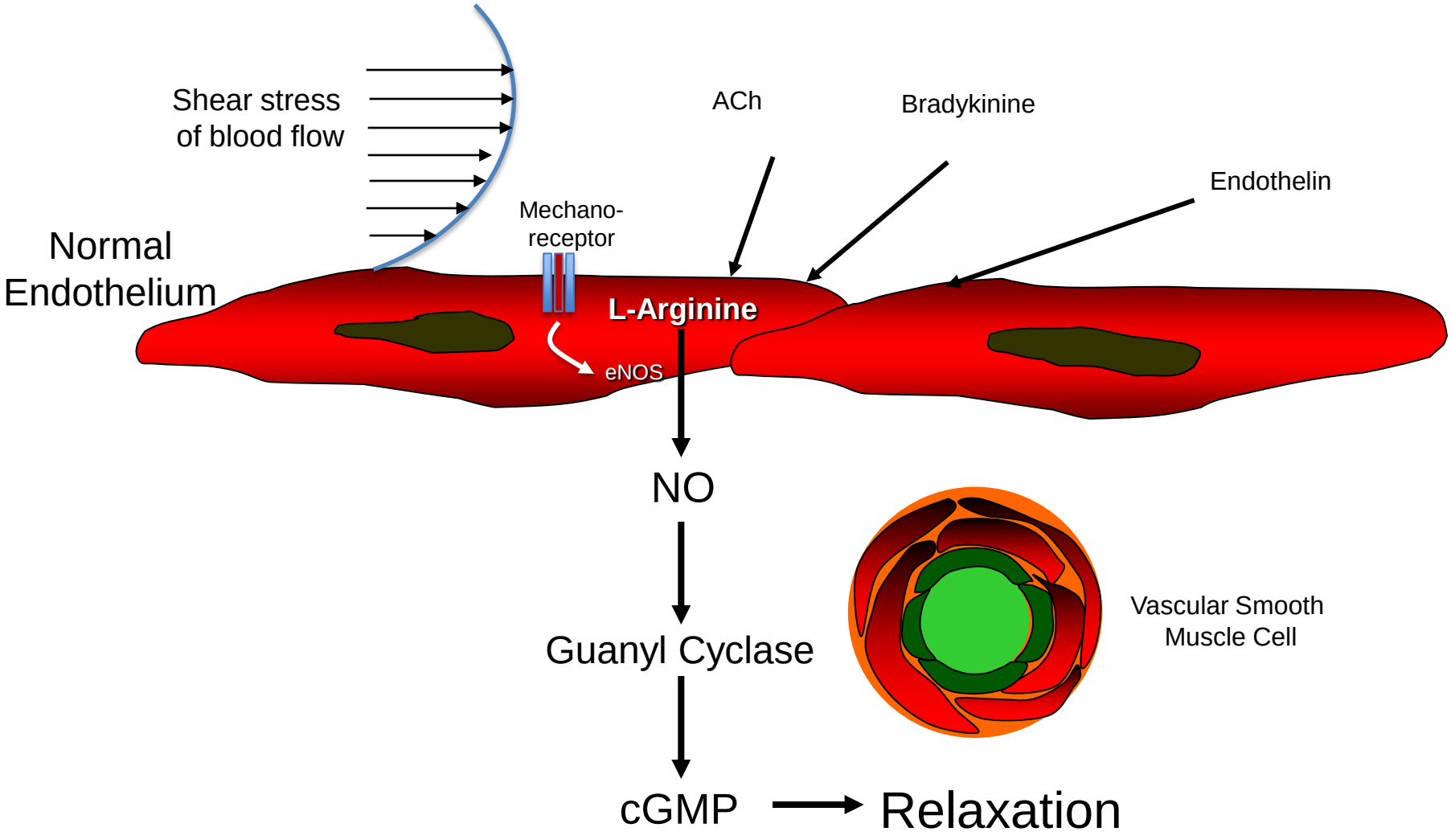
Endothelial Control of vascular tone



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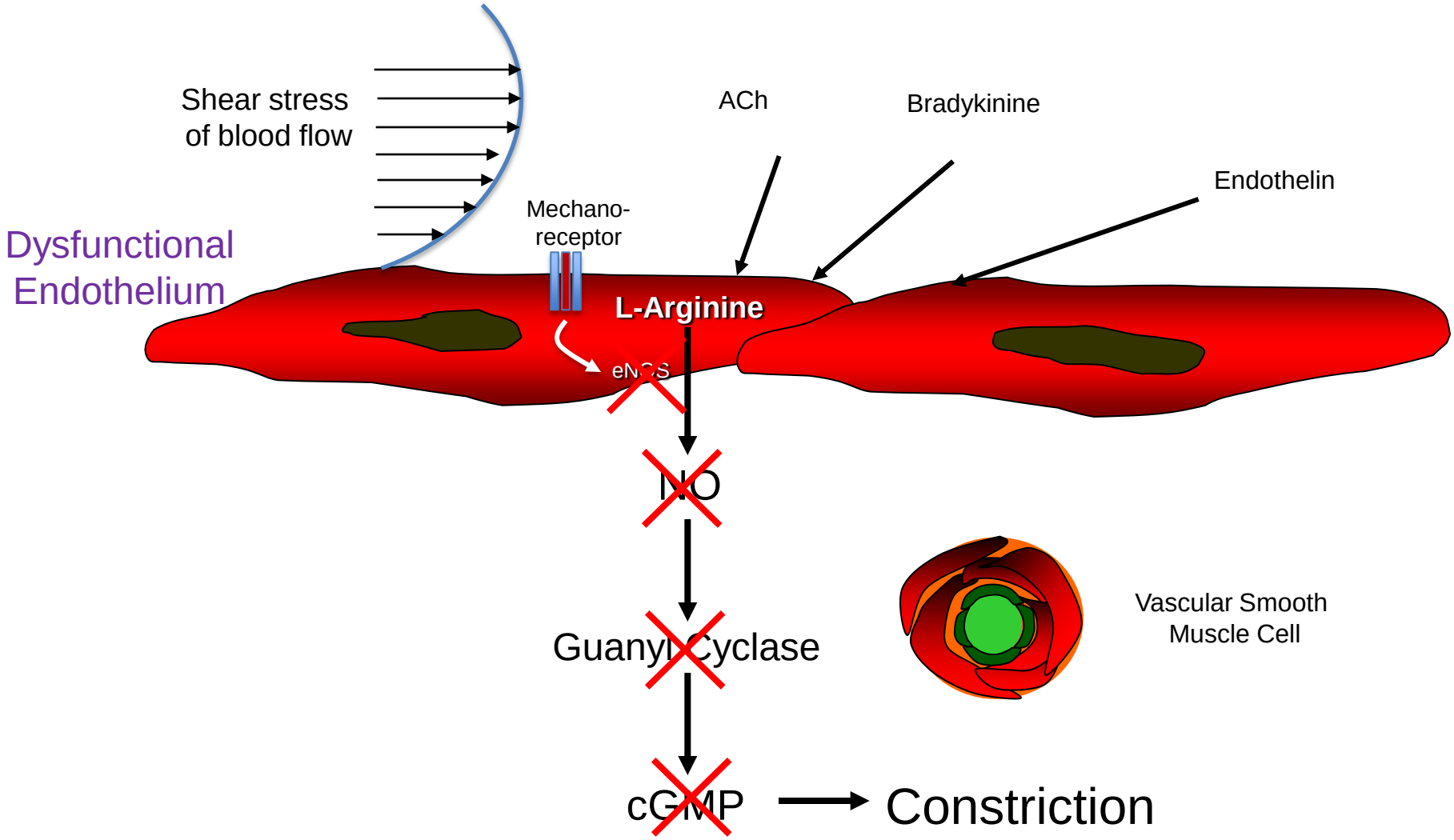

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Importance of Maximal Vasodilation

Epicardial

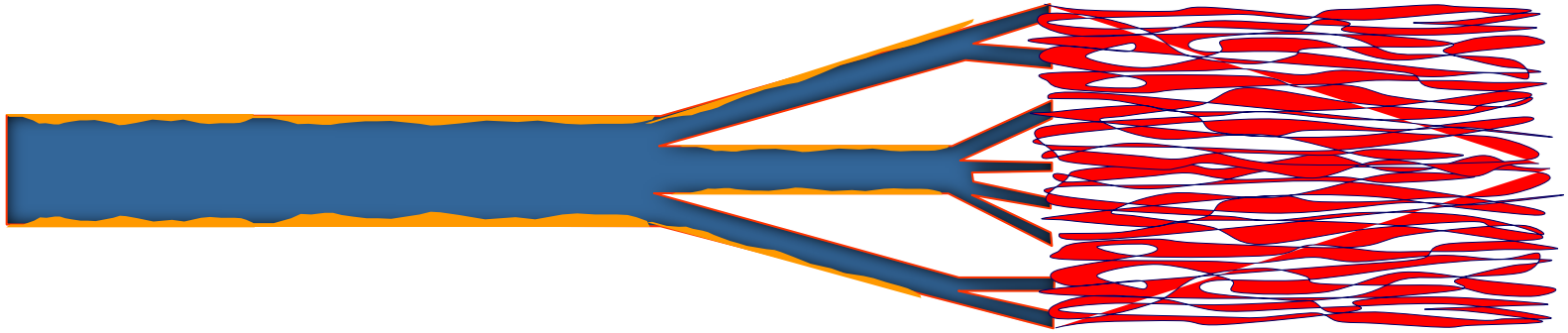
= Conductance

Arteries > 550 µ

Microvasculature

= Resistance

Arteries < 550 µ



Nitrates → ~~Vasospasm~~

Adenosine → ~~Autoregulation~~

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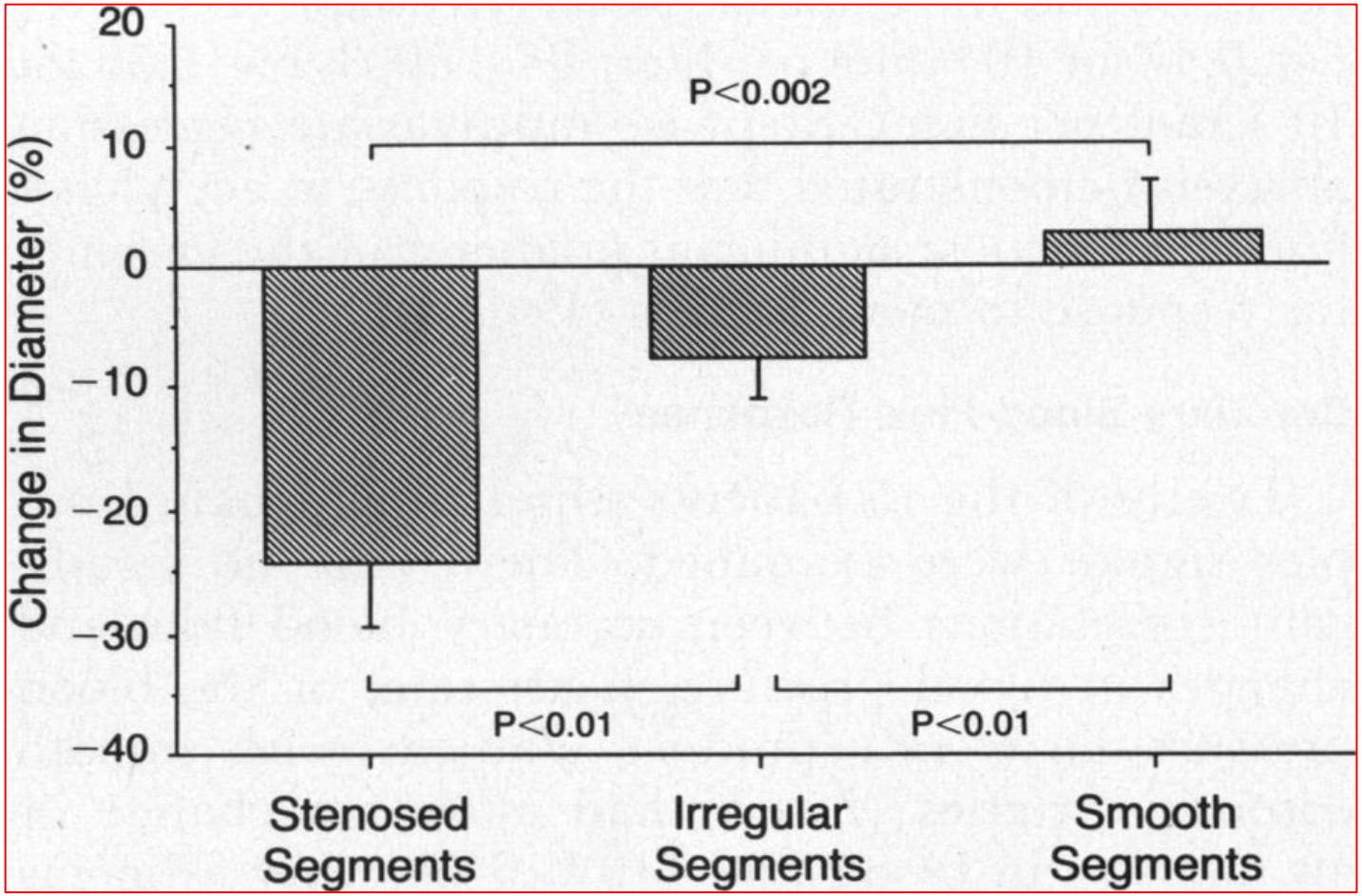
Endothelial Control of Coronary Blood Flow

Effect of Mental Stress on the Diameter of Coronary Arteries



Yeung AC et al. N Engl J Med 1991;325:1551-1556.

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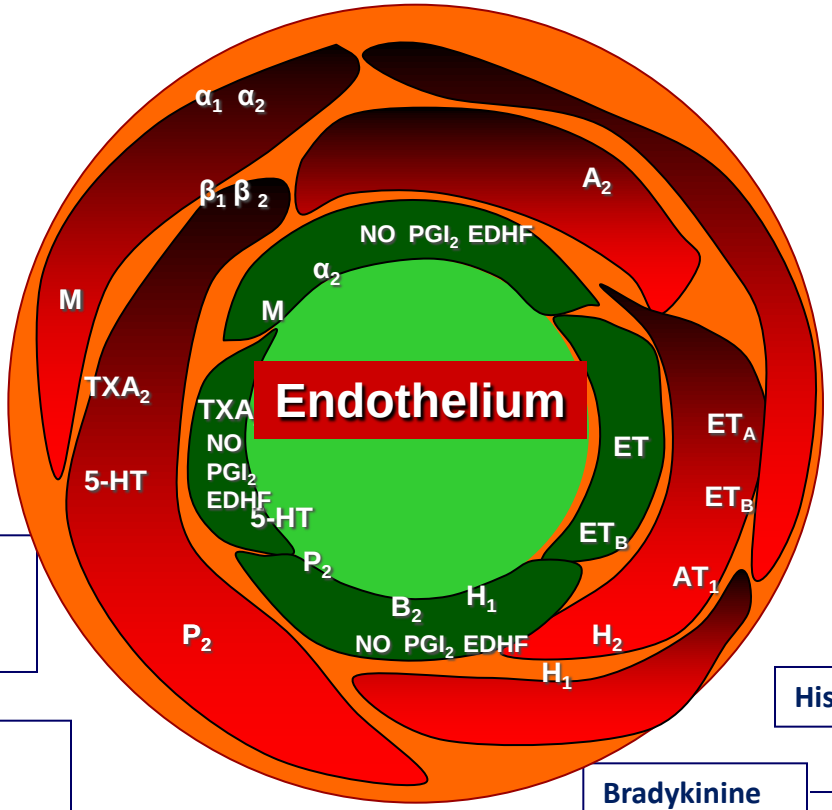
The Control of Myocardial Blood Flow



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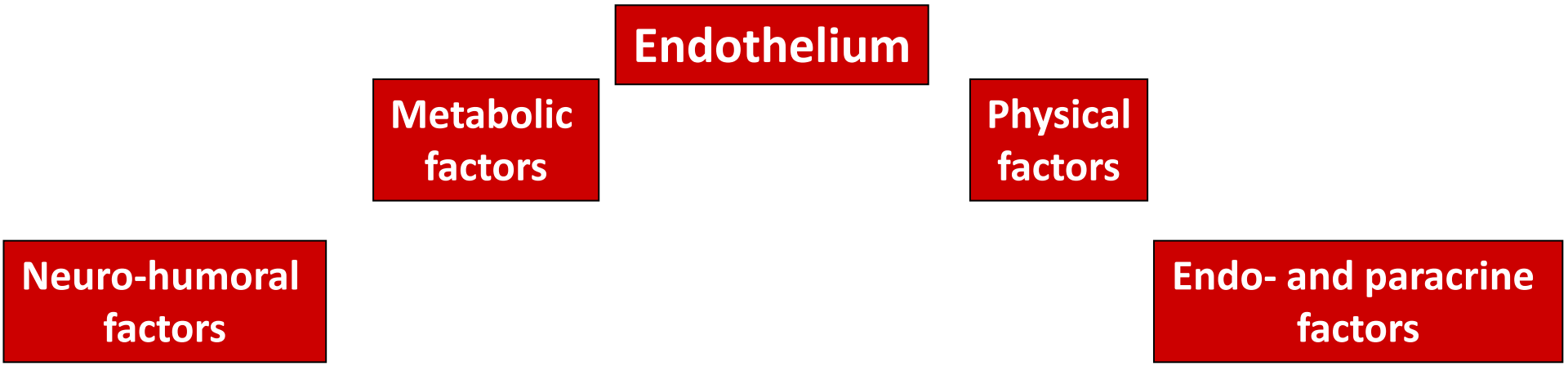
The Control of Myocardial Blood Flow



Multiple, interacting, cumulative, nonlinear mechanisms

Coronary Autoregulation

Adapted from D.J.G.M. Duncker

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Autoregulation

The ability of the heart of maintaining flow constant in case of change of perfusion pressure without the intervention of any other external mechanism

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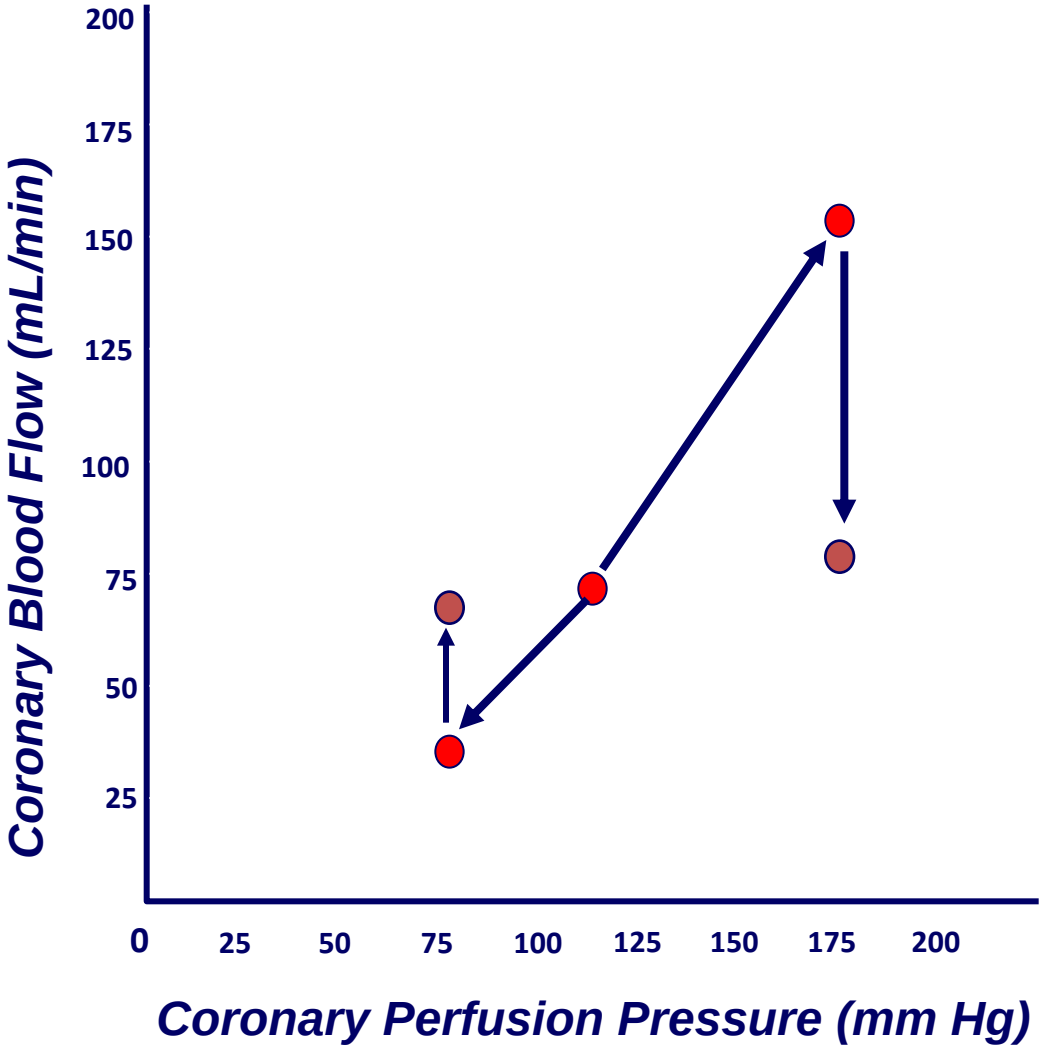
Coronary Autoregulation



Rubio and Berne, Prog CV Disease 1975

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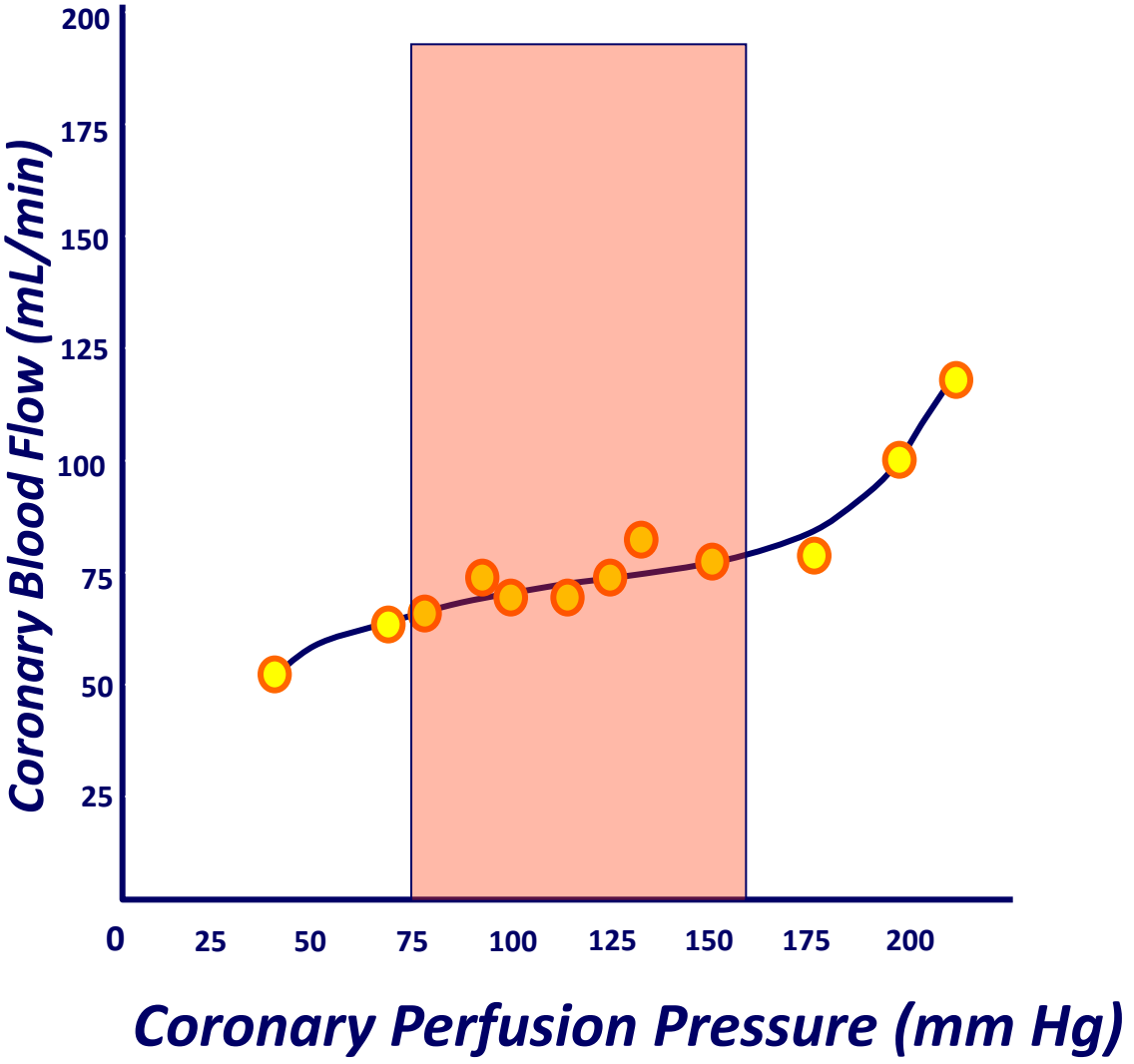
Autoregulatory Range



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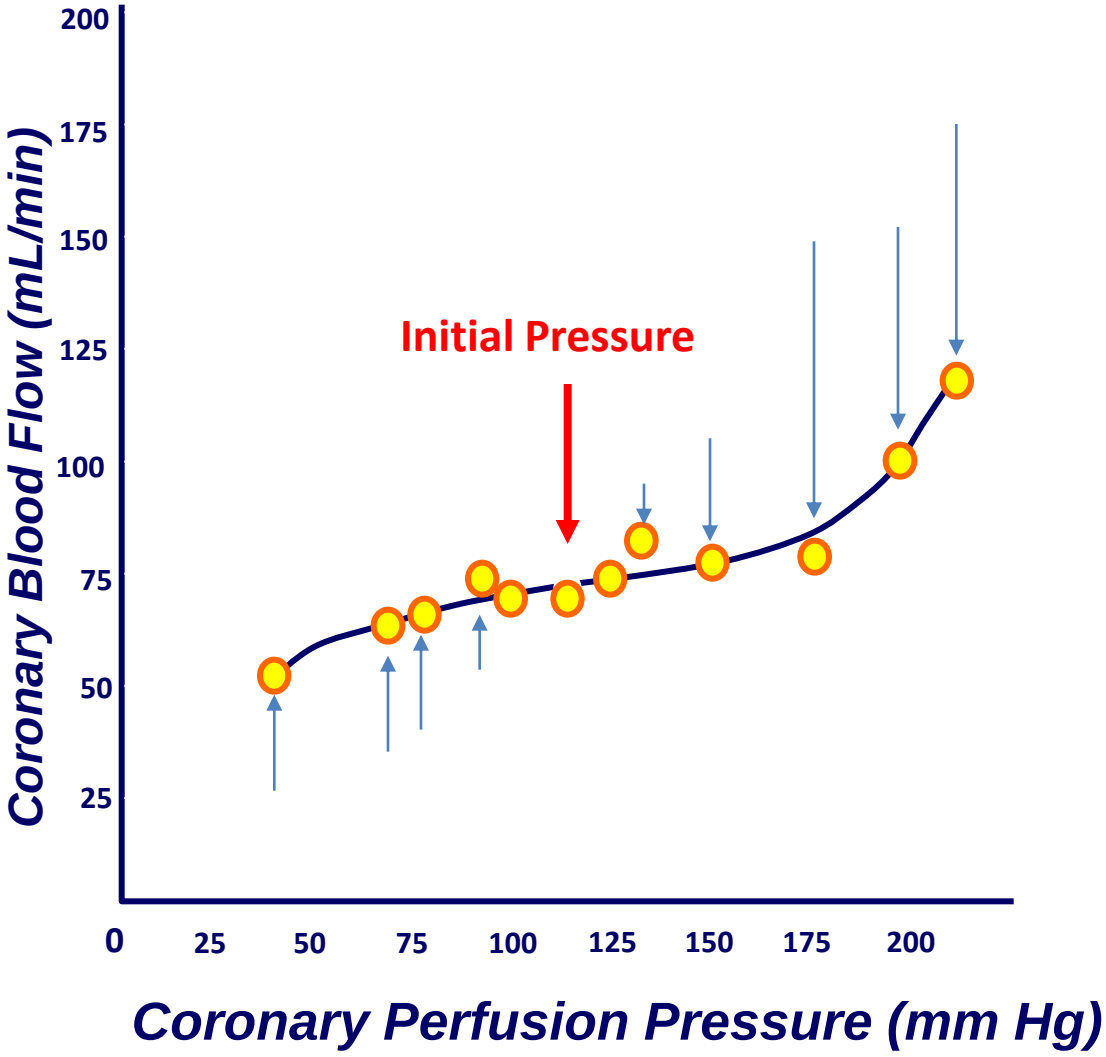
Autoregulatory Range



Rubio and Berne, Prog CV Disease 1975

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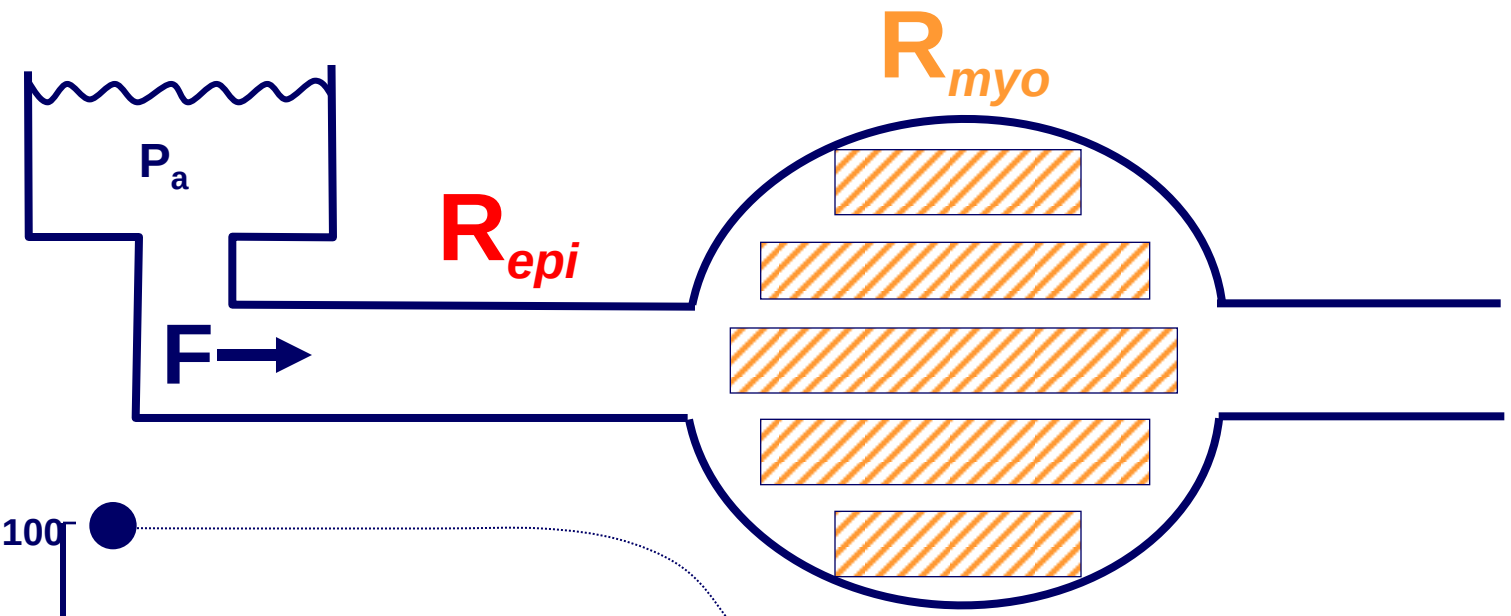
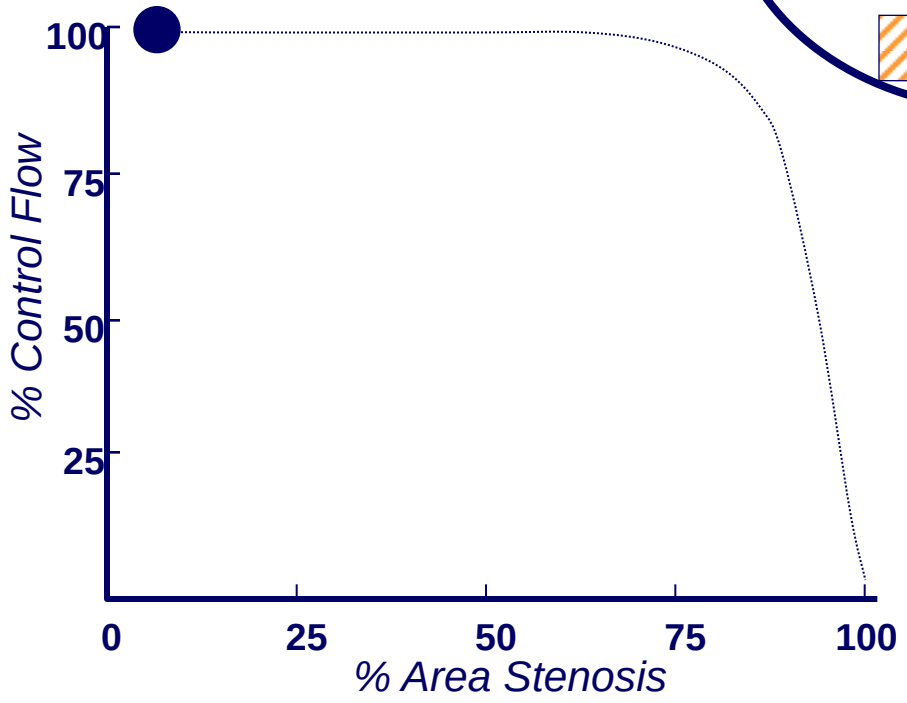
Flow, Pressure, and Resistance





$$F = \frac{\Delta P}{R_{epi} + R_{myo}}$$

K. Lance Gould, 1974

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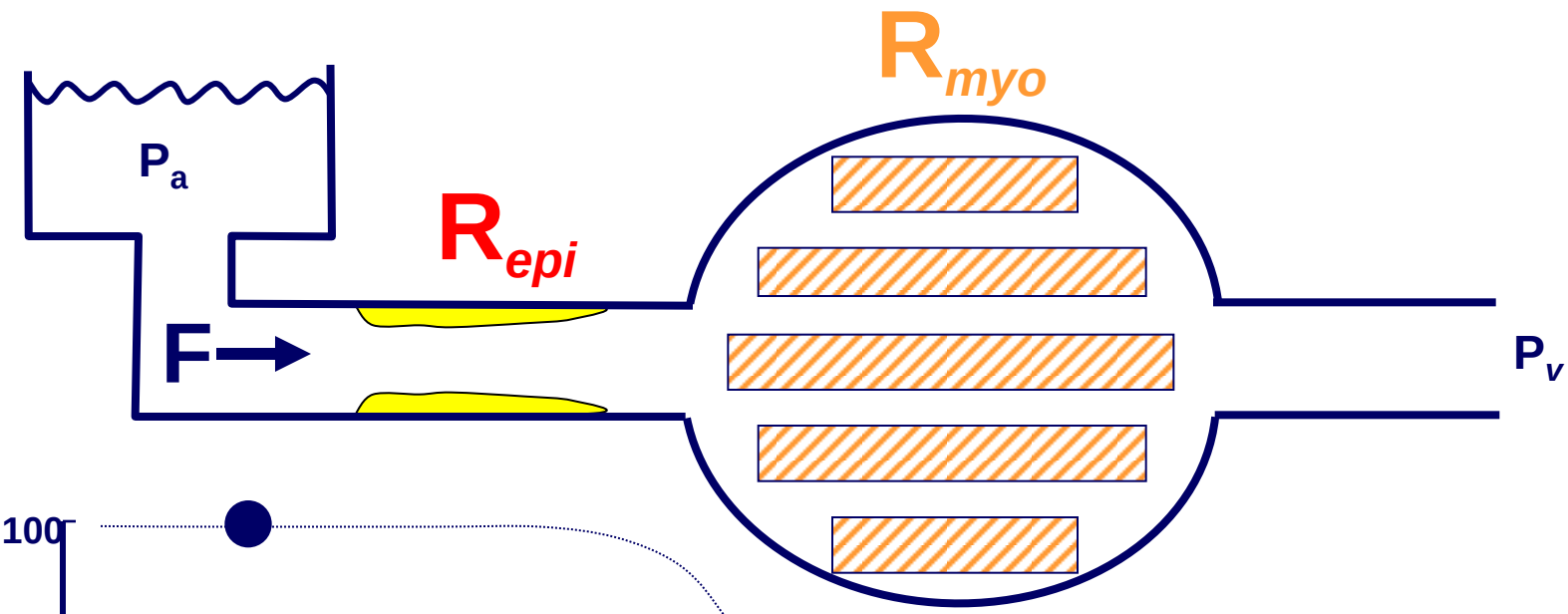
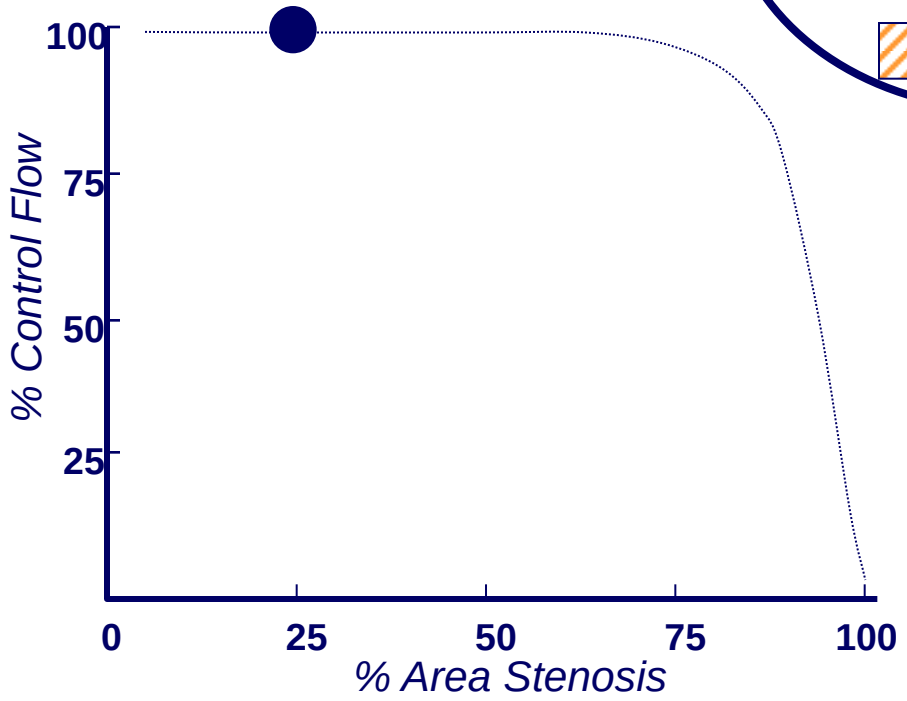
Flow, Pressure, and Resistance





$$F = \frac{\Delta P}{R_{epi}\uparrow + R_{myo}\downarrow}$$

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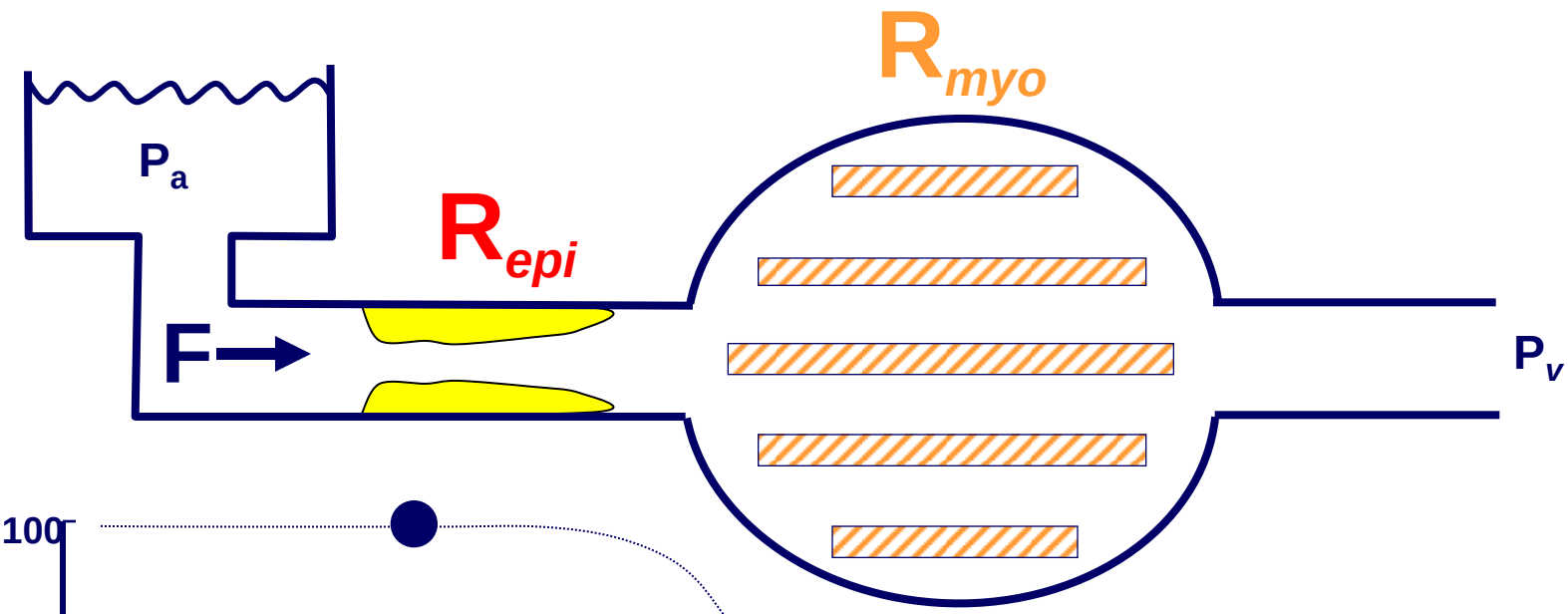

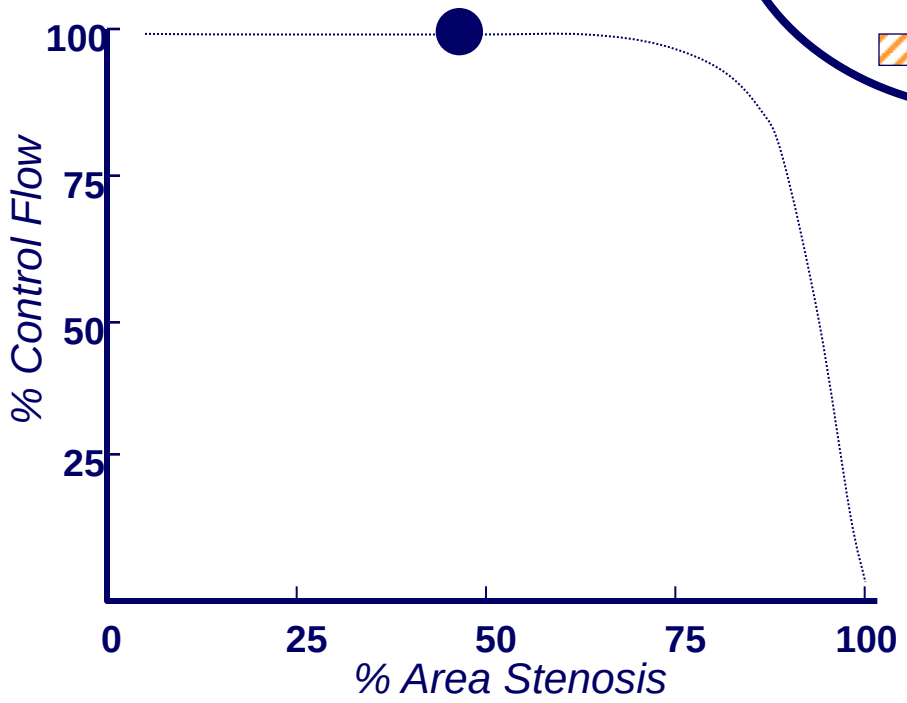

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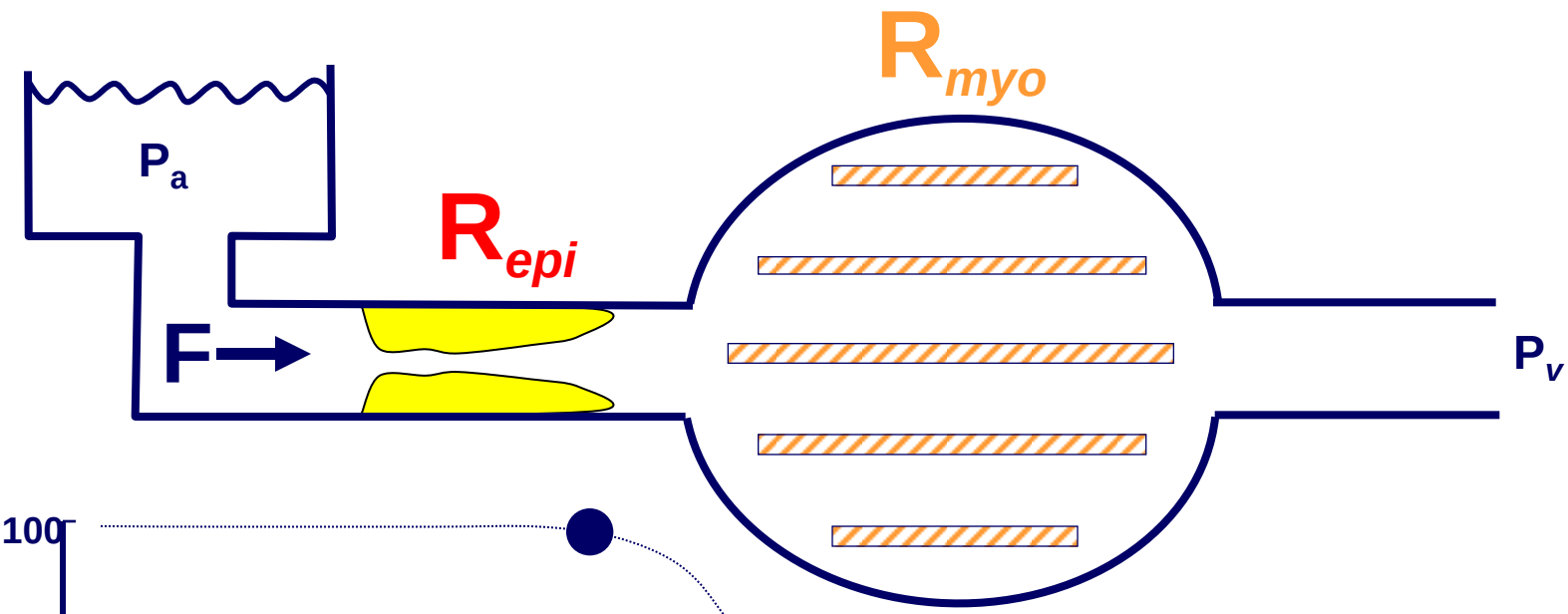

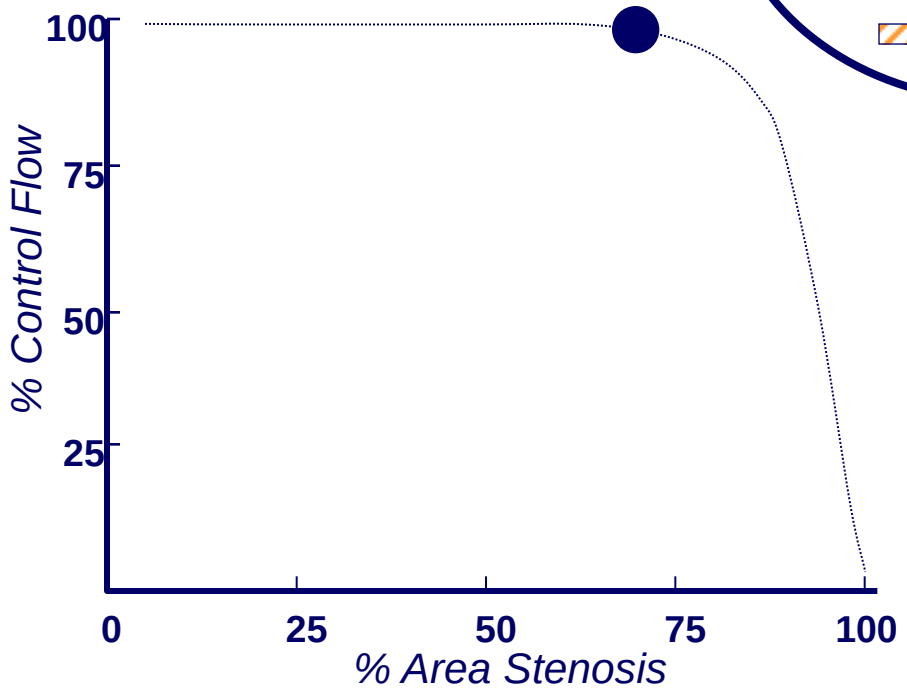

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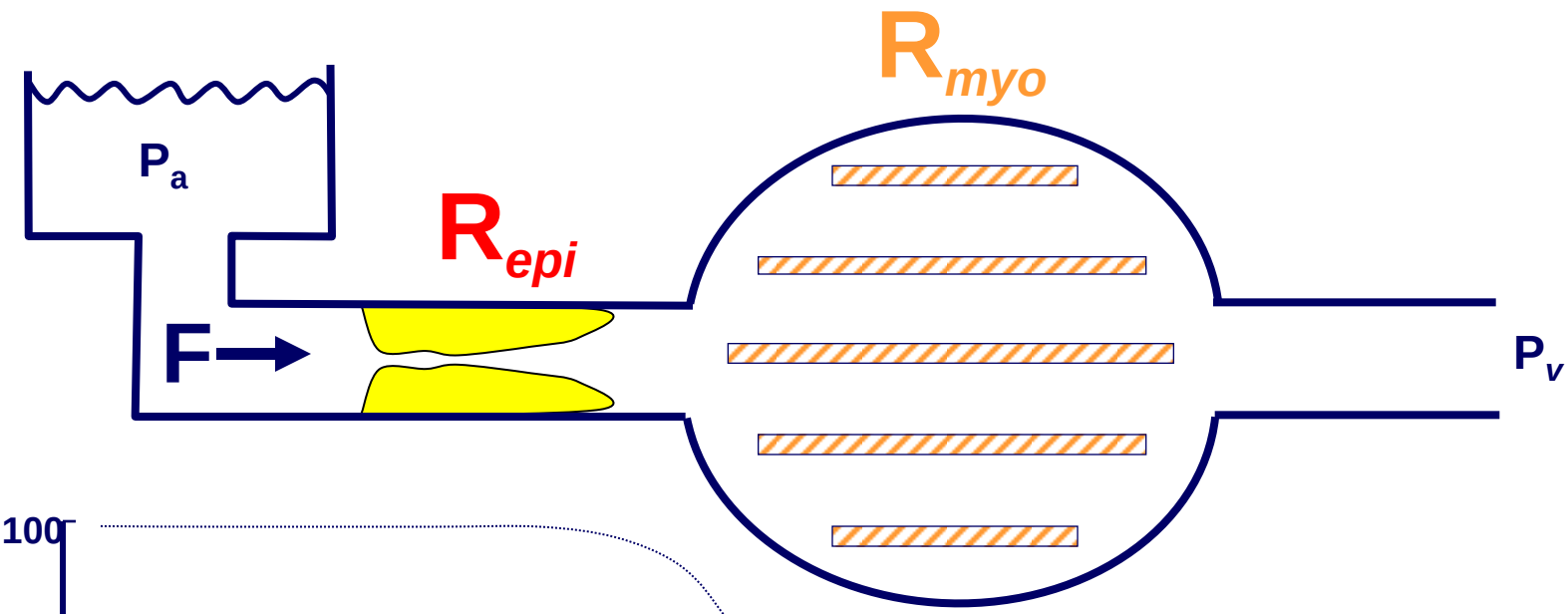
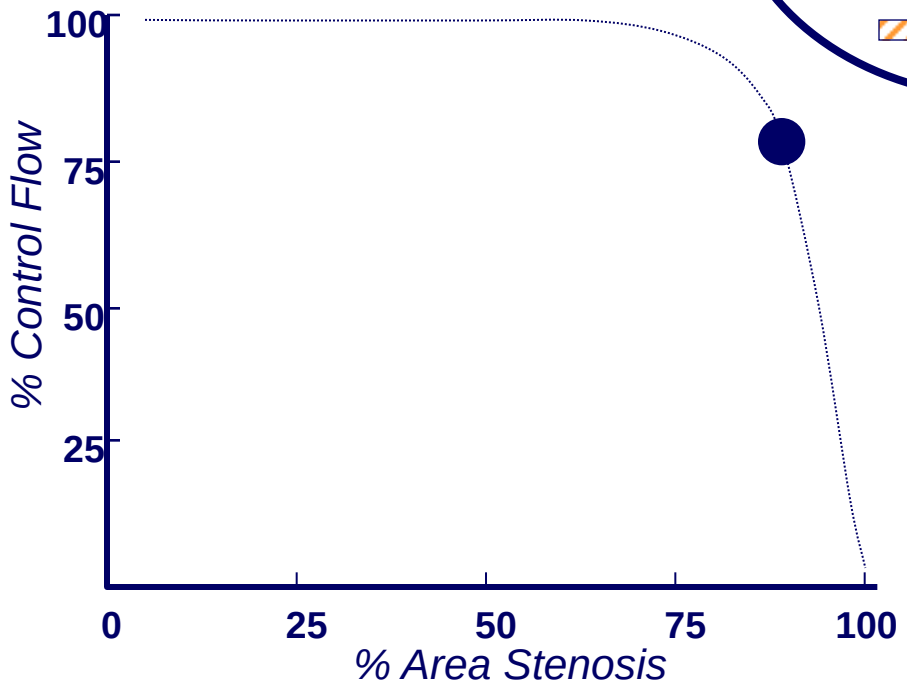
Flow, Pressure, and Resistance





$$F = \frac{\Delta P}{R_{epi}\uparrow + R_{myo}\downarrow}$$

K. Lance Gould, 1974

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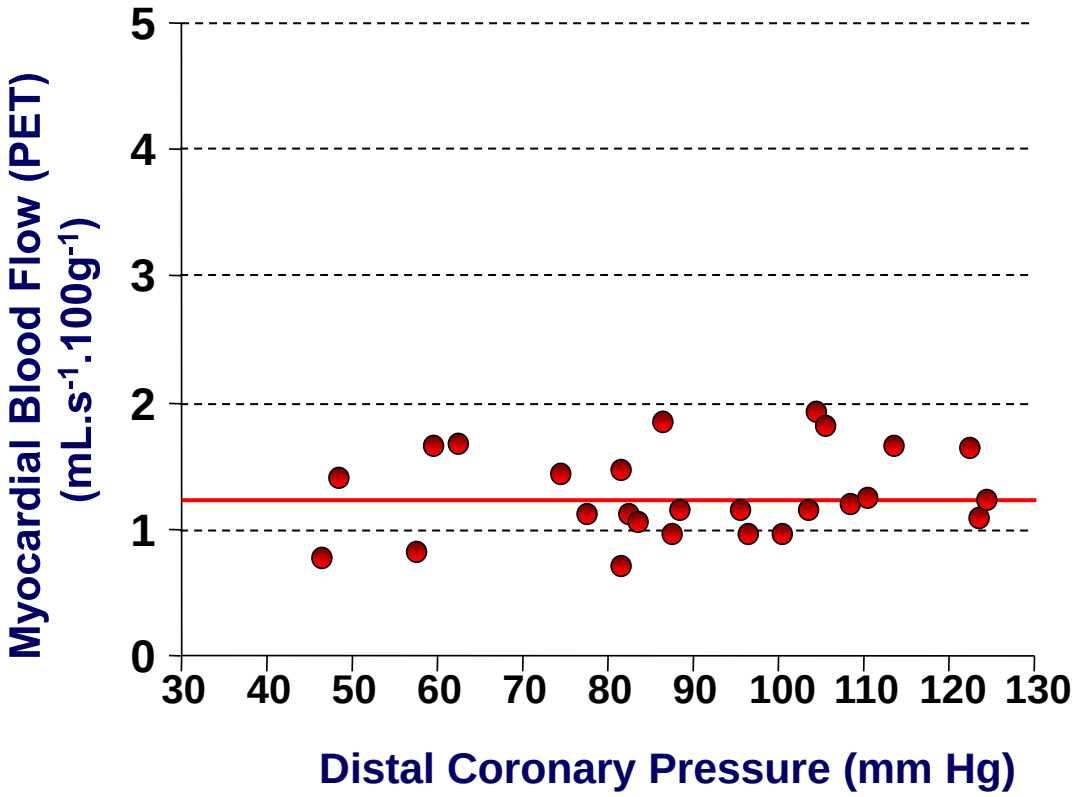
Autoregulation

- Proximal LAD stenosis (n = 26)
- Normal LV systolic function
- PET fow measurements (^{15}O-labeled water) at rest



De Bruyne et al, 1996

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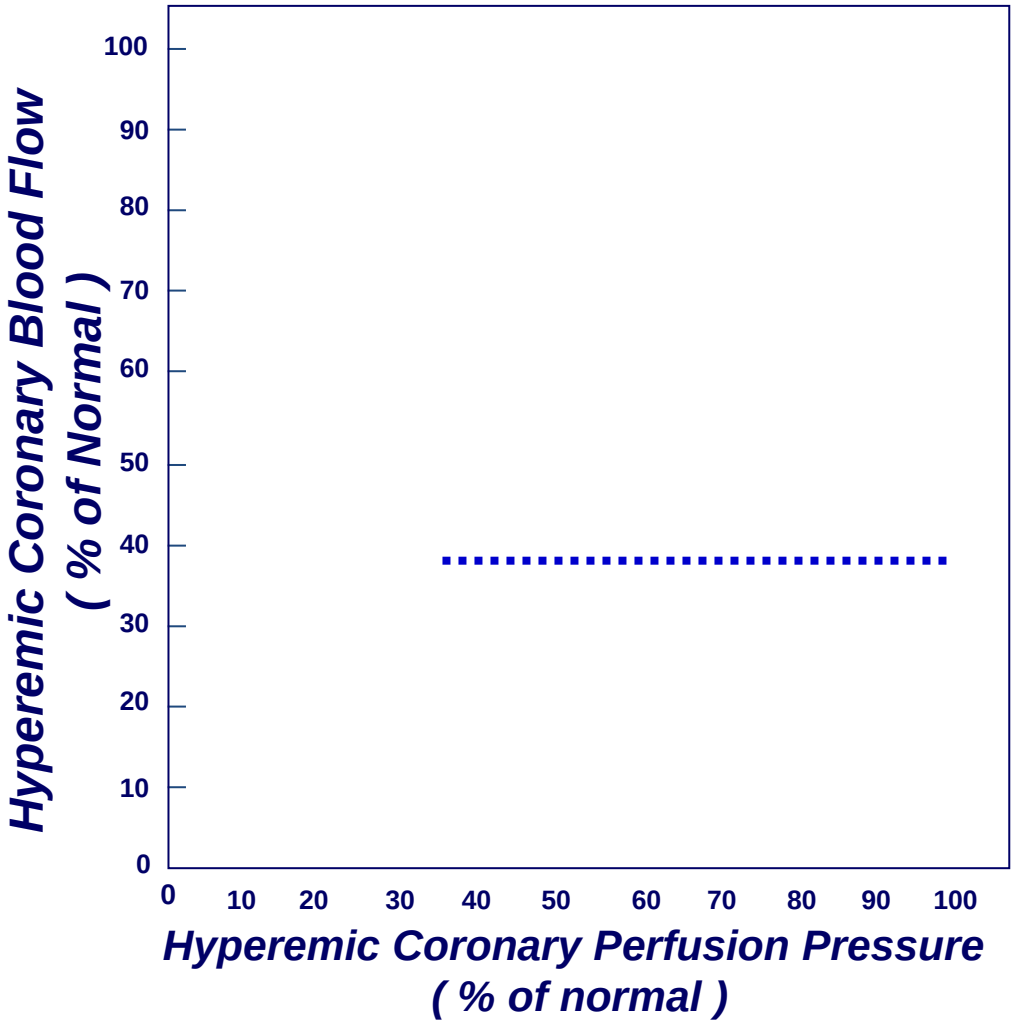
Pressure-Flow Relationship At Rest: Autoregulation



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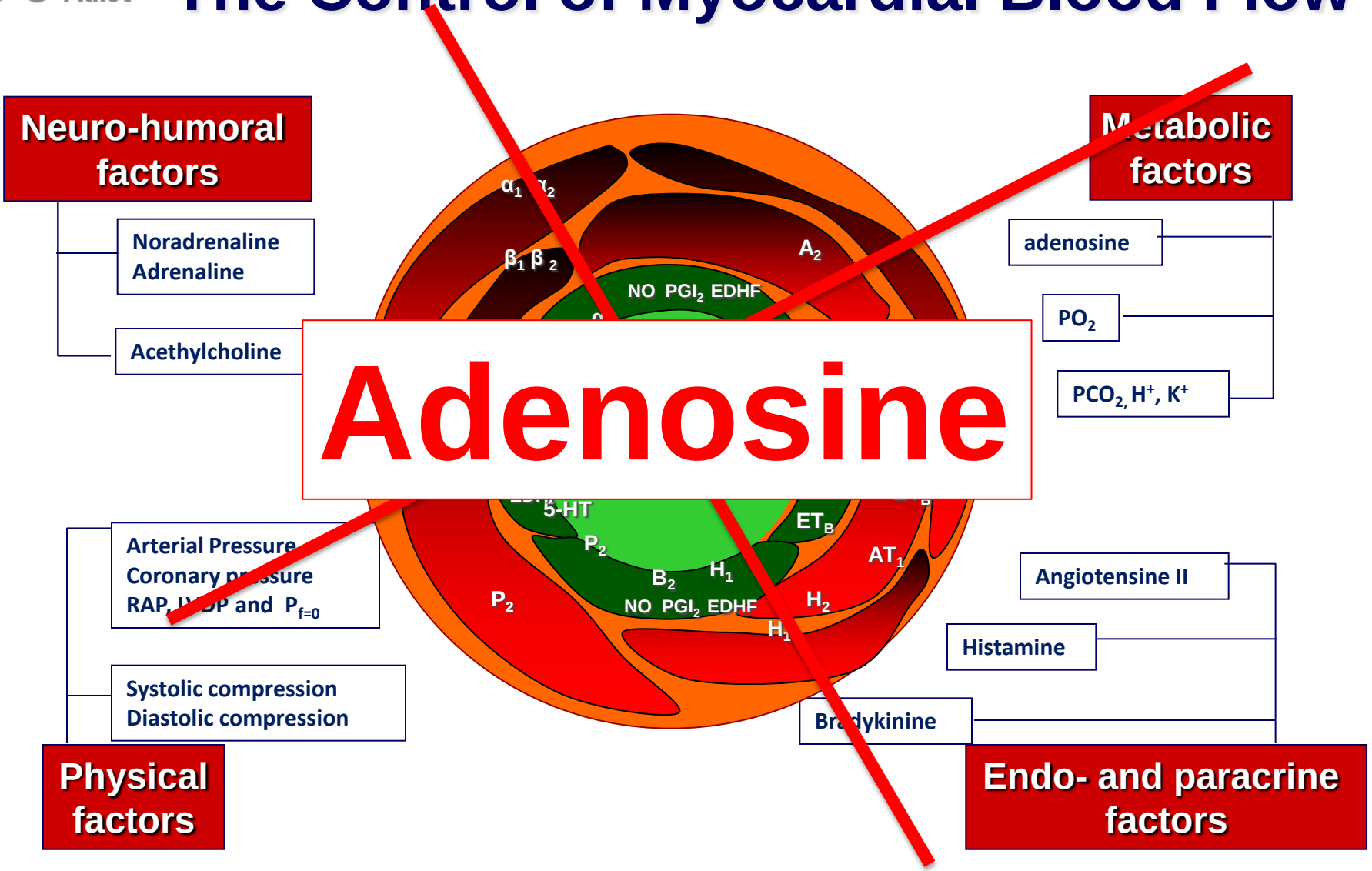
The Control of Myocardial Blood Flow



Adapted from D.J.G.M. Duncker and Bache R Physiol Rev 2008

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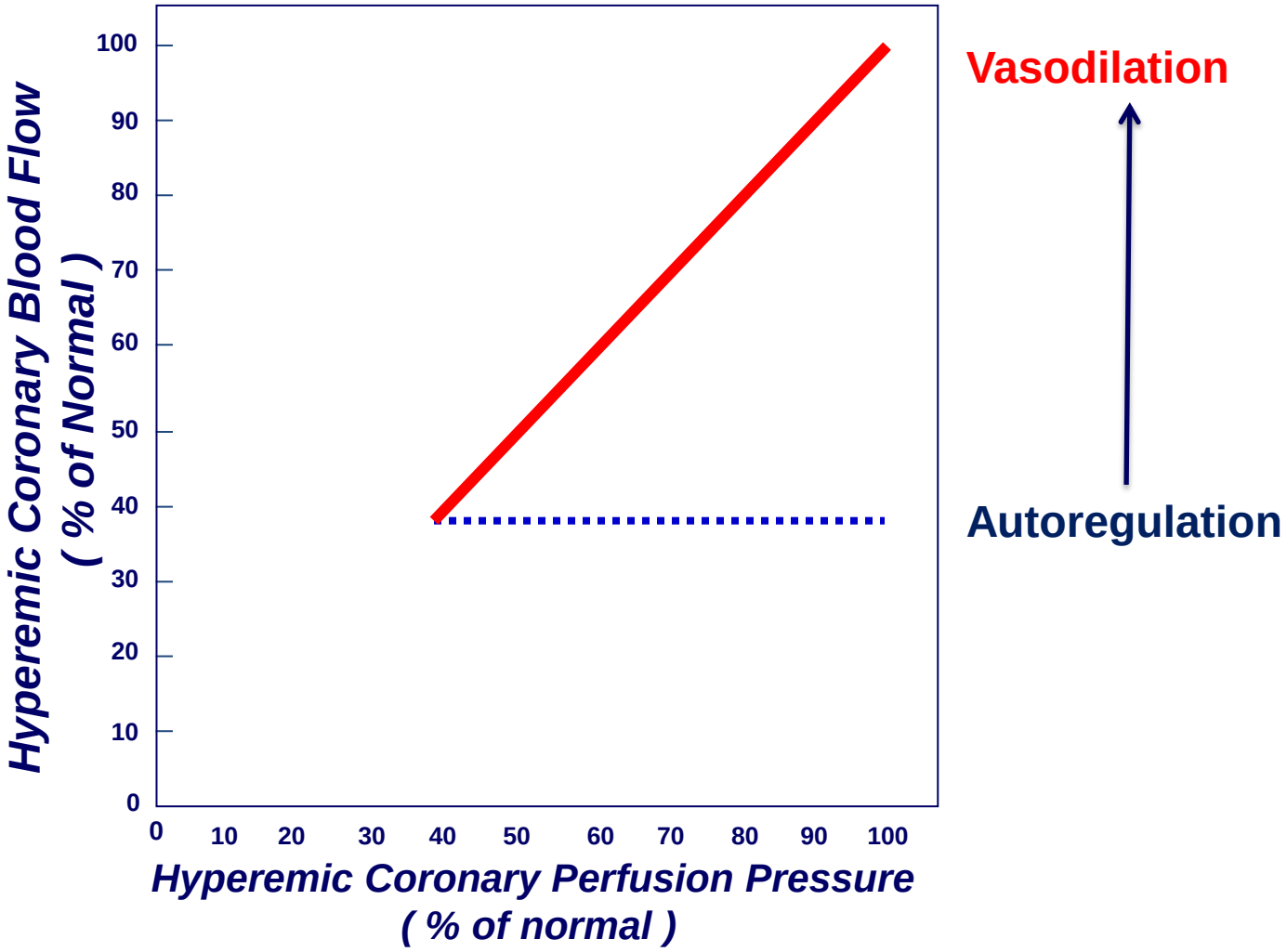
Pressure-Flow Relationship During Maximal Vasodilation



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People who wish to treat patients with CAD without coronary physiology must settle for a suboptimal treatment