Regulation of Coronary Blood Flow

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Dirk J. Duncker

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- Introduction
- Control of Coronary Resistance Vessels
- Autoregulation: Pressure Flow Relation
- Hemodynamic Effects of a Coronary Stenosis

Duncker & Bache *Physiol Rev* 2008
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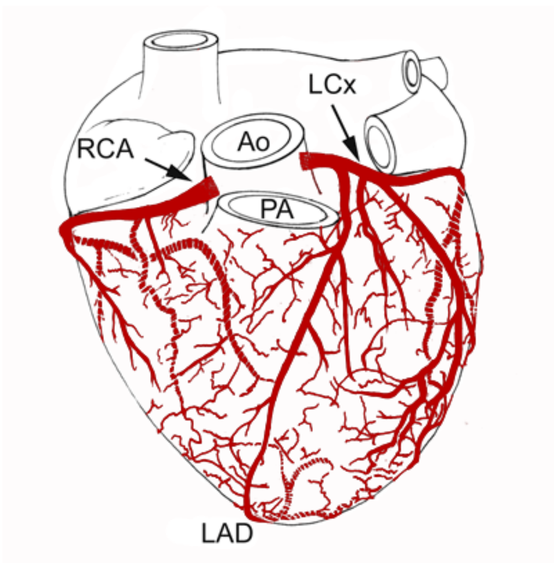
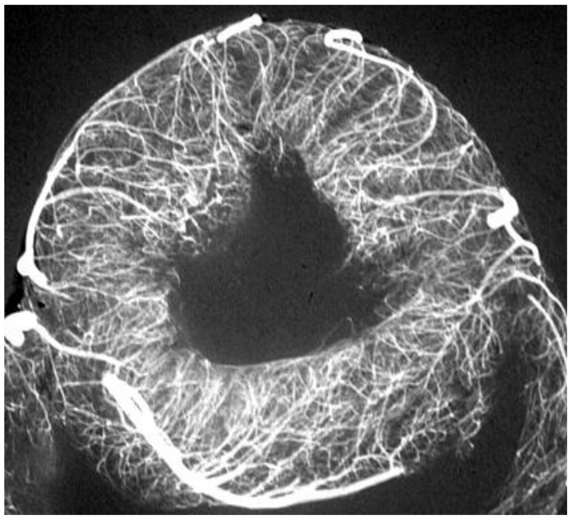
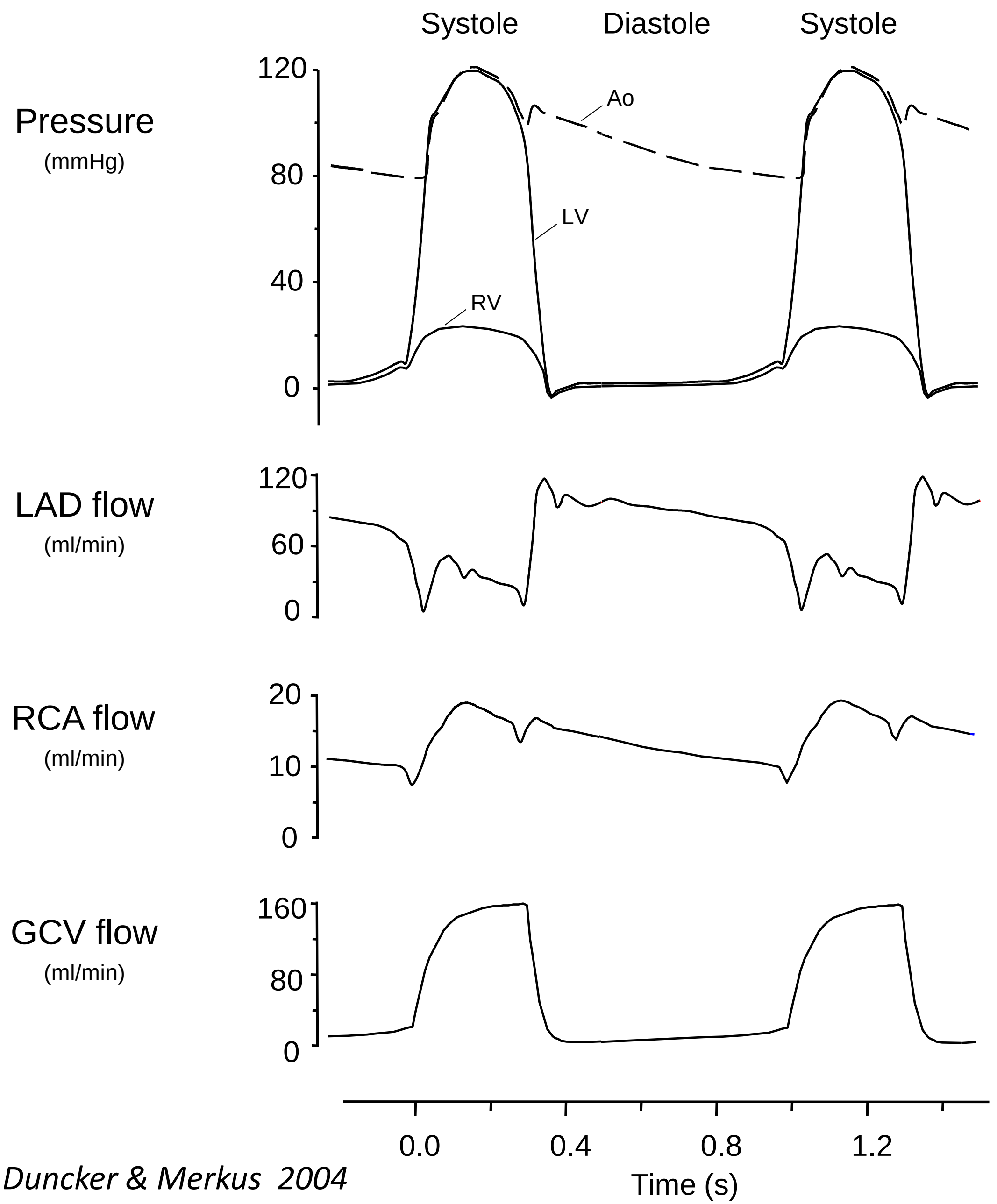
Canty & Duncker *Braunwald's Heart Disease* 2014

Cyclic Compression of the Coronary Microvasculature



Courtesy of Harold Laughlin





Duncker & Merkus 2004

Unique aspects of the coronary circulation

- Cyclic compression of the vasculature
- High resting myocardial metabolic rate

  Cardiac muscle 1 ml/min/g flow

  Skeletal muscle 0.1 ml/min/g flow

  - High capillary density

    Cardiac muscle 3000-4000/mm2

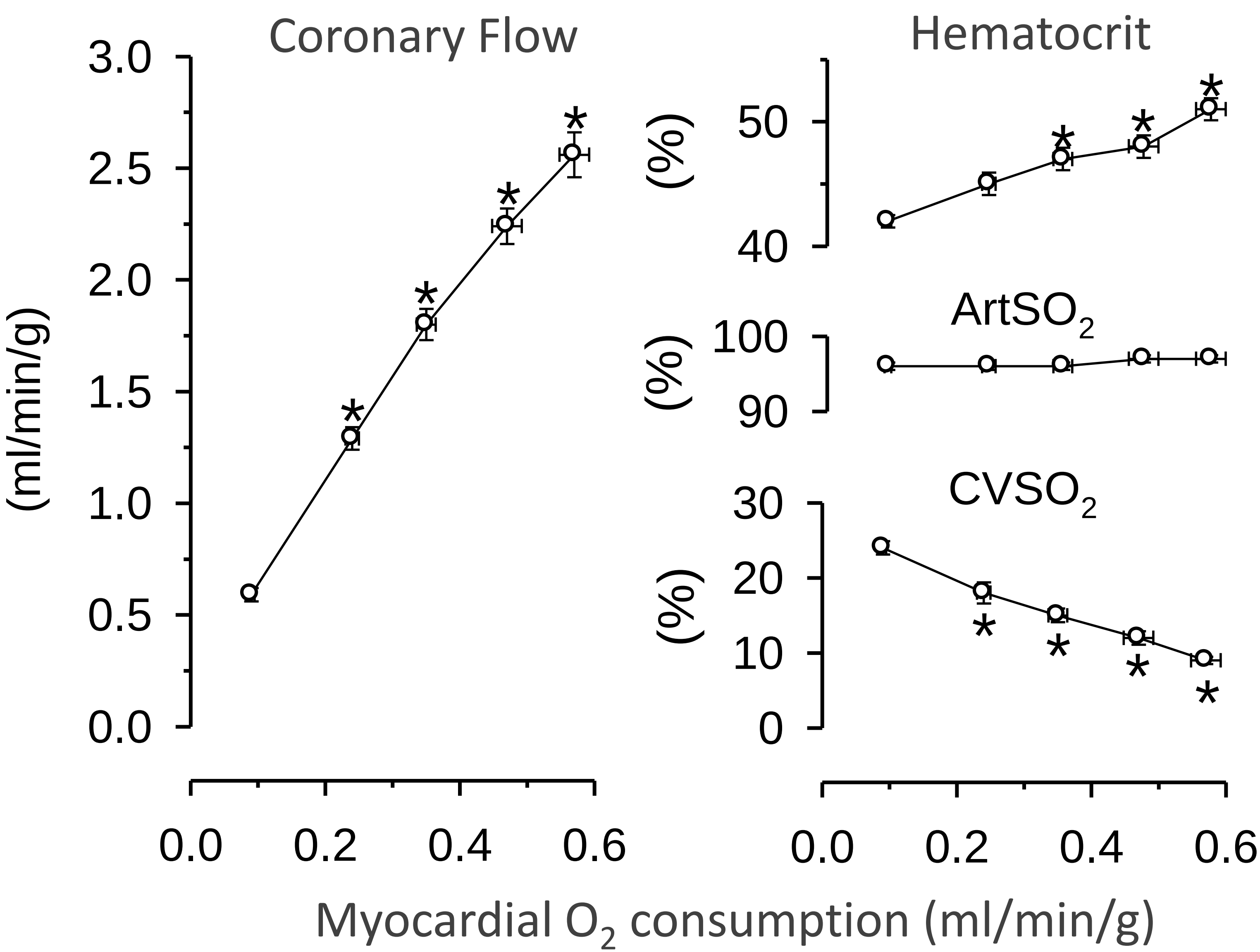
    Skeletal muscle 500-1000/mm2

  - High oxygen extraction

    Cardiac muscle 60-80%

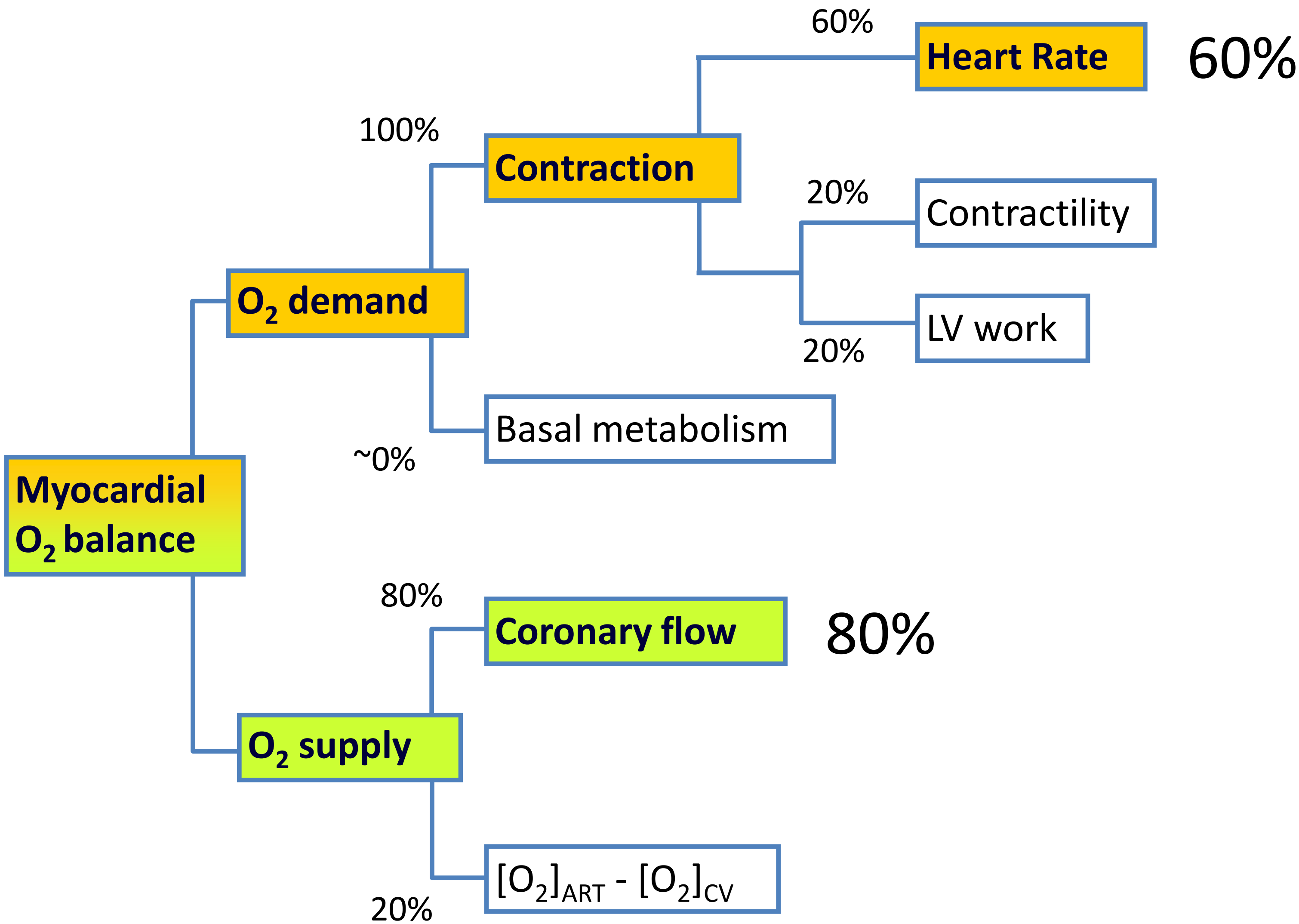
    Skeletal muscle 20-30%

Myocardial O_2 balance during exercise



Von Restorff et al Pfluegers Arch 1977

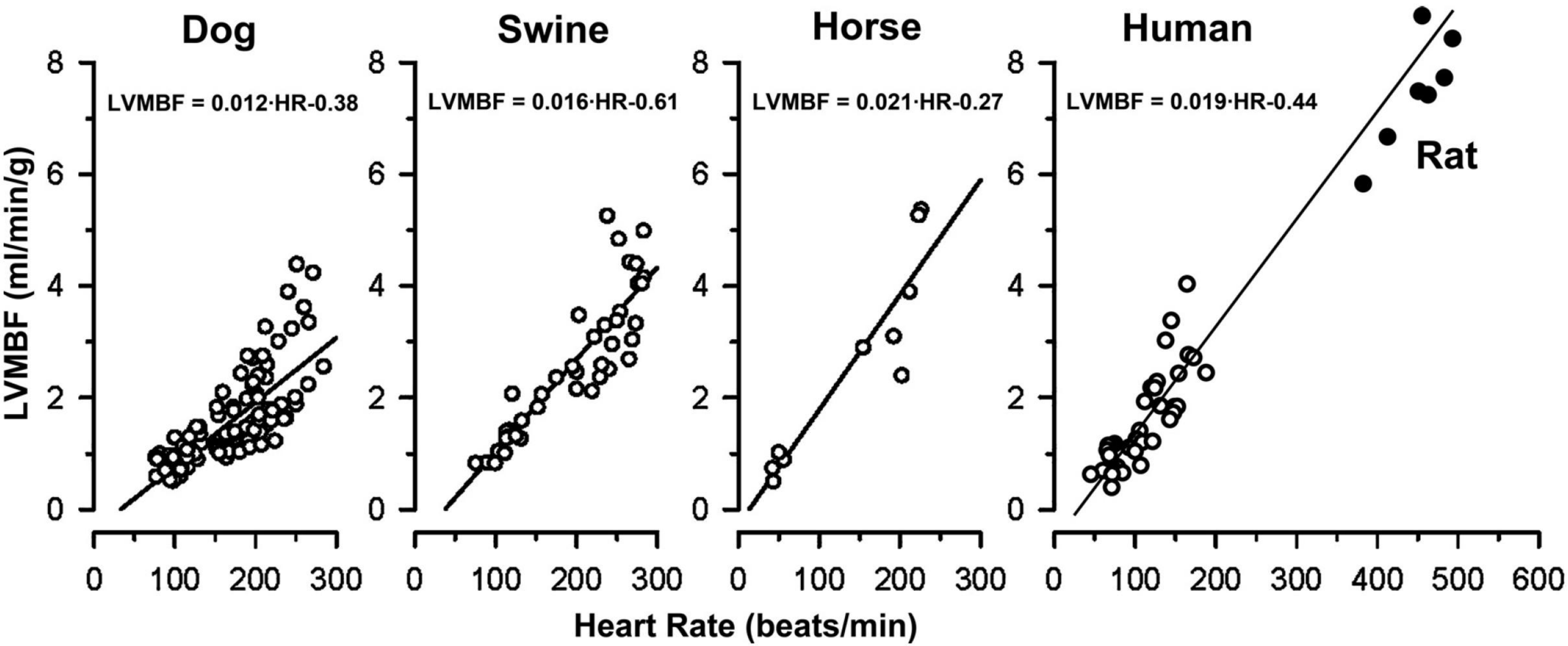
Myocardial O_2 balance during exercise



Duncker & Bache Physiol Reviews 2008

Metabolic Vasodilation

Exercise



LVMBF = LV Myocardial Blood Flow

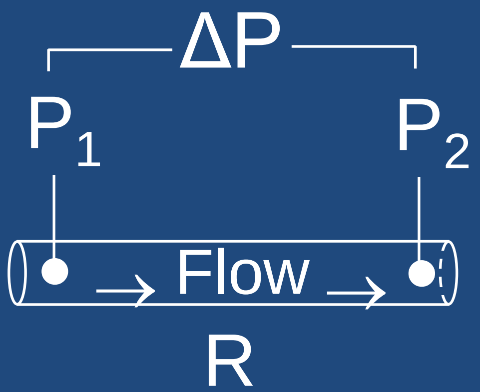
Laughlin, Davis,…., Bache, Merkus, Duncker Compr Physiol 2012

Laws of Hemodynamics

- Darcy's law

$$\Delta P = \text{Flow} \times R$$

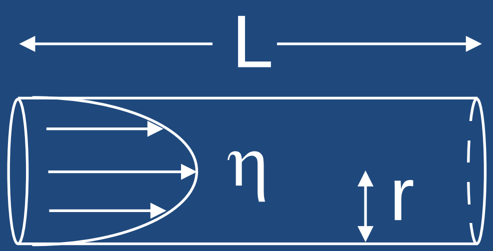
$$\text{Flow} = \frac{\Delta P}{R}$$



P = pressure
R = resistance

- Poiseuille's law

$$R = \frac{8\,\eta\,L}{\pi\,r^4}$$



L = length
r = radius
η = viscosity
R = resistance

JR Levick An Introduction to Cardiovascular Physiology 2010

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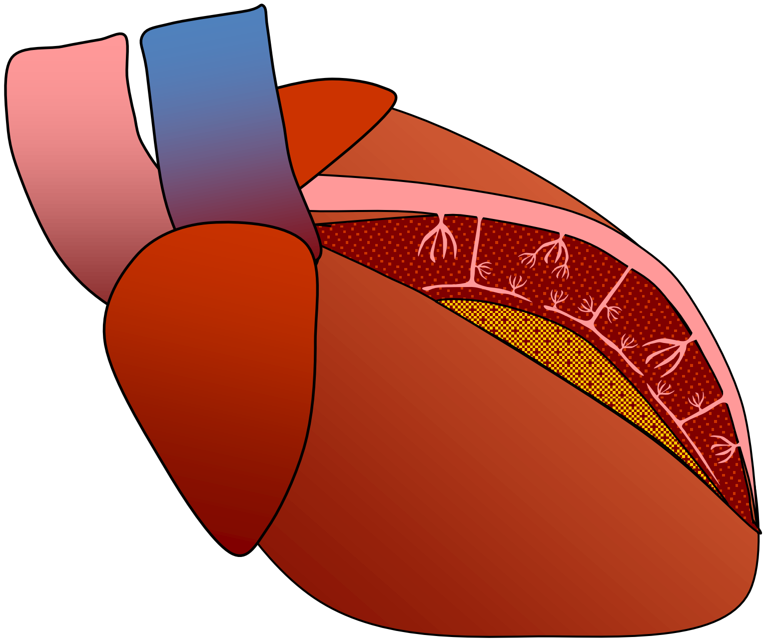
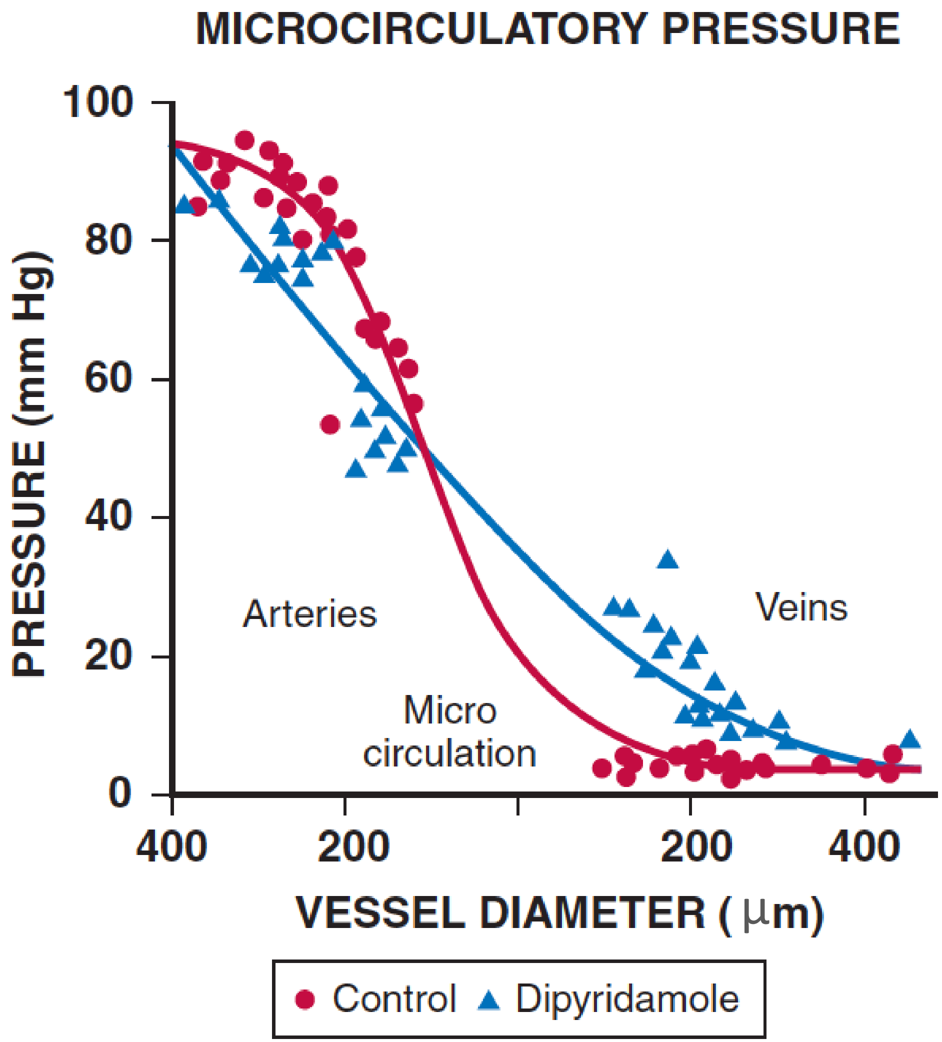
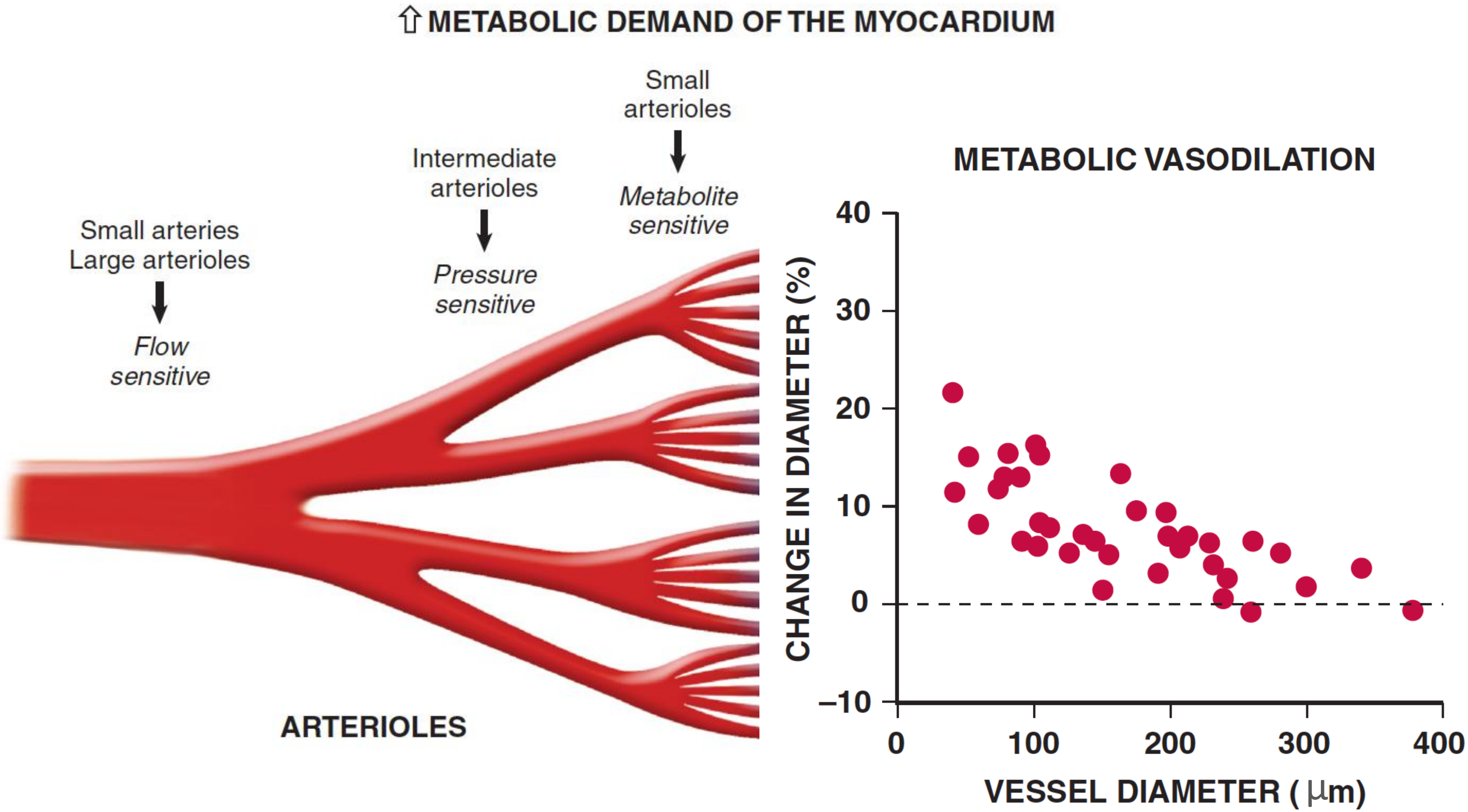
Distribution of Resistance in Coronary Microcirculation





Chilian et al Am J Physiol 1989



Davis et al APS Handbook of Physiology 2008

Zhang, …, Chilian APS Handbook of Physiology 2008

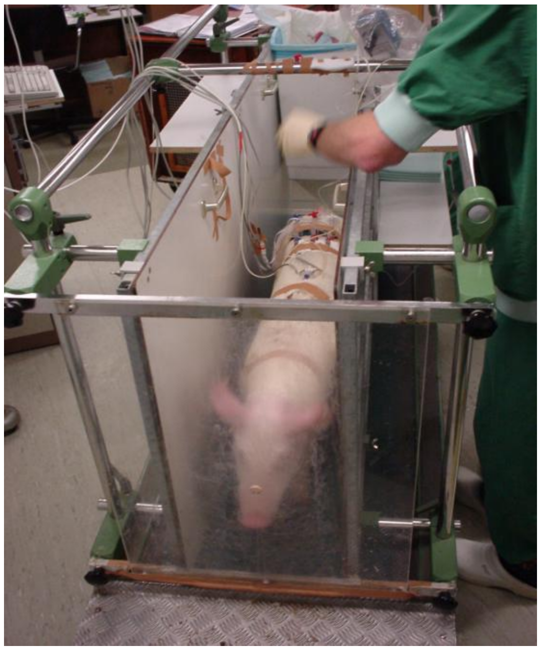
Control of tissue blood flow

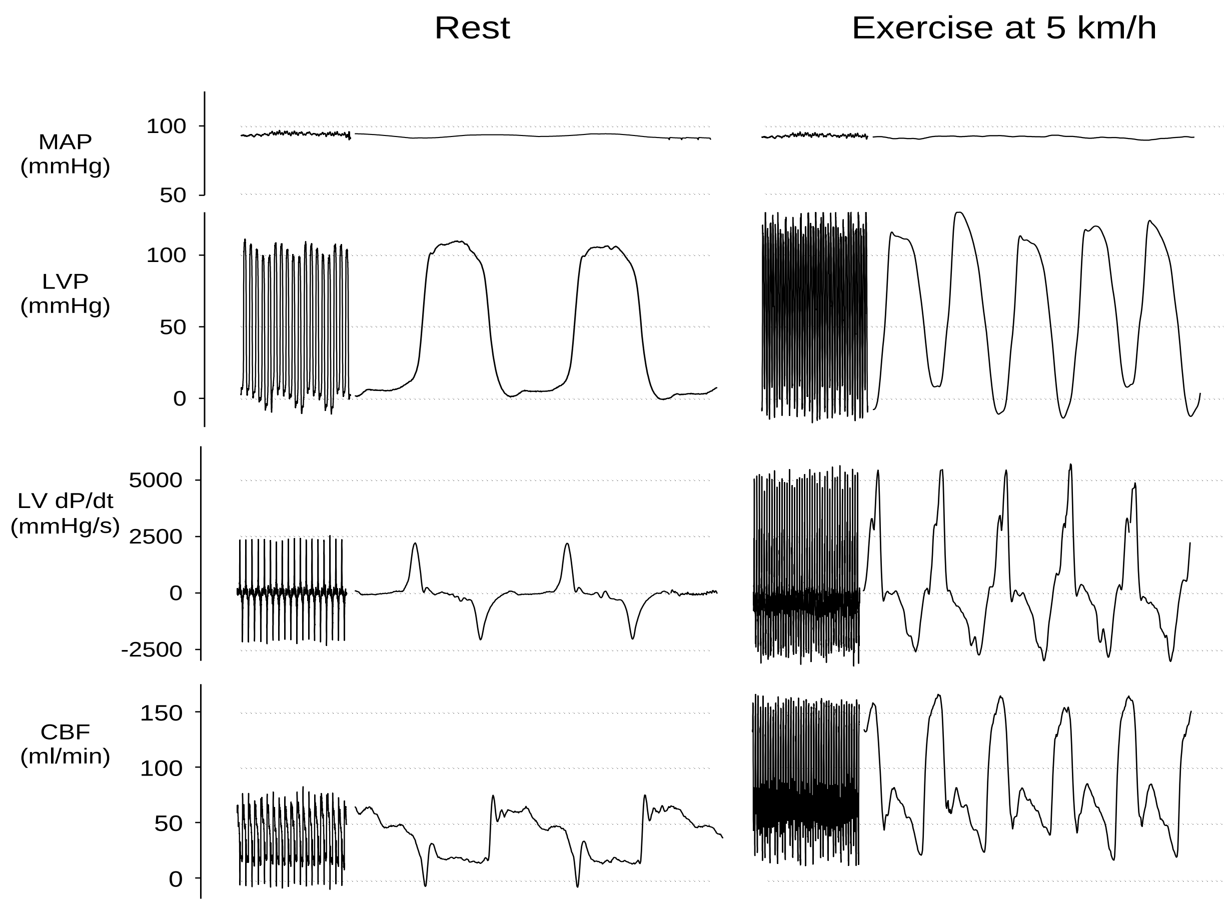
"Blood goes where it is needed"
John Hunter 1794

"He must have wondered how blood "knows" where it is needed?"
LB Rowell JAP 2004

The ultimate cardiac challenge

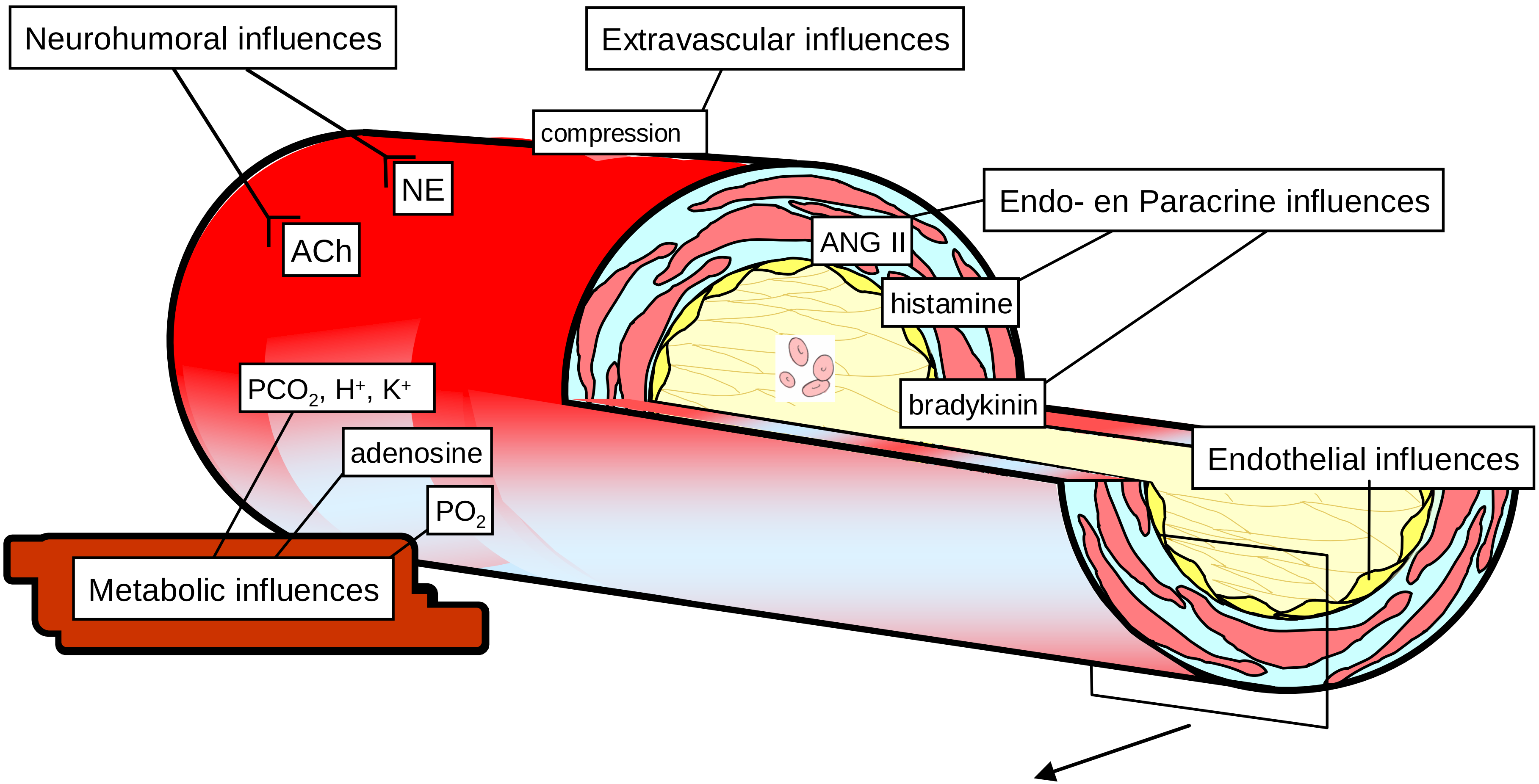
Exercise





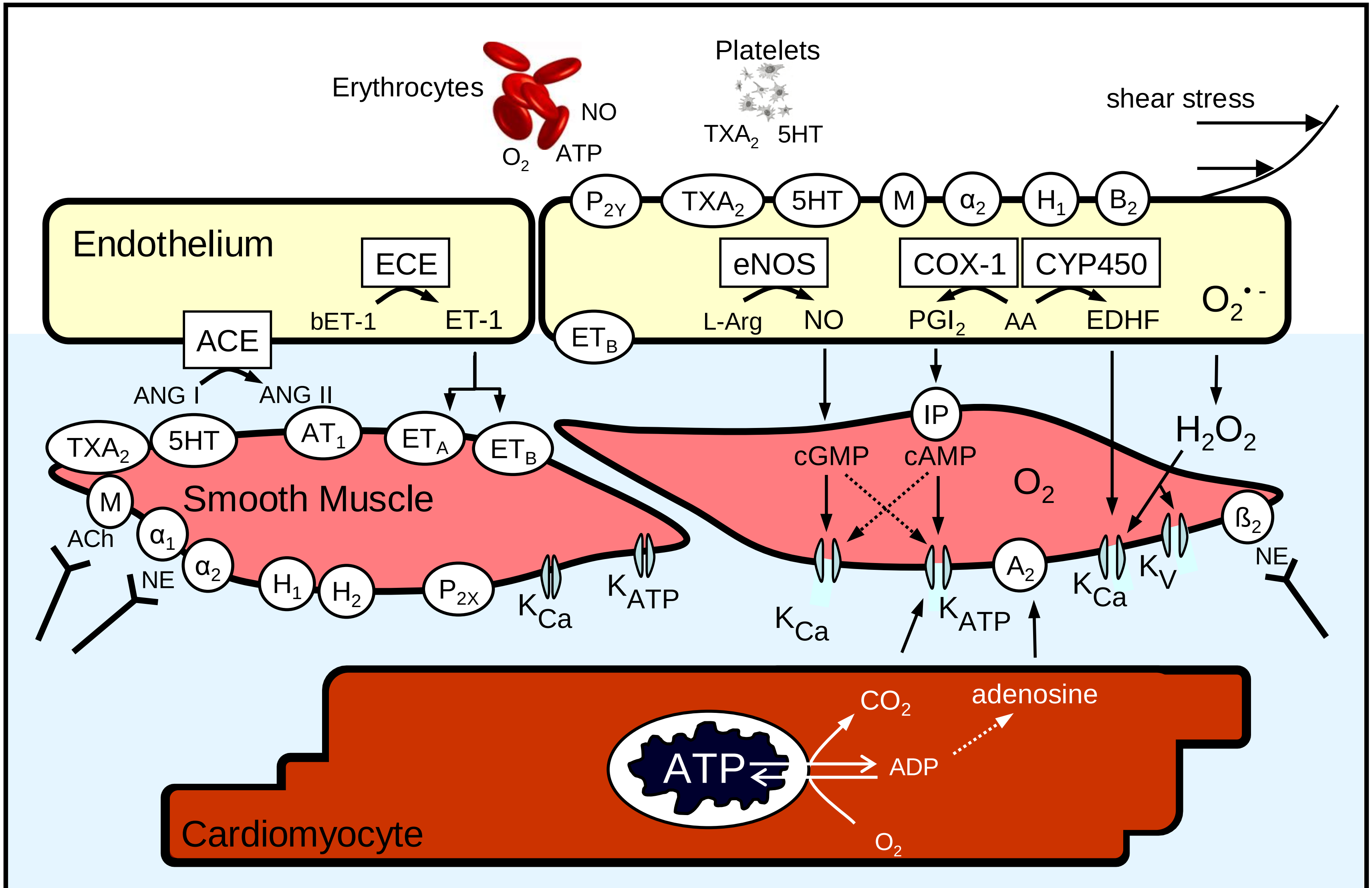
Duncker et al. Circ Res 1998
Duncker & Merkus J Physiol 2007
Duncker & Bache Physiol Rev 2008
Laughlin, …, Duncker Compr Physiol 2012

Control of Coronary Microvascular Tone



Duncker & Bache Physiol Reviews 2008

Control of Coronary Microvascular Tone



Duncker & Bache Physiol Reviews 2008

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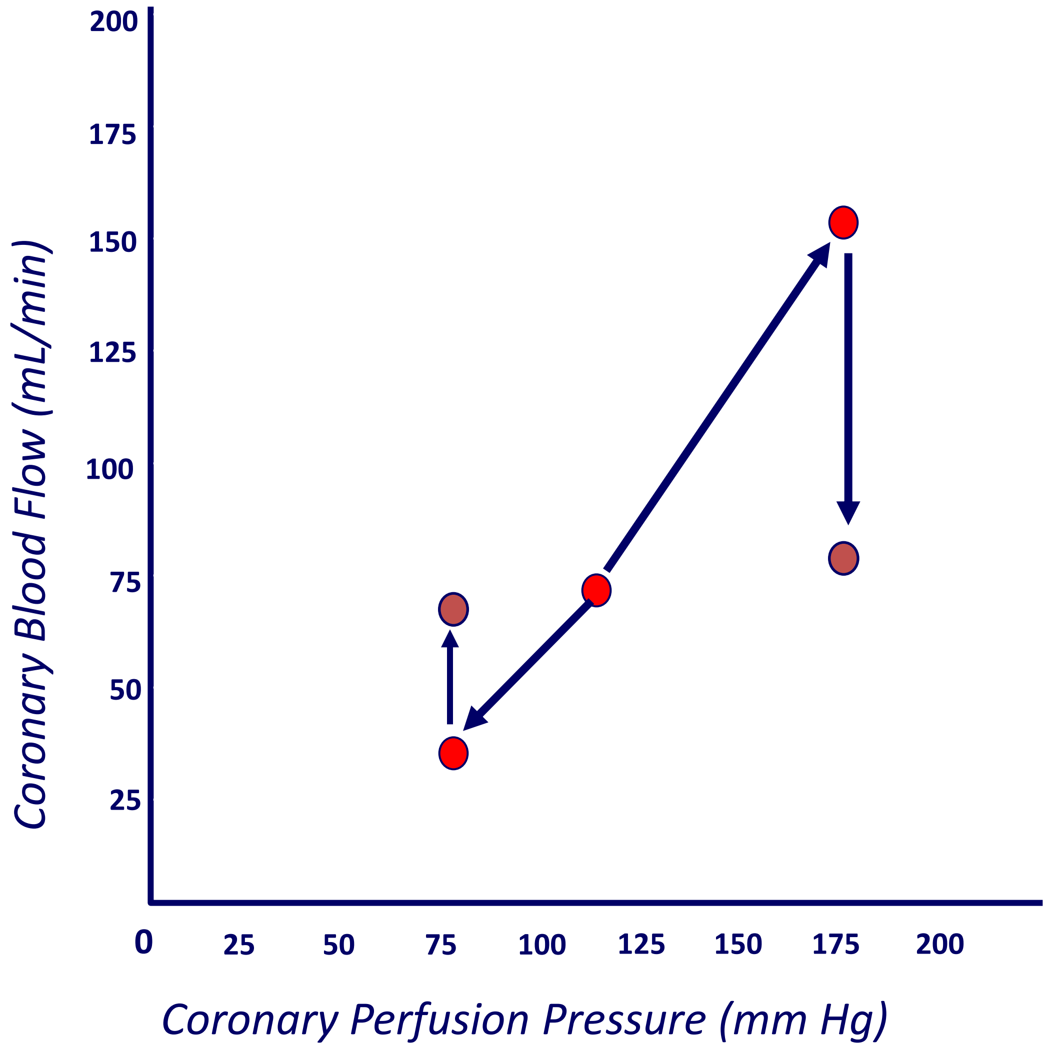
Autoregulation

The ability of the heart to maintain flow constant in the face of a change in perfusion pressure without the intervention of any other external mechanism

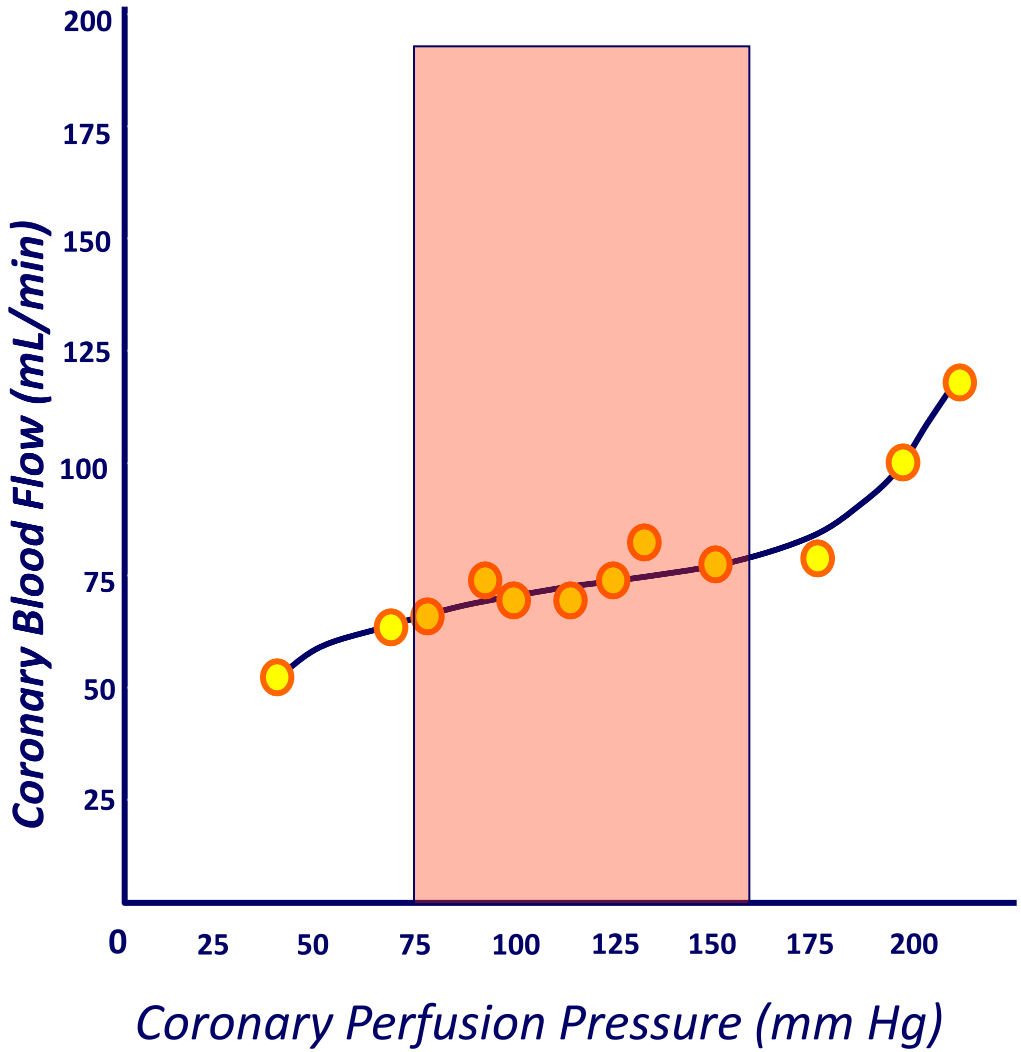
Coronary Autoregulation



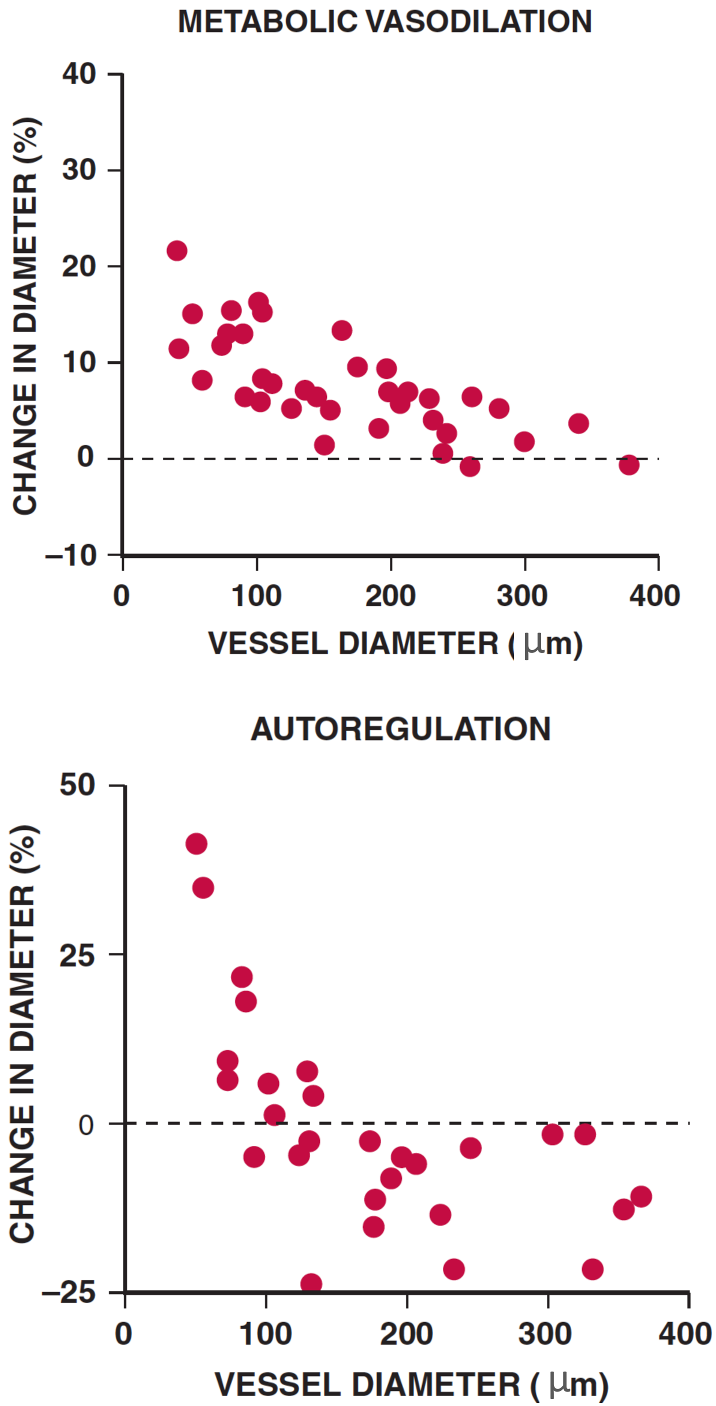
ETP April 24-26, 2014 (Courtesy of Bernard De Bruyne)

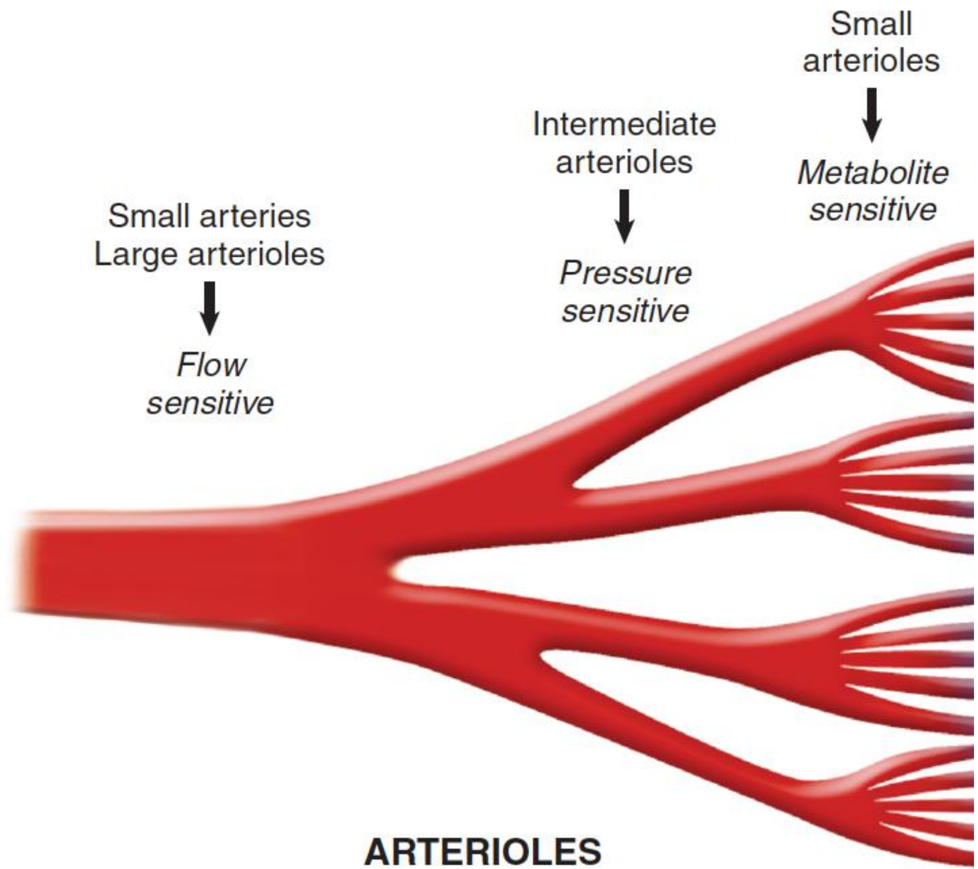
Rubio and Berne, Prog CV Disease 1975

Autoregulatory Range



Rubio and Berne, Prog CV Disease 1975

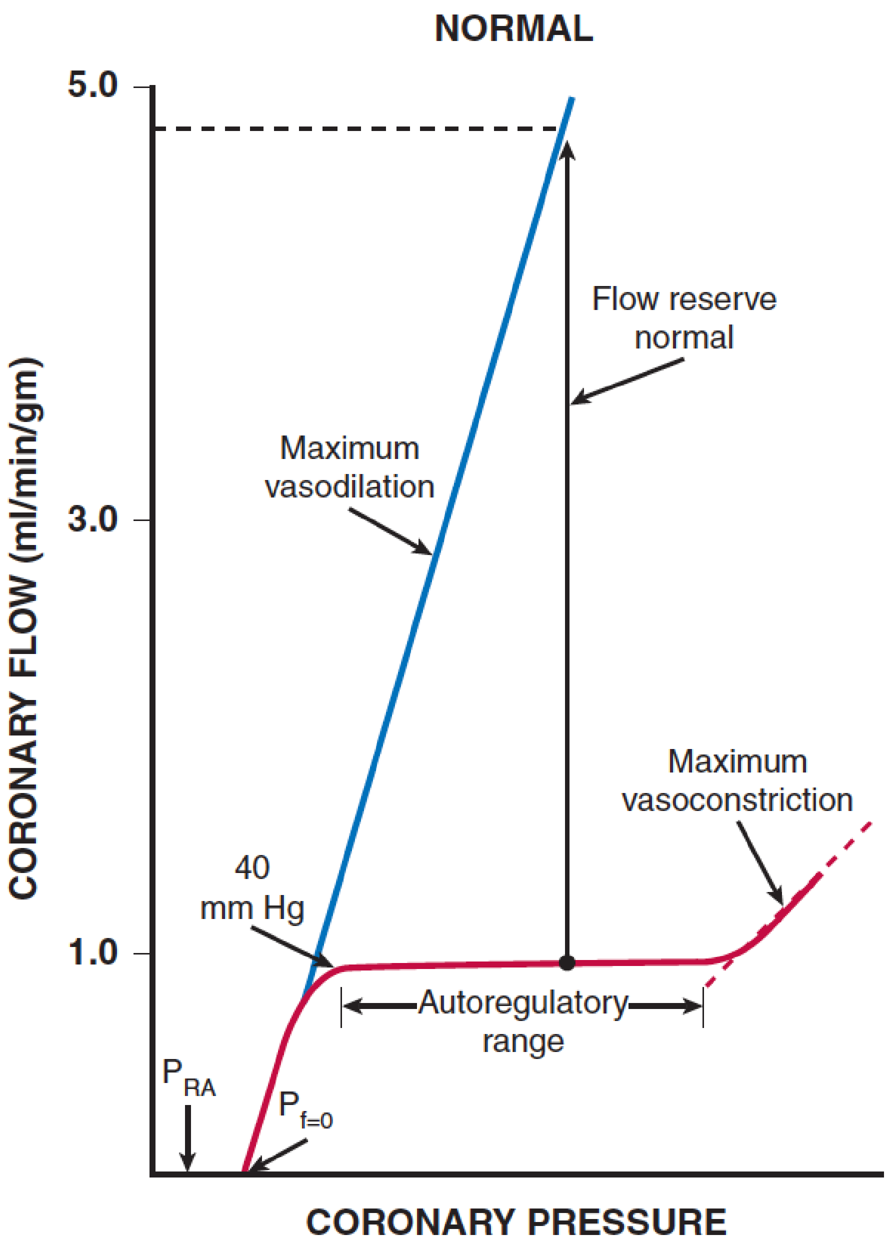




Davis et al APS Handbook of Physiology 2008

Zhang, Rogers, Merkus, … Chilian APS Handbook of Physiology 2008

Coronary Pressure-Flow Relation



ΔP = Flow x R

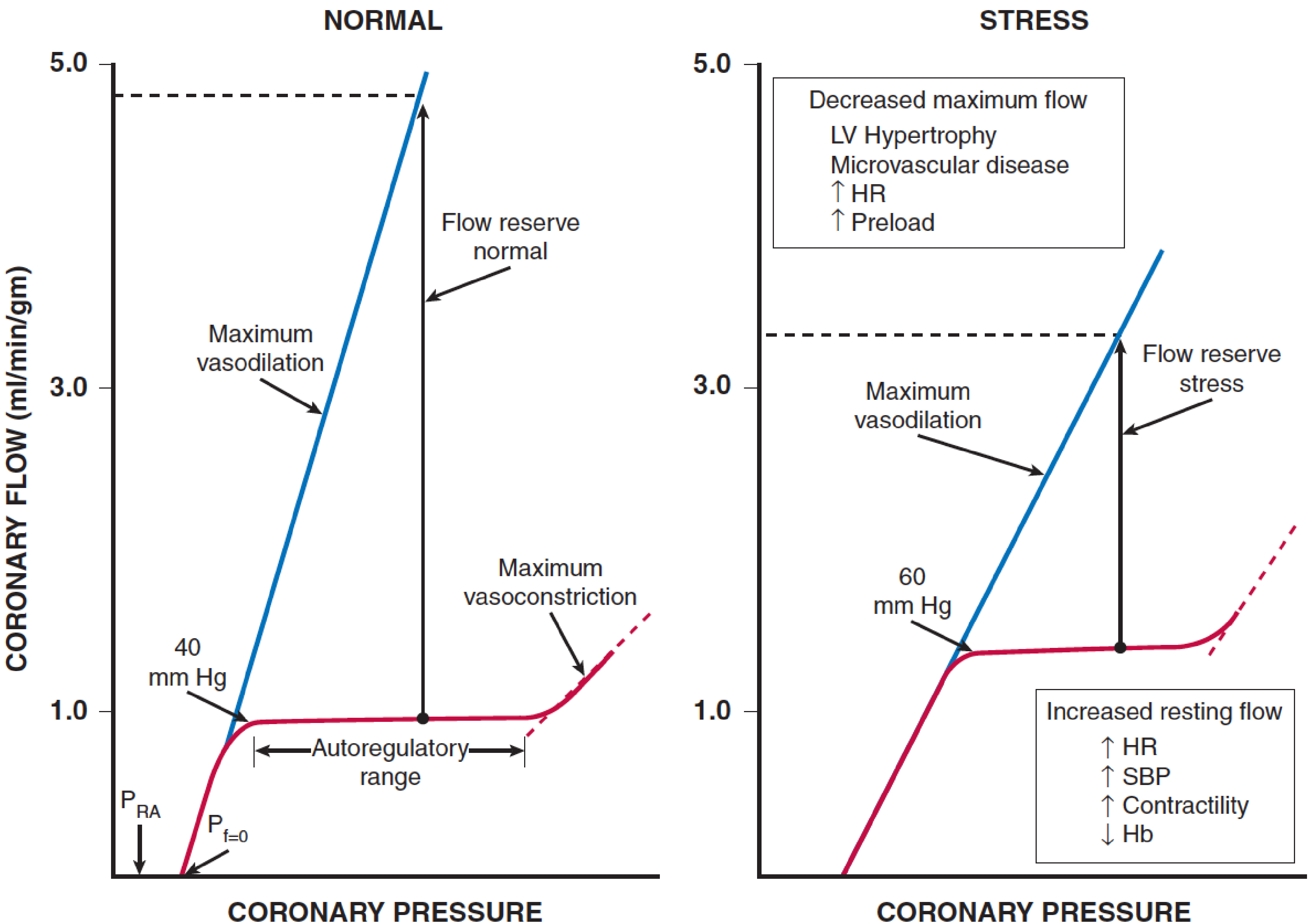
$R_{min} = \Delta P/Flow_{max}$

$C_{max} = 1/R_{min} = Flow_{max}/\Delta P$

P = pressure
R = resistance
C = conductance

Canty & Duncker Braunwald's Heart Disease 2014

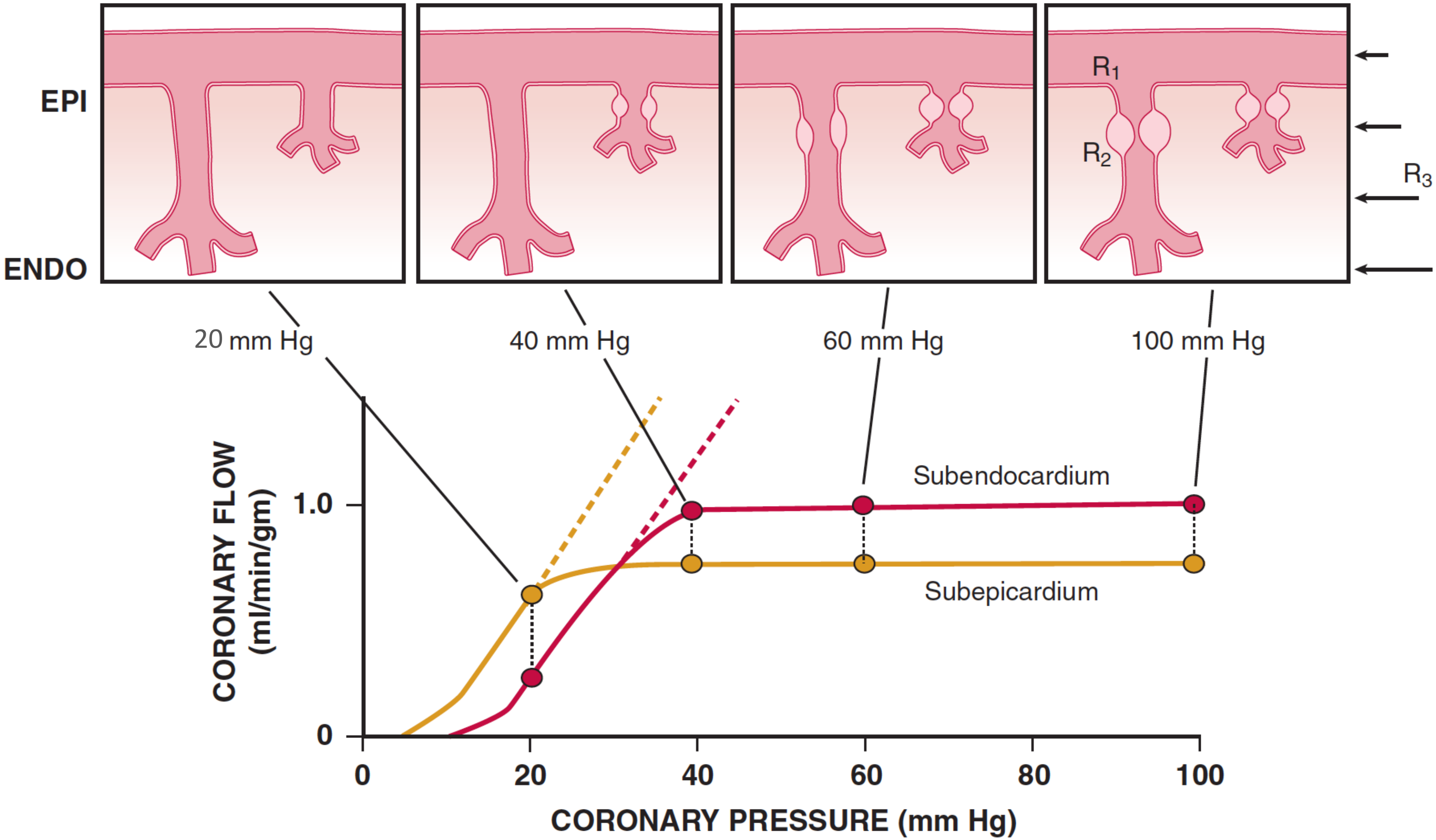
Coronary Pressure-Flow Relation



Canty & Duncker Braunwald's Heart Disease 2014

Coronary Pressure-Flow Relation

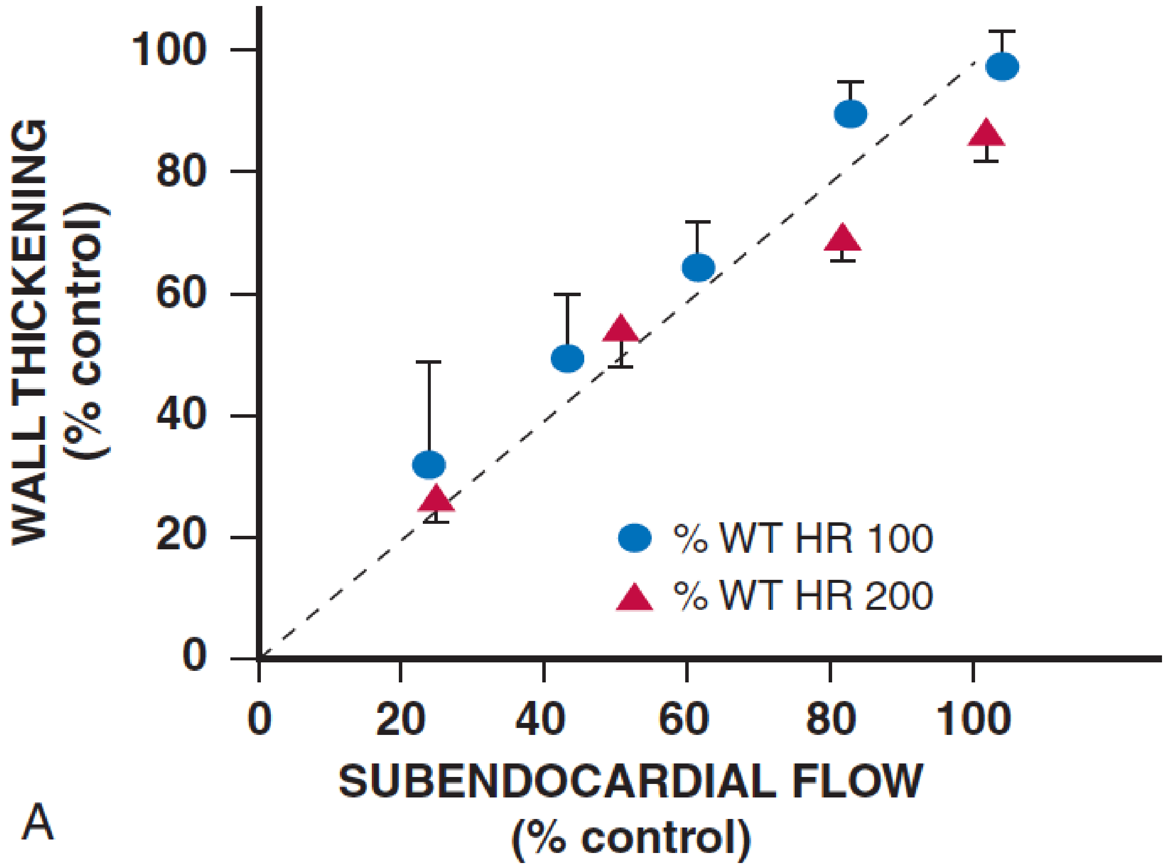
Subendocardial Vulnerability



Canty & Duncker Braunwald's Heart Disease 2014

Coronary Flow-Function Relation

Subendocardial vulnerability



Canty Circ Res 1988; Canty et al Circulation 1990

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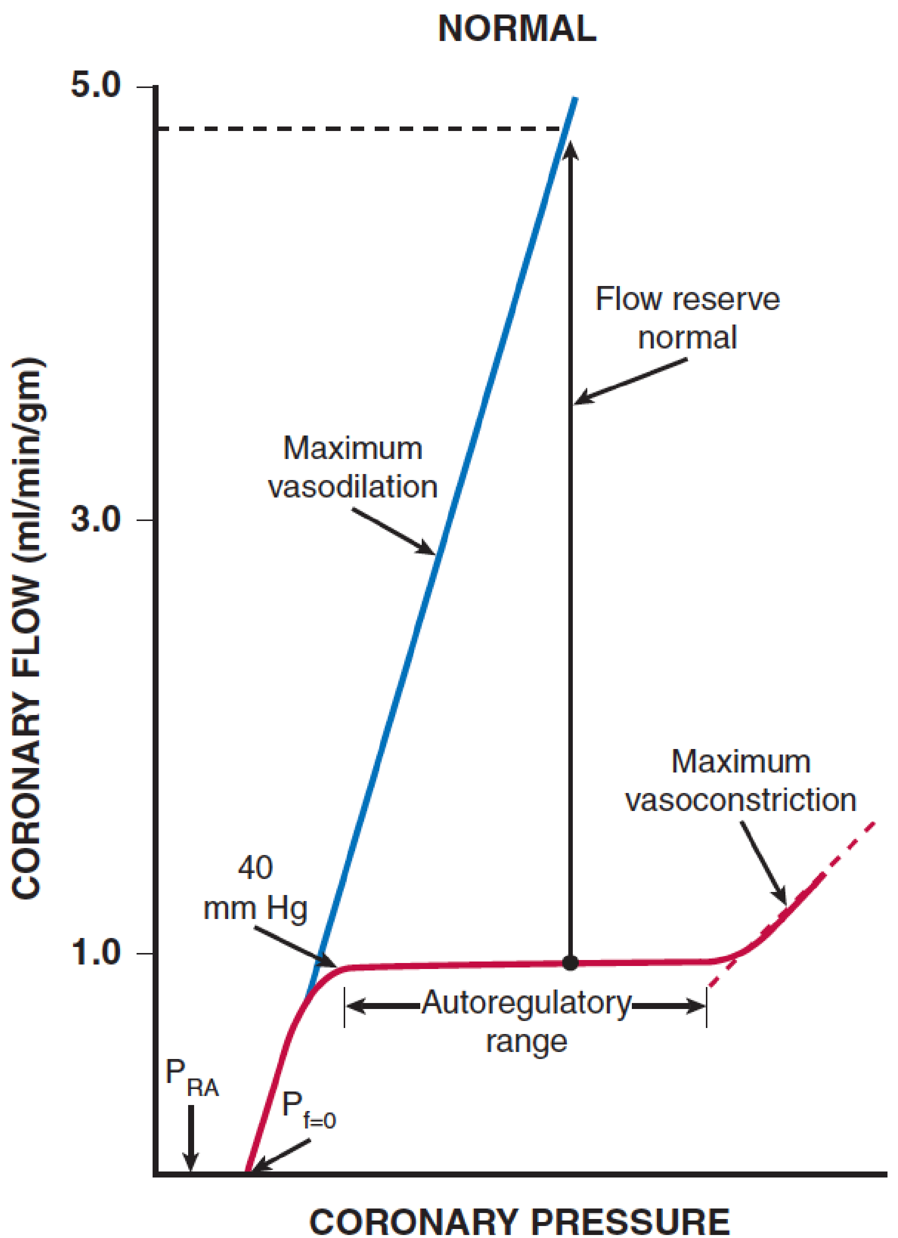

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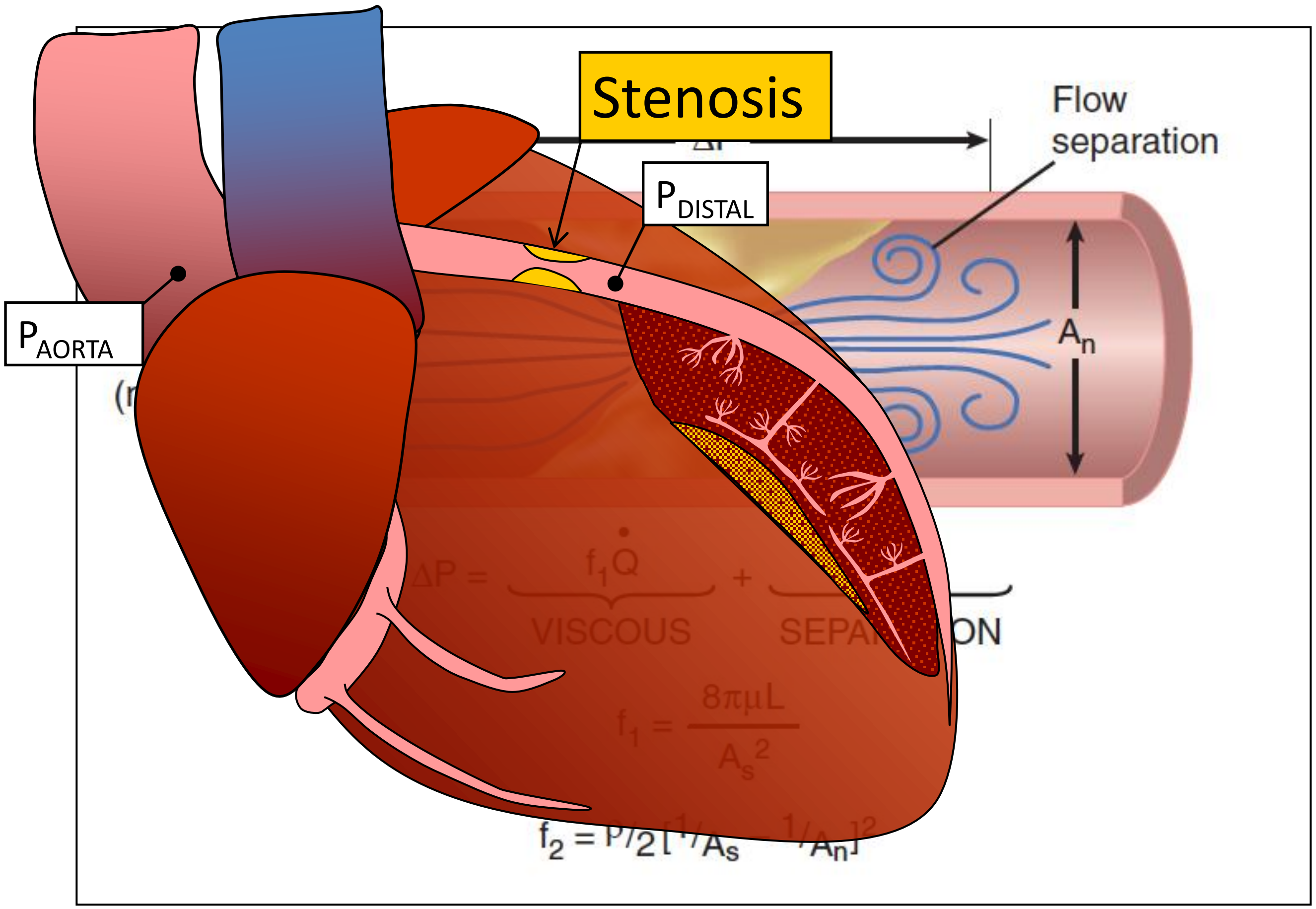
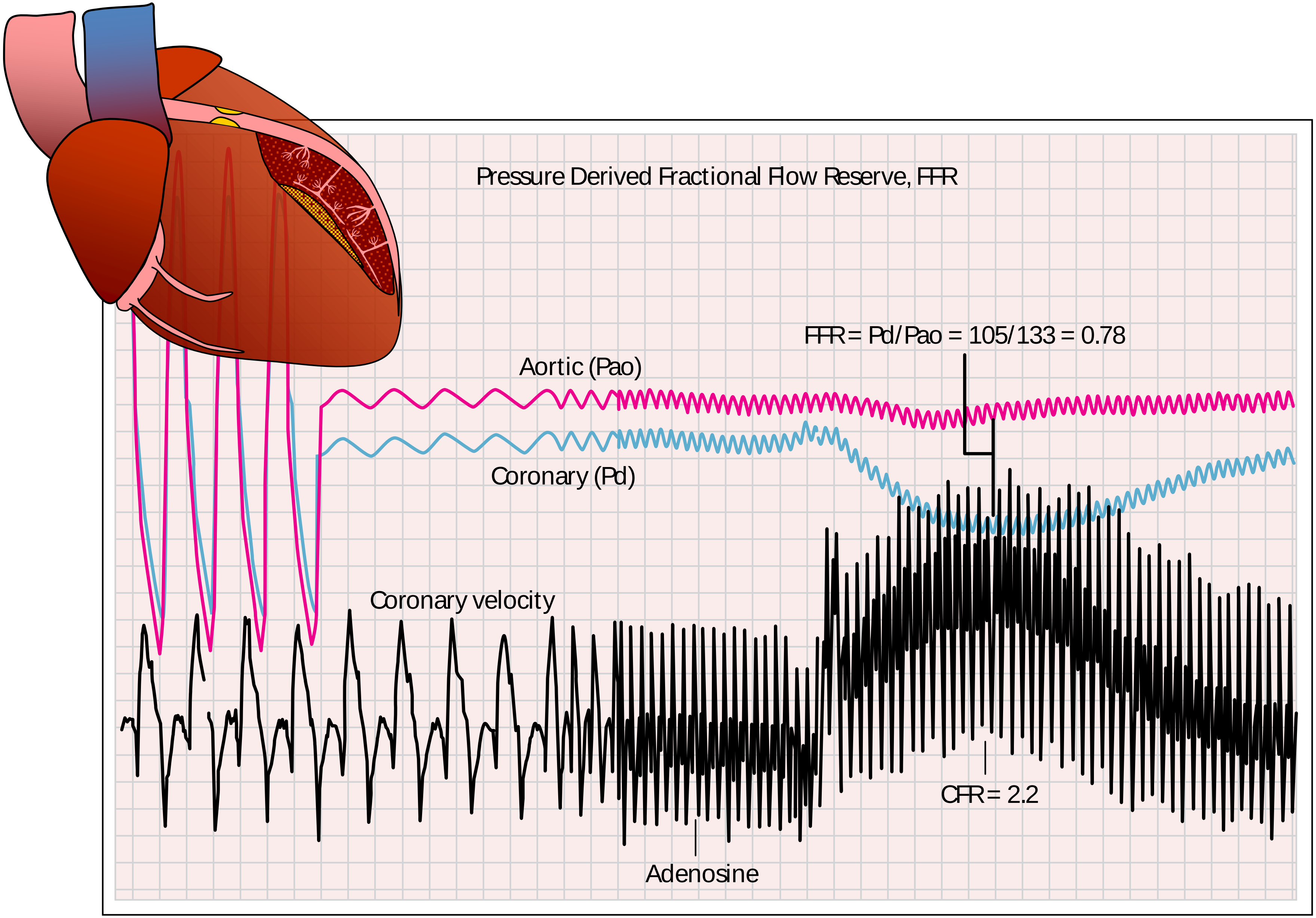
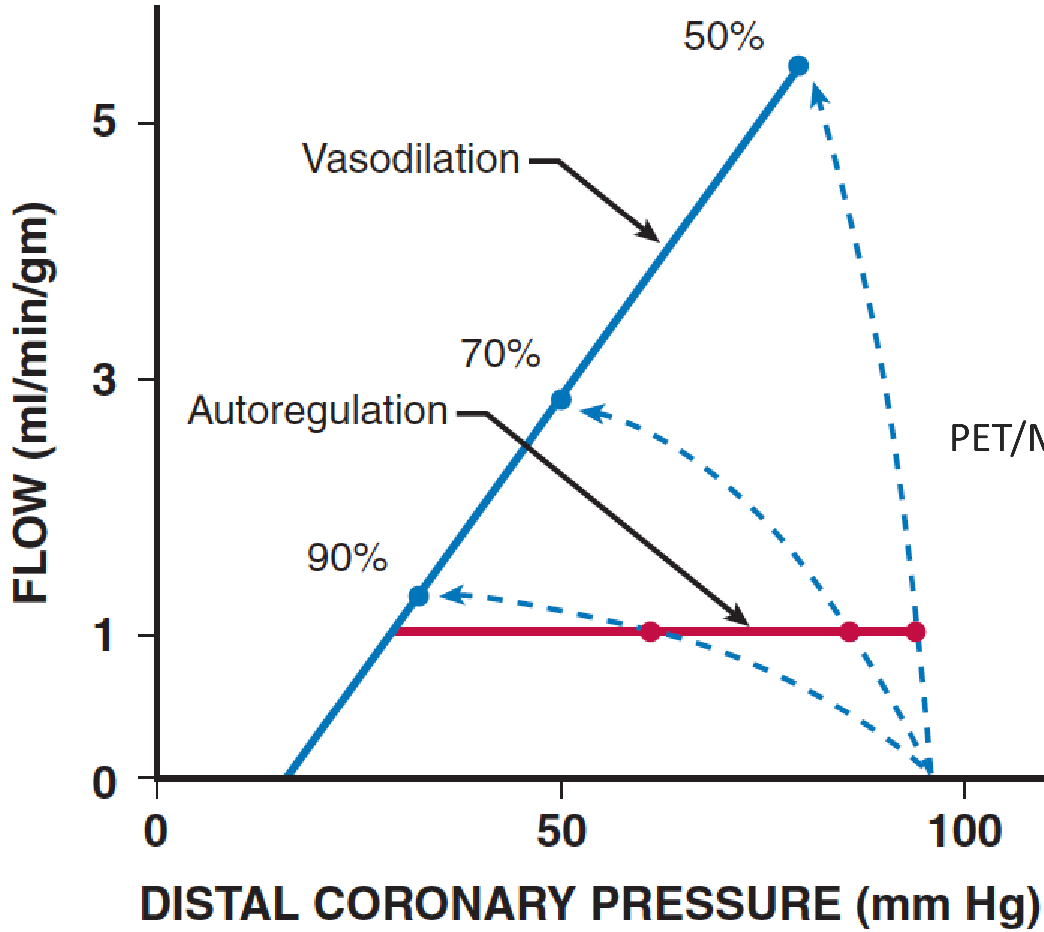

Stenosis
P_{DISTAL}
P_{AORTA}
Flow
separation
A_n
VISCOUS
$f_1 = \frac{8\pi\mu L}{A_s^2}$



Pressure Derived Fractional Flow Reserve, FFR
FFR = Pd/Pao = 105/133 = 0.78
Aortic (Pao)
Coronary (Pd)
Coronary velocity
CFR = 2.2
Adenosine

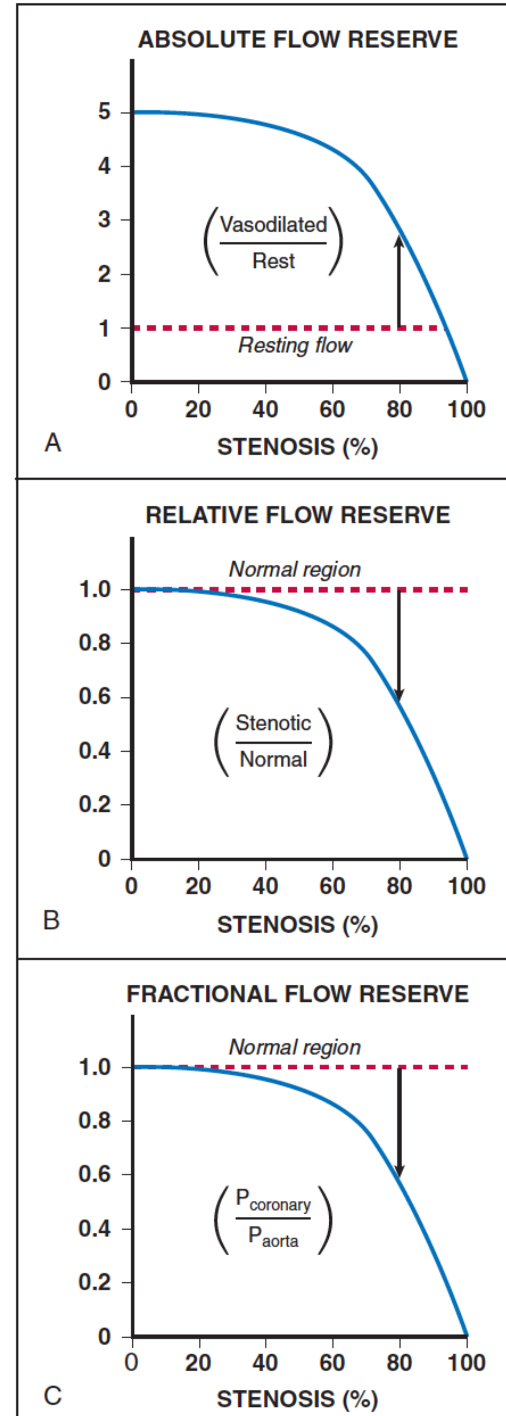
Assessment of Coronary Reserve



Flow velocity wire

PET/MRI/CT Perfusion

Pressure wire



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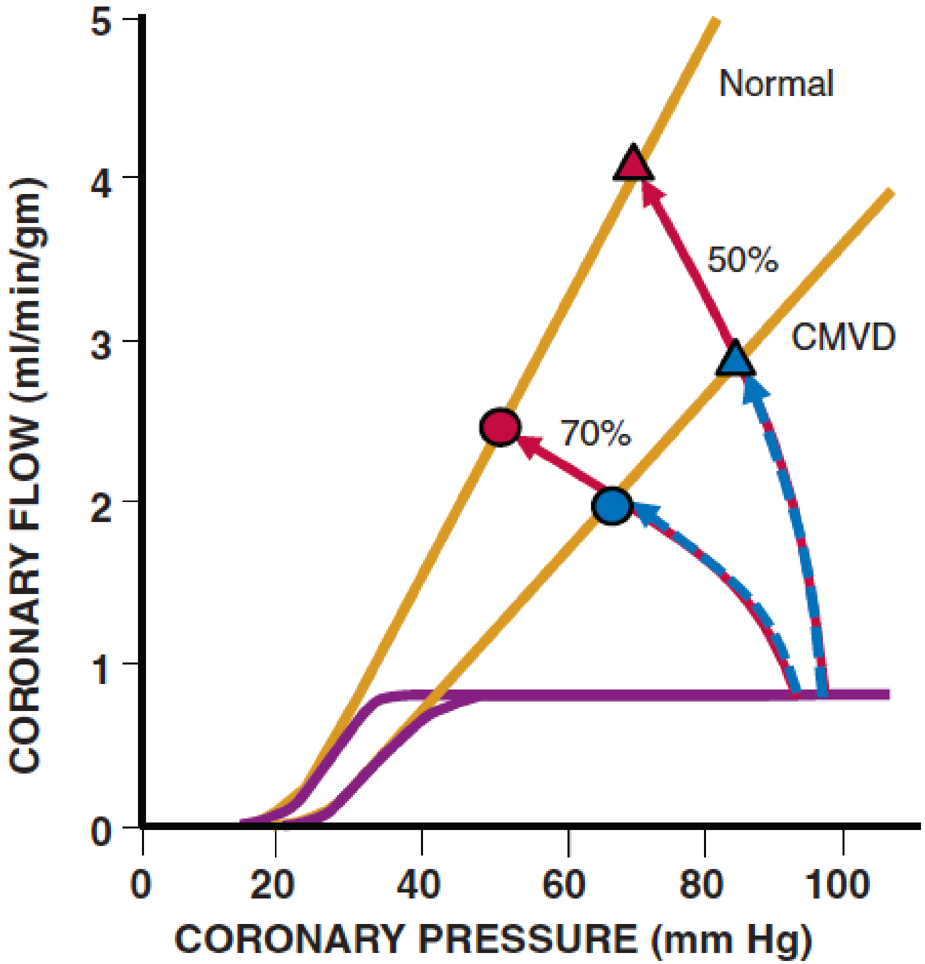
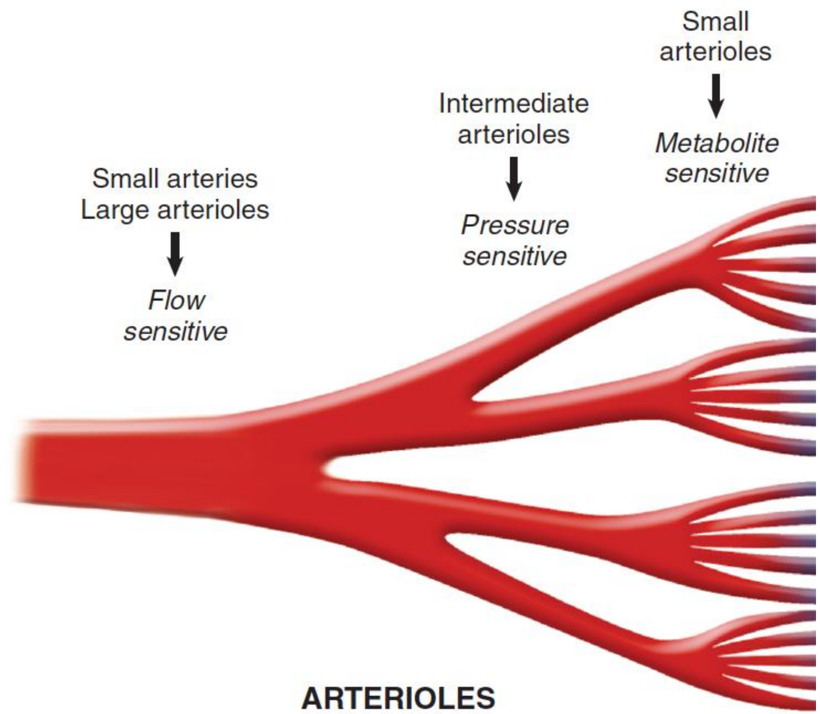
Coronary Pressure-Flow Relation

Influence of Coronary Microvascular Disease





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