

Regulation of Coronary Blood Flow

23-04-2015

Dirk J. Duncker

Div Experimental Cardiology, Thoraxcenter

Erasmus MC, University Medical Center Rotterdam

The Netherlands

Regulation of Coronary Blood Flow

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

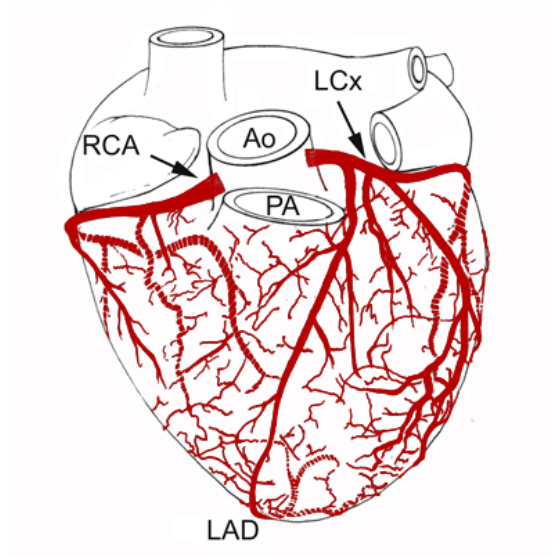
Duncker & Bache *Physiol Rev* 2008

Van de Hoeff et al *J Mol Cell Cardiol* 2012

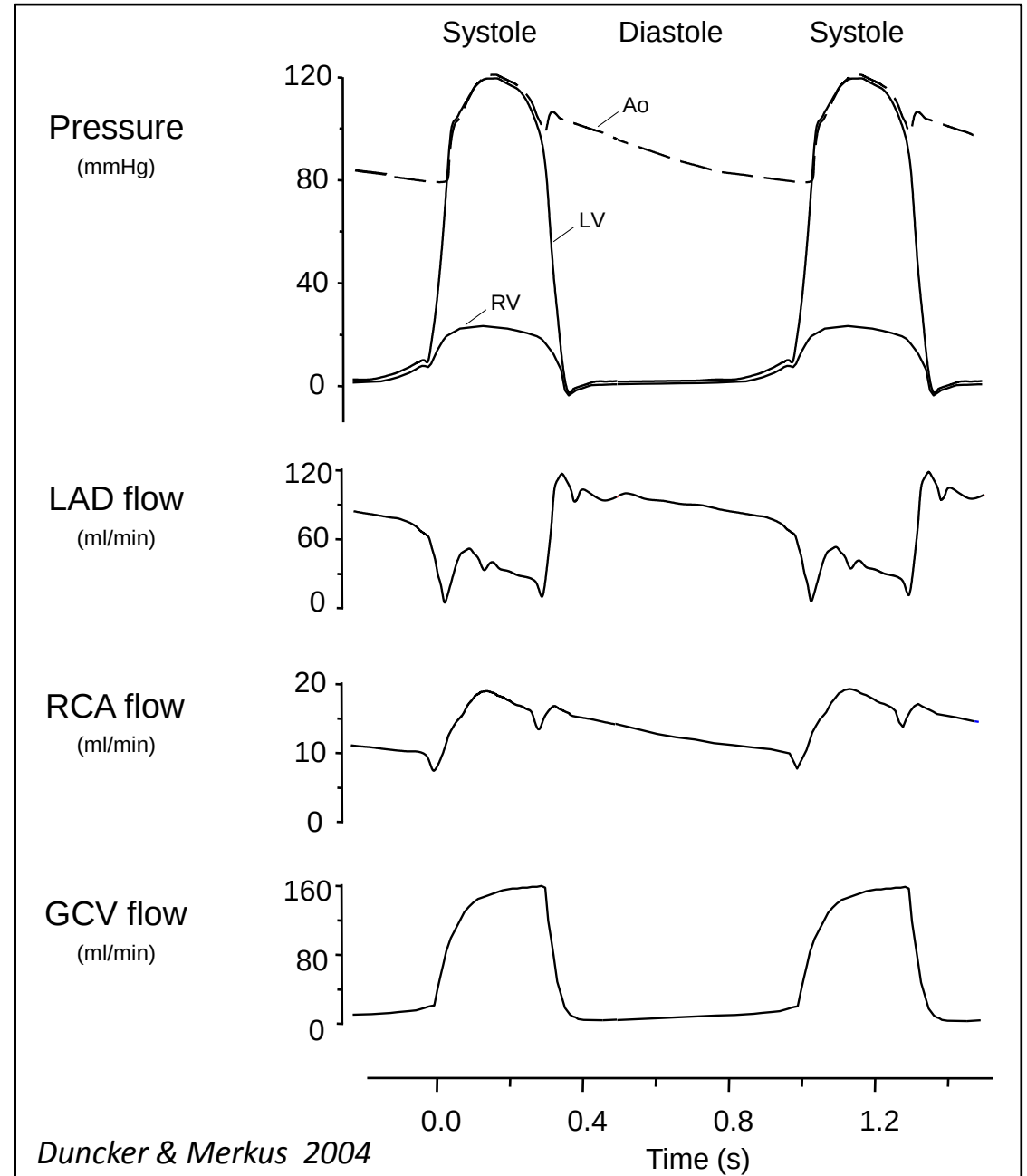
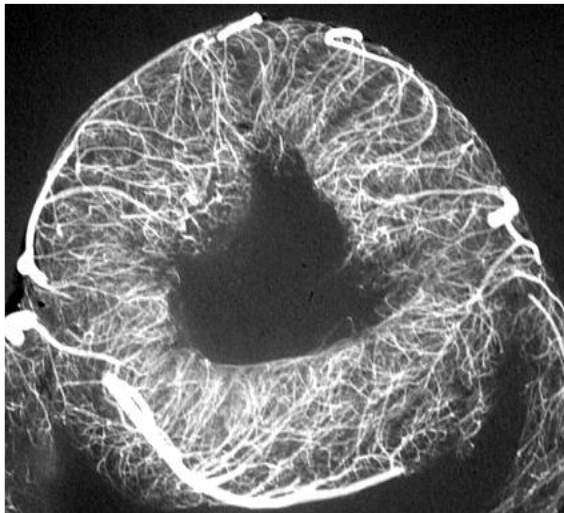
Laughlin et al *Compr Physiol* 2012

Duncker et al *Prog Cardiovasc Dis* 2015

Cyclic Compression of the Coronary Microvasculature



Courtesy of Harold Laughlin



Unique aspects of the coronary circulation

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

Cardiac muscle flow 1.0 ml/min/g

Skeletal muscle flow 0.1 ml/min/g

- High myocardial capillary density

Cardiac muscle 3000-4000/mm²

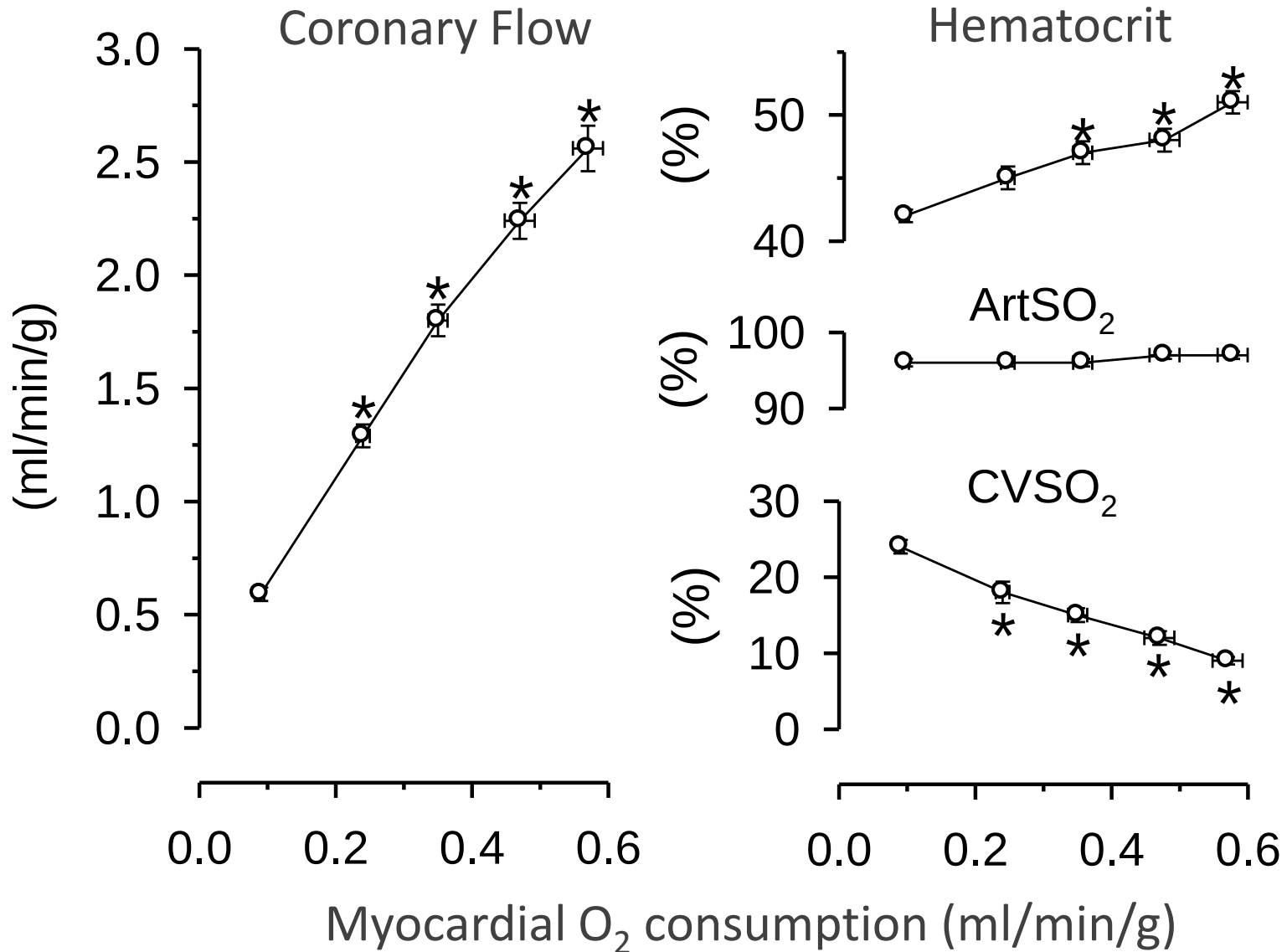
Skeletal muscle 500-1000/mm²

- High myocardial oxygen extraction

Cardiac muscle 60-80%

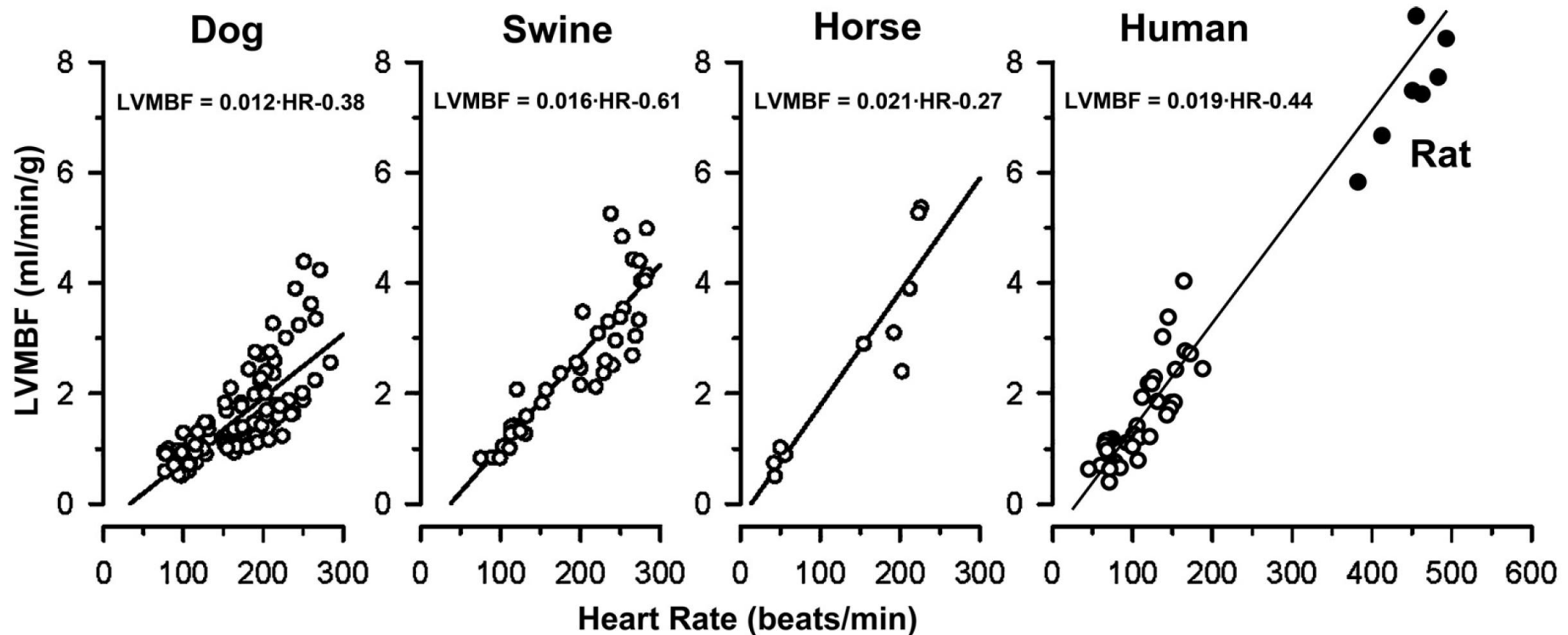
Skeletal muscle 20-30%

Myocardial O₂ balance during exercise



Metabolic Vasodilation

Exercise



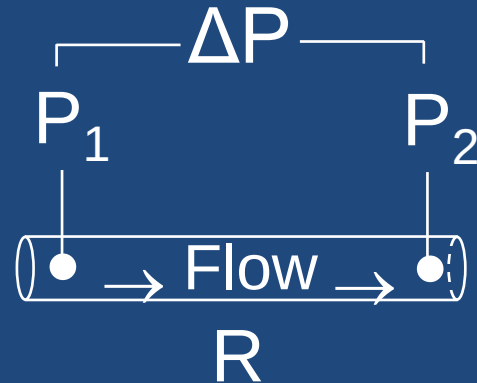
LVMBF = LV Myocardial Blood Flow

Laws of Hemodynamics

- Darcy's law

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

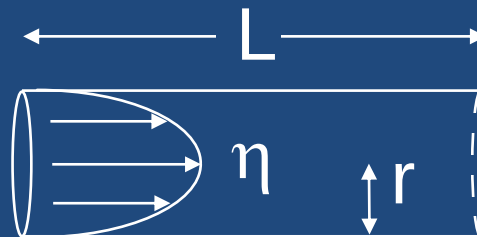
$$\text{Flow} = \frac{\Delta P}{R}$$



P = pressure
R = resistance

- Poiseuille's law

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



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

Regulation of Coronary Blood Flow

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

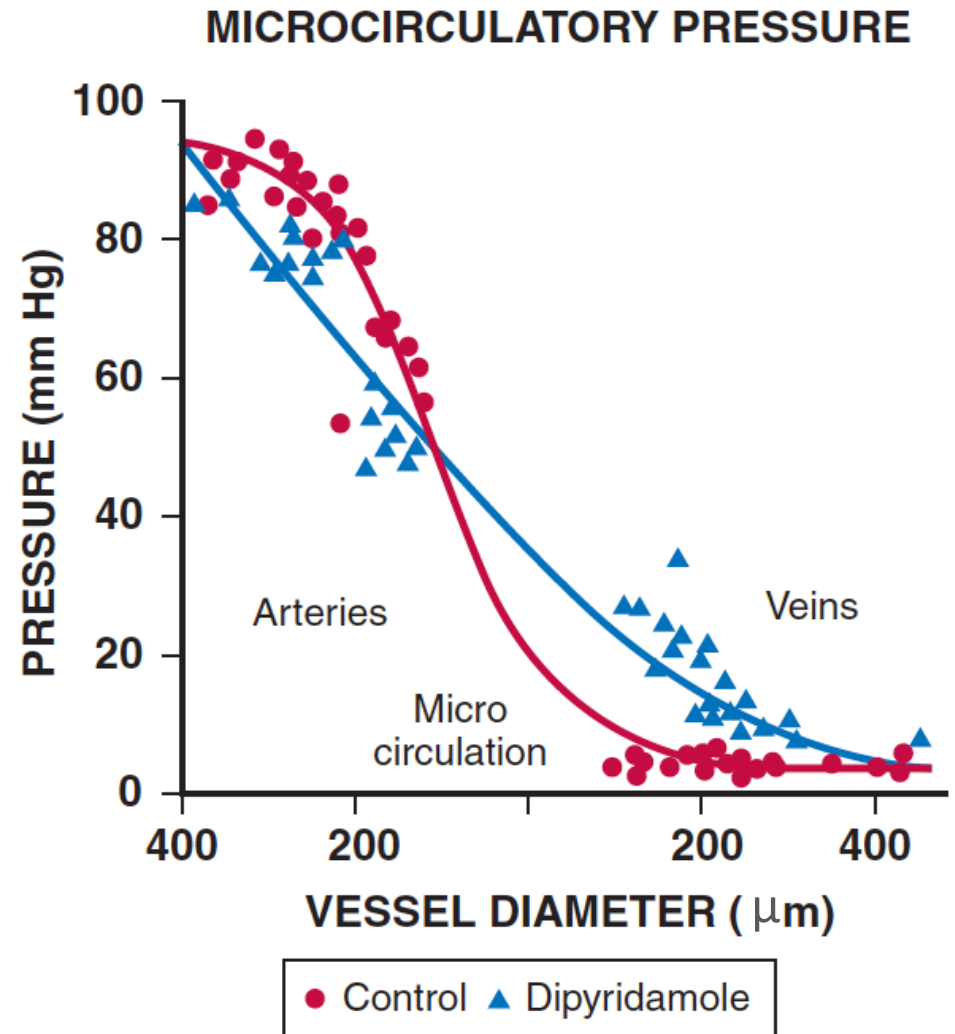
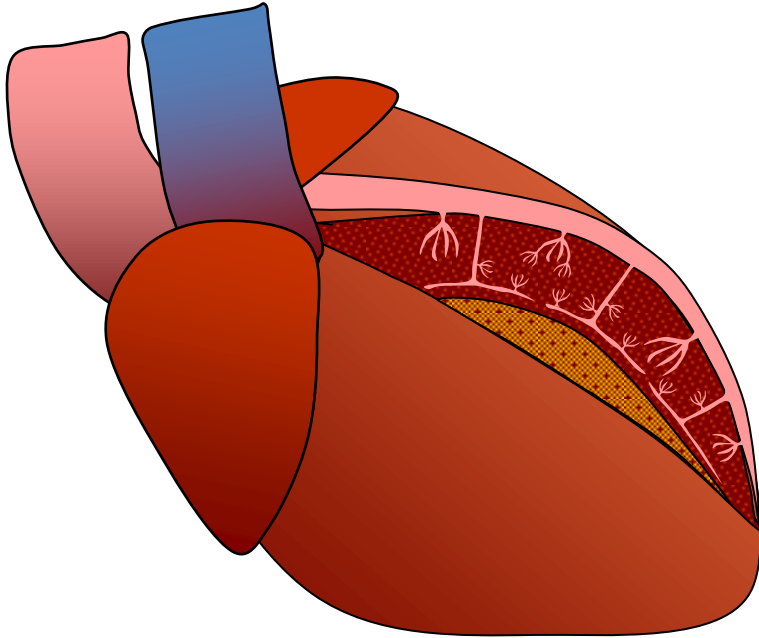
Duncker & Bache *Physiol Rev* 2008

Van de Hoeff et al *J Mol Cell Cardiol* 2012

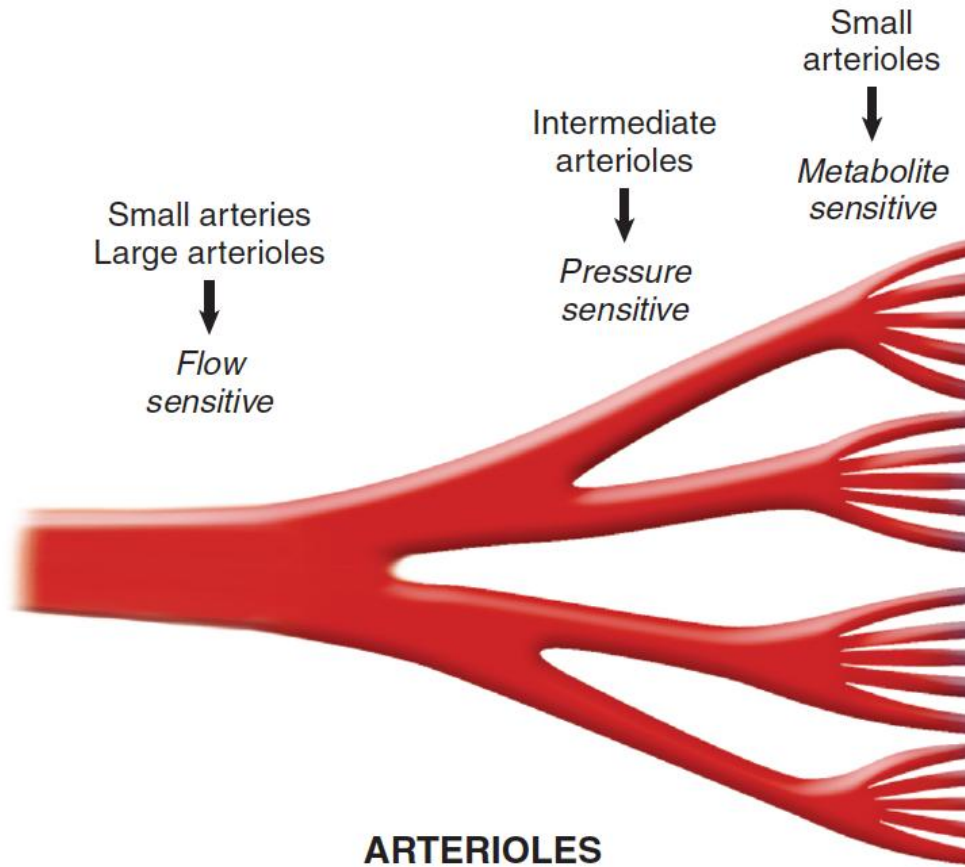
Laughlin et al *Compr Physiol* 2012

Duncker et al *Prog Cardiovasc Dis* 2015

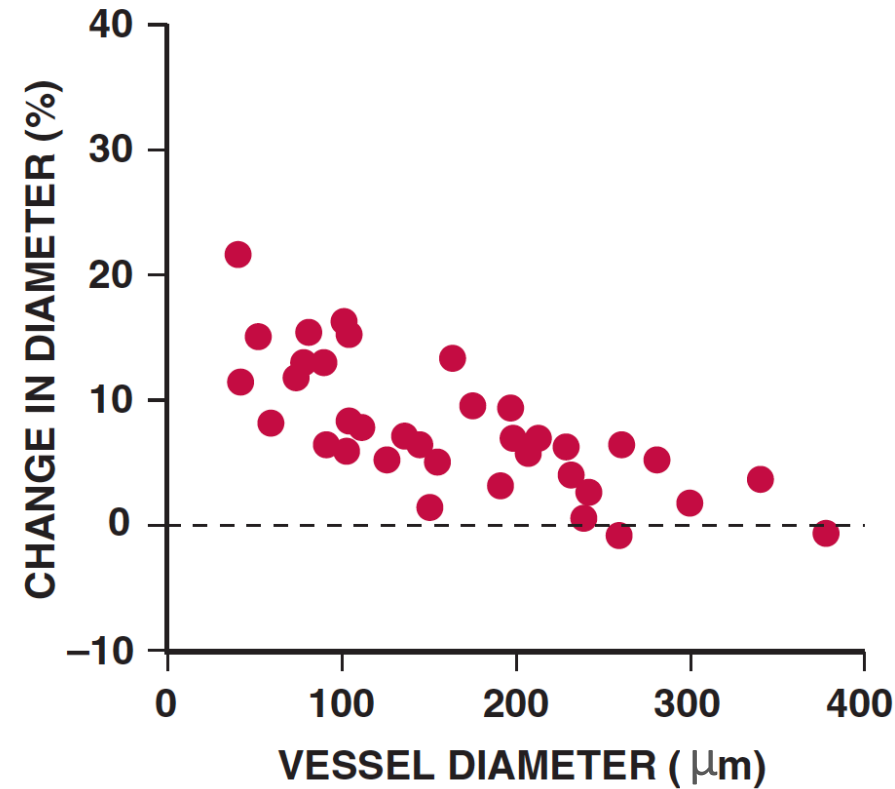
Distribution of Resistance in Coronary Microcirculation



↑ METABOLIC DEMAND OF THE MYOCARDIUM



METABOLIC VASODILATION



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”

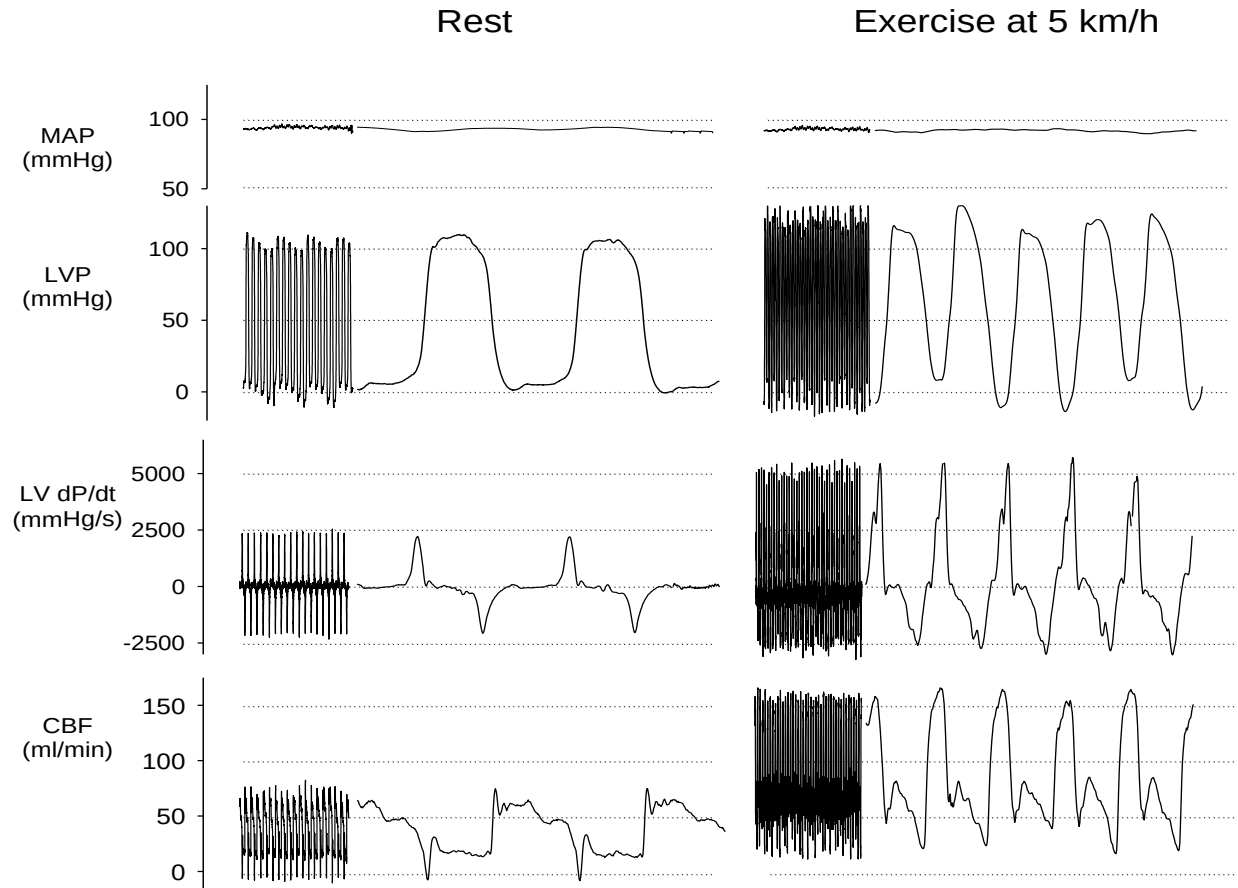
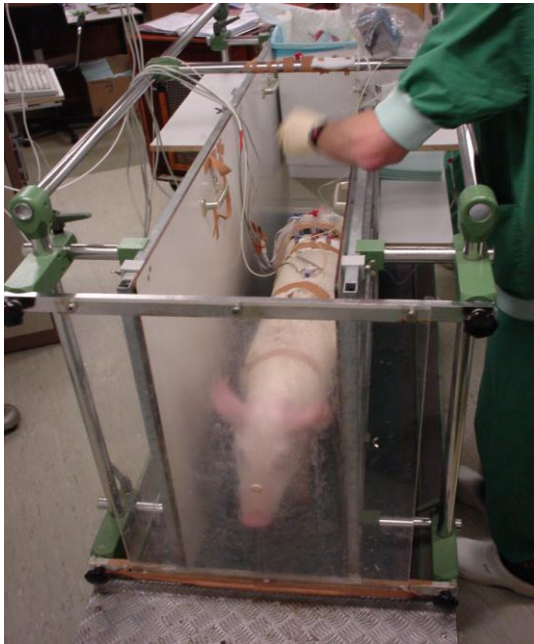
John Hunter 1794

“He must have wondered how blood
“knows” where it is needed?”

LB Rowell JAP 2004

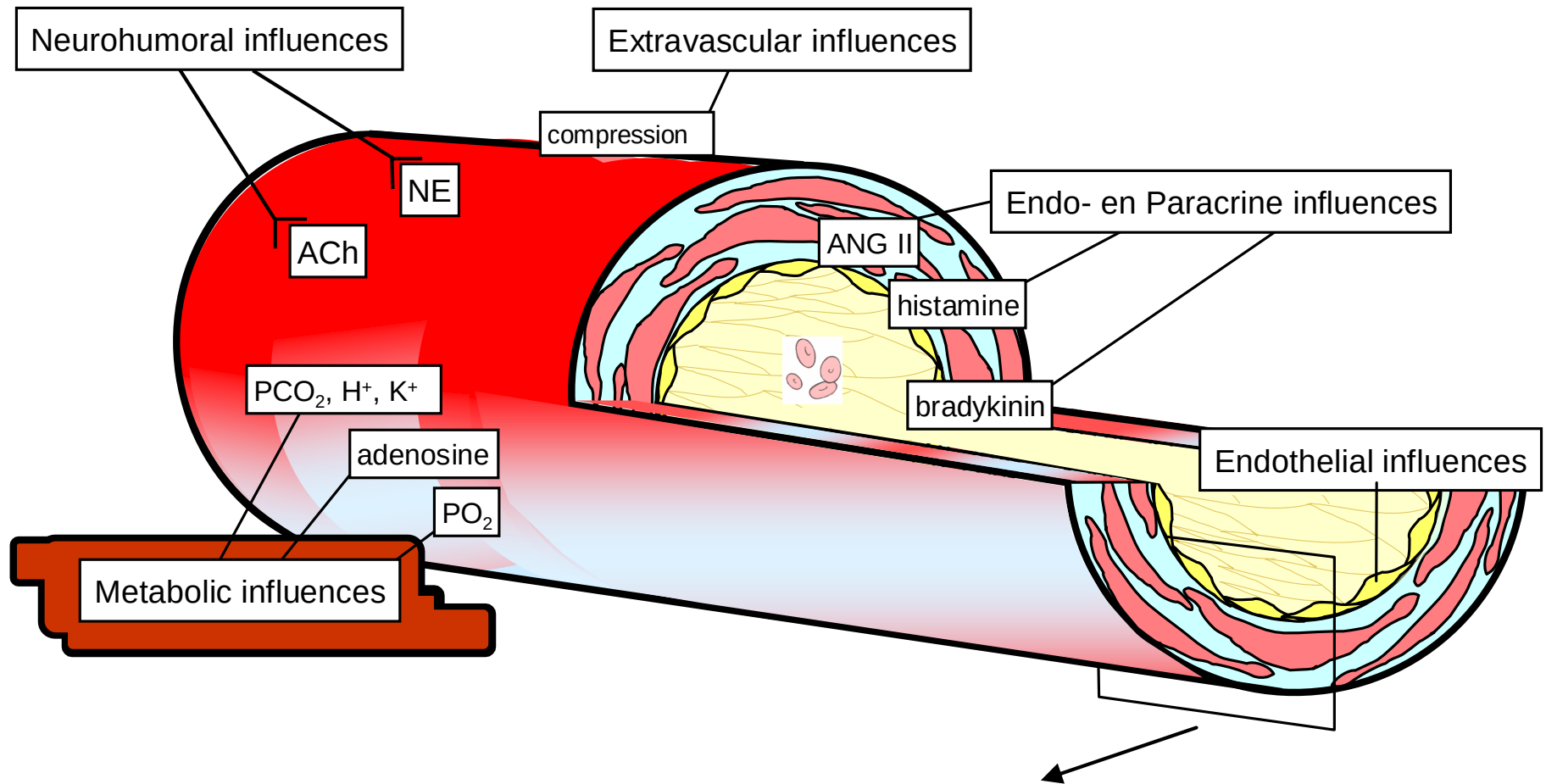
The ultimate cardiac challenge

Exercise

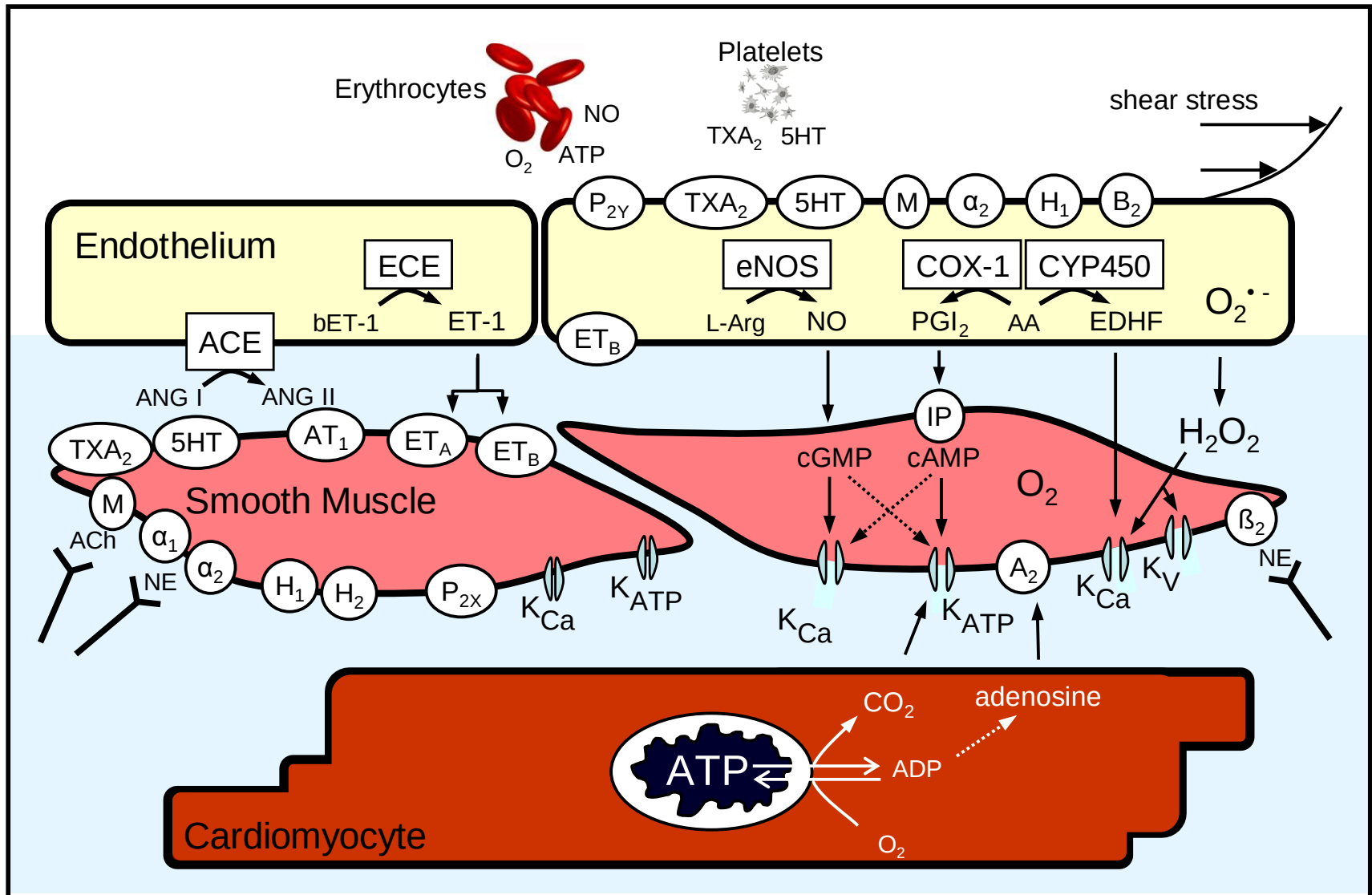


Duncker et al. Circ Res 1998
Duncker & Merkus J Physiol 2007
Duncker et al JMCC 2012

Control of Coronary Microvascular Tone



Control of Coronary Microvascular Tone



Regulation of Coronary Blood Flow

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

Duncker & Bache *Physiol Rev* 2008

Van de Hoeff et al *J Mol Cell Cardiol* 2012

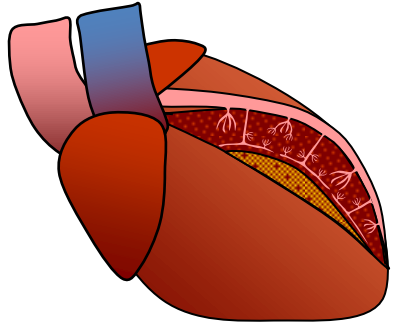
Laughlin et al *Compr Physiol* 2012

Duncker et al *Prog Cardiovasc Dis* 2015

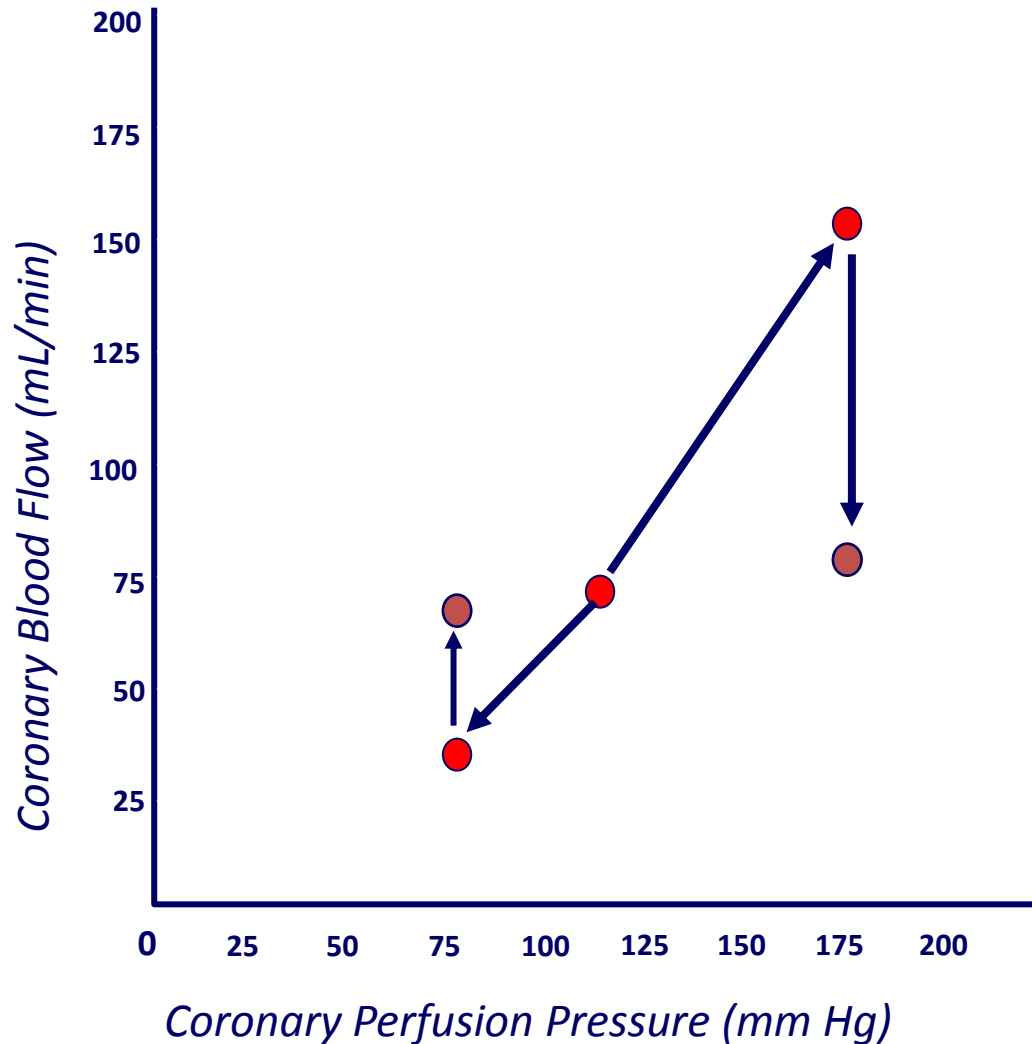
Autoregulation

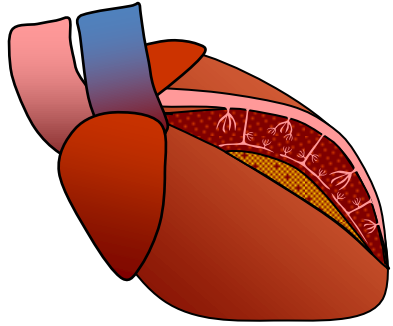
**The ability of the heart to maintain flow constant
in the face of a change in perfusion pressure**

...while myocardial metabolism remains unchanged

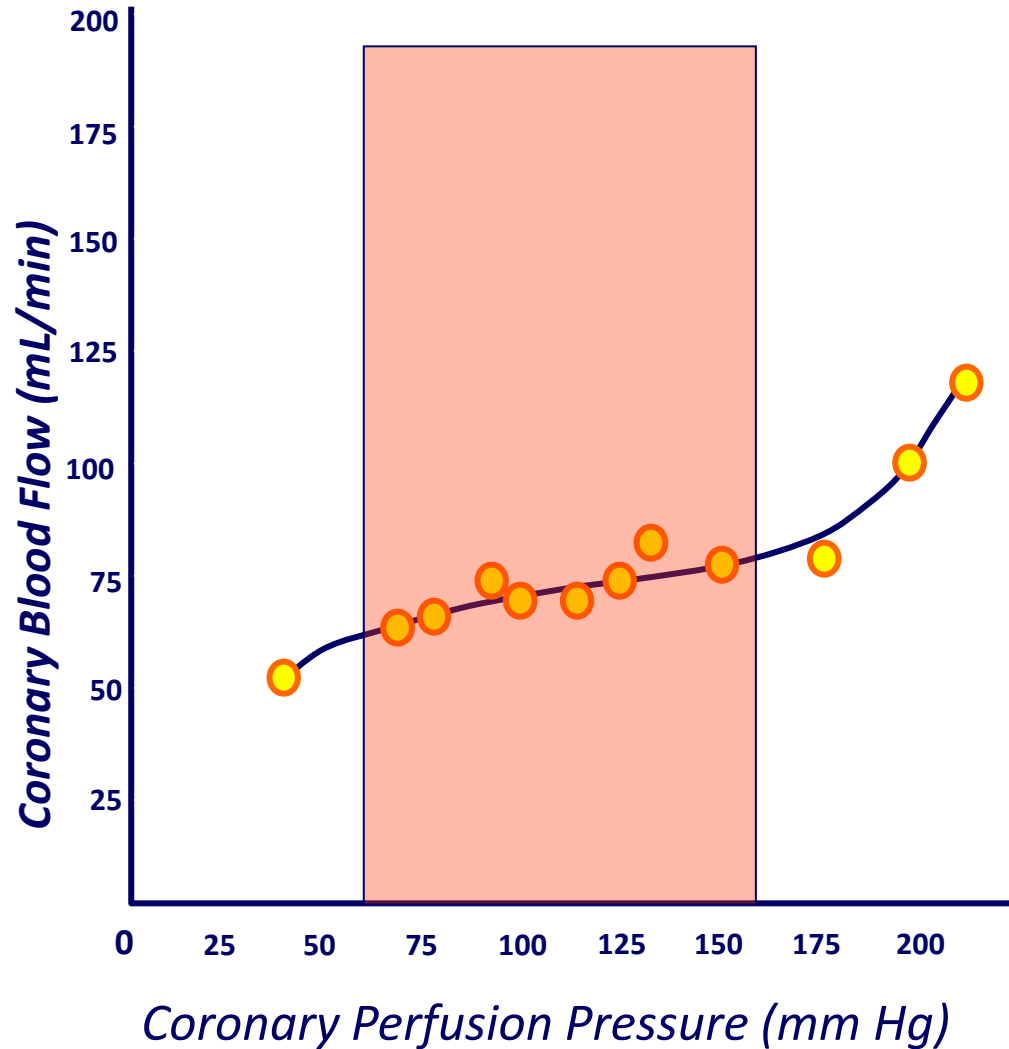


Coronary Autoregulation

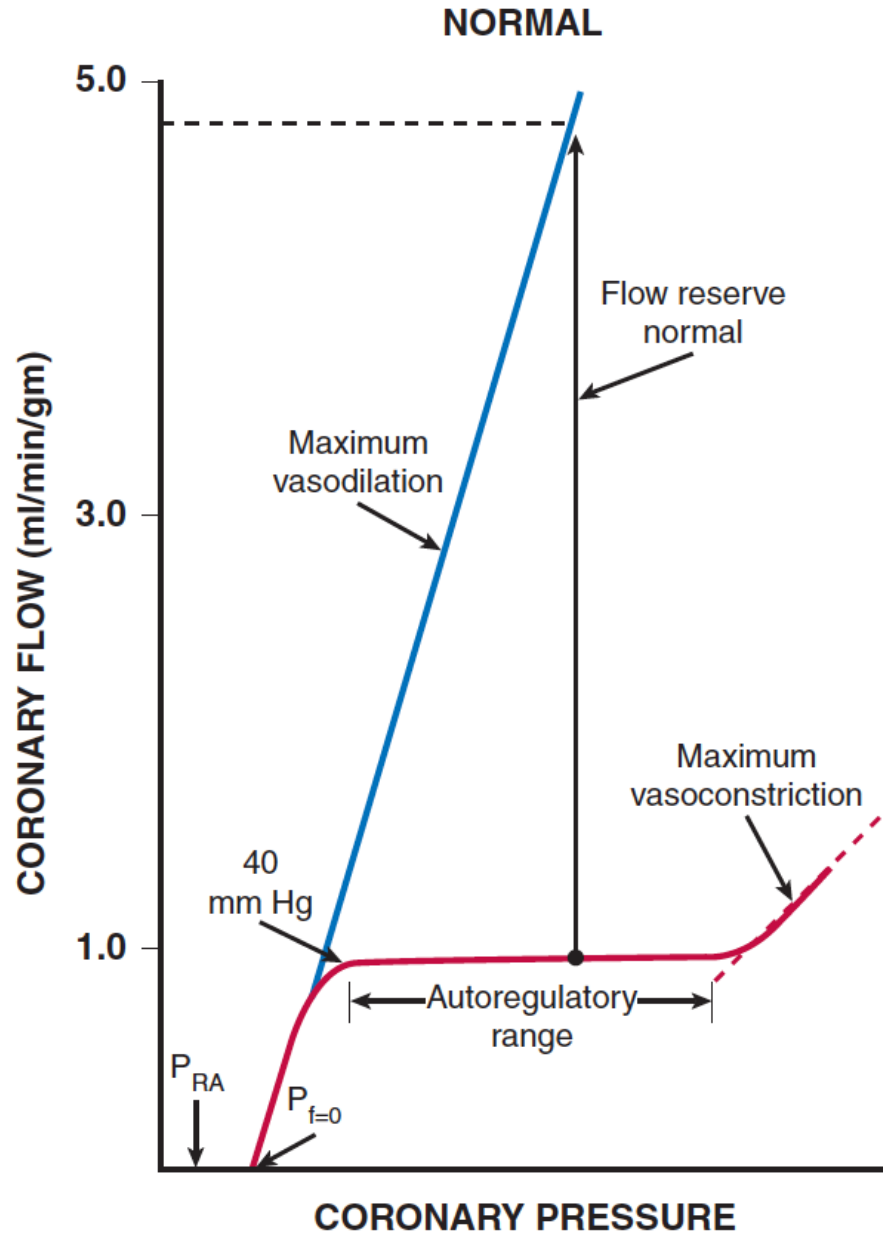




Autoregulatory Range

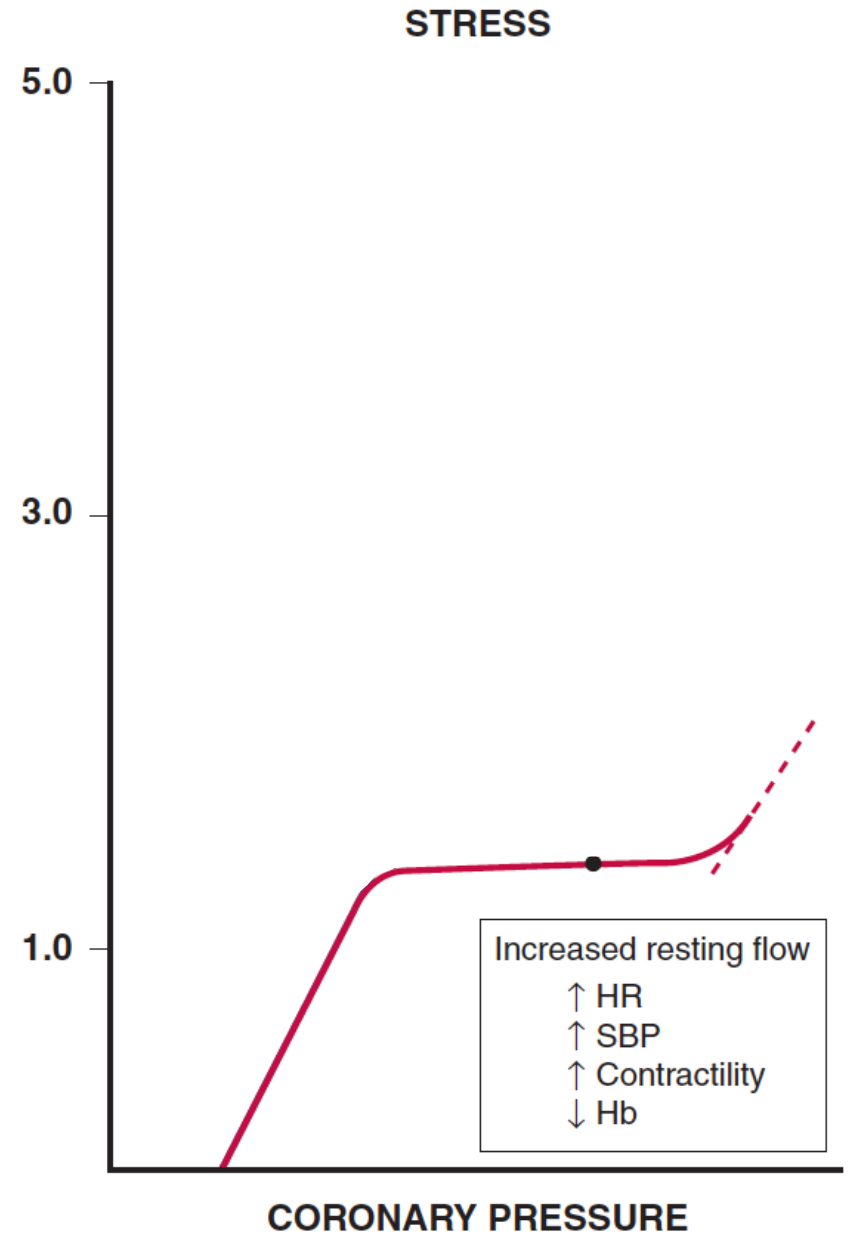
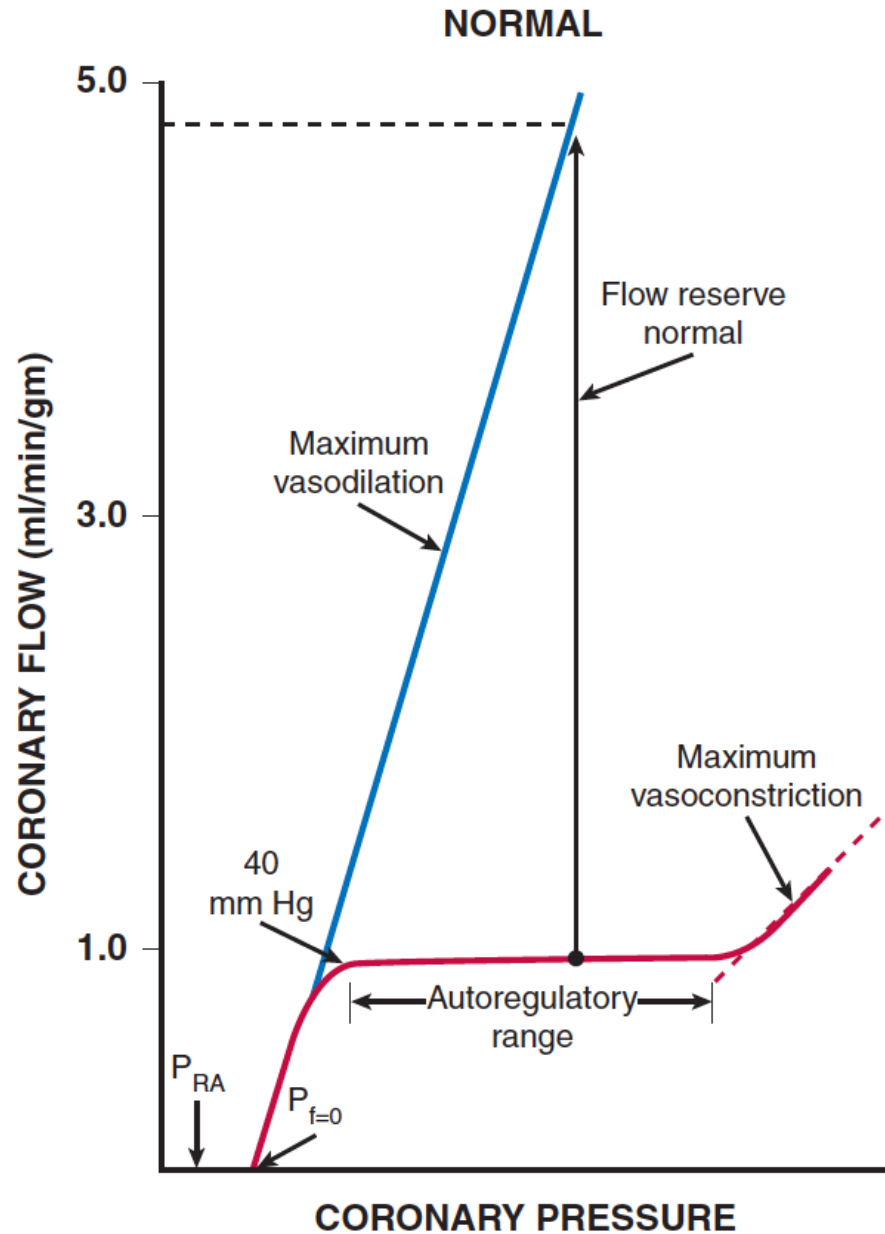


Coronary Pressure-Flow Relation

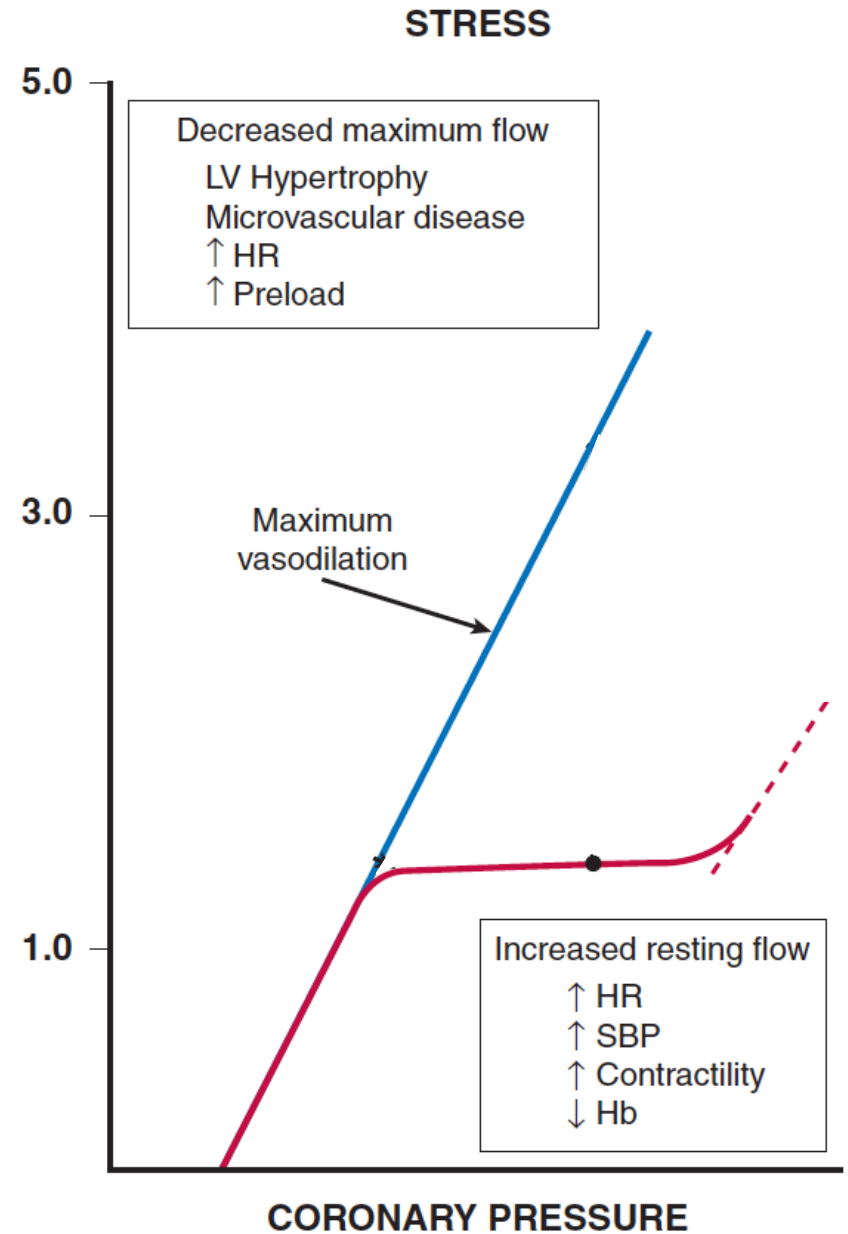
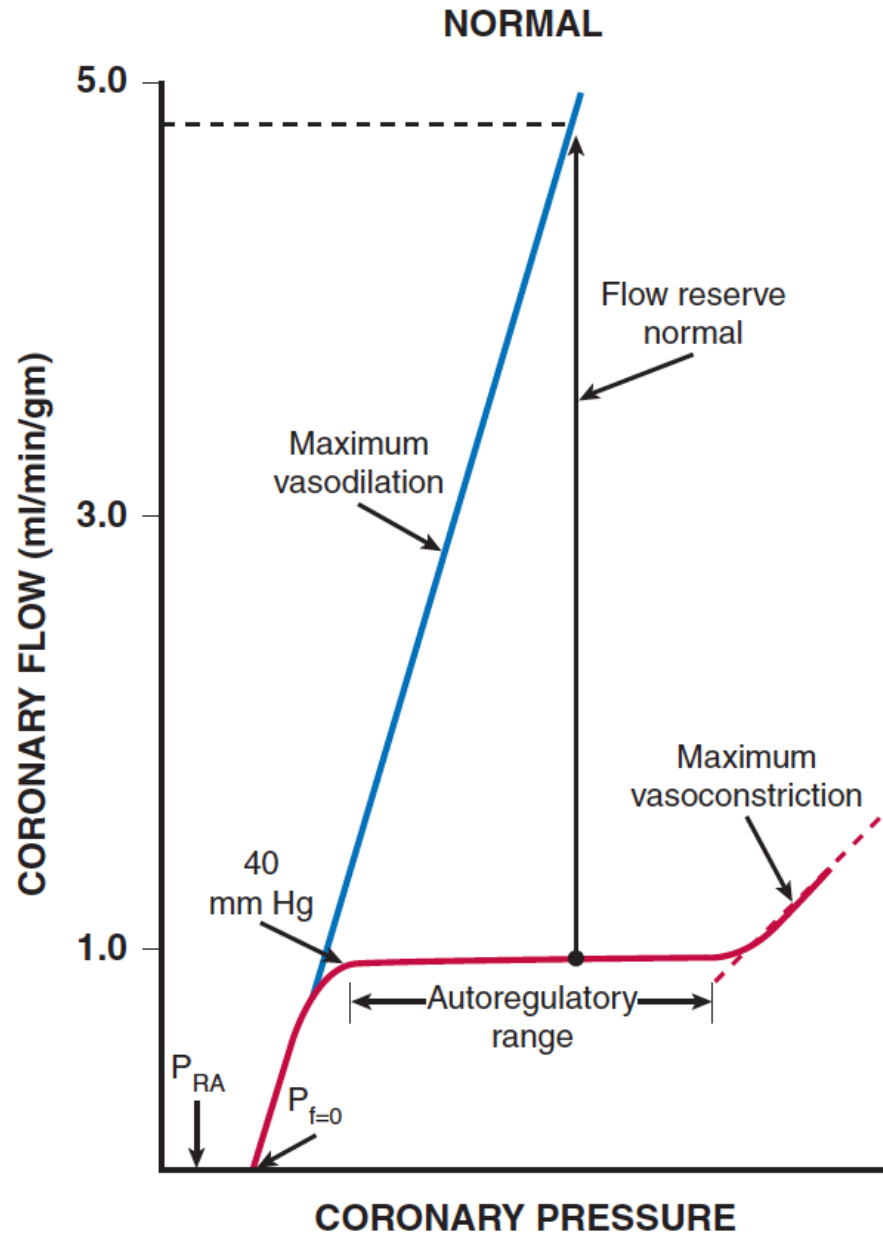


$$\text{Flow}_{\text{max}} / \Delta P = \text{Conductance}_{\text{max}}$$

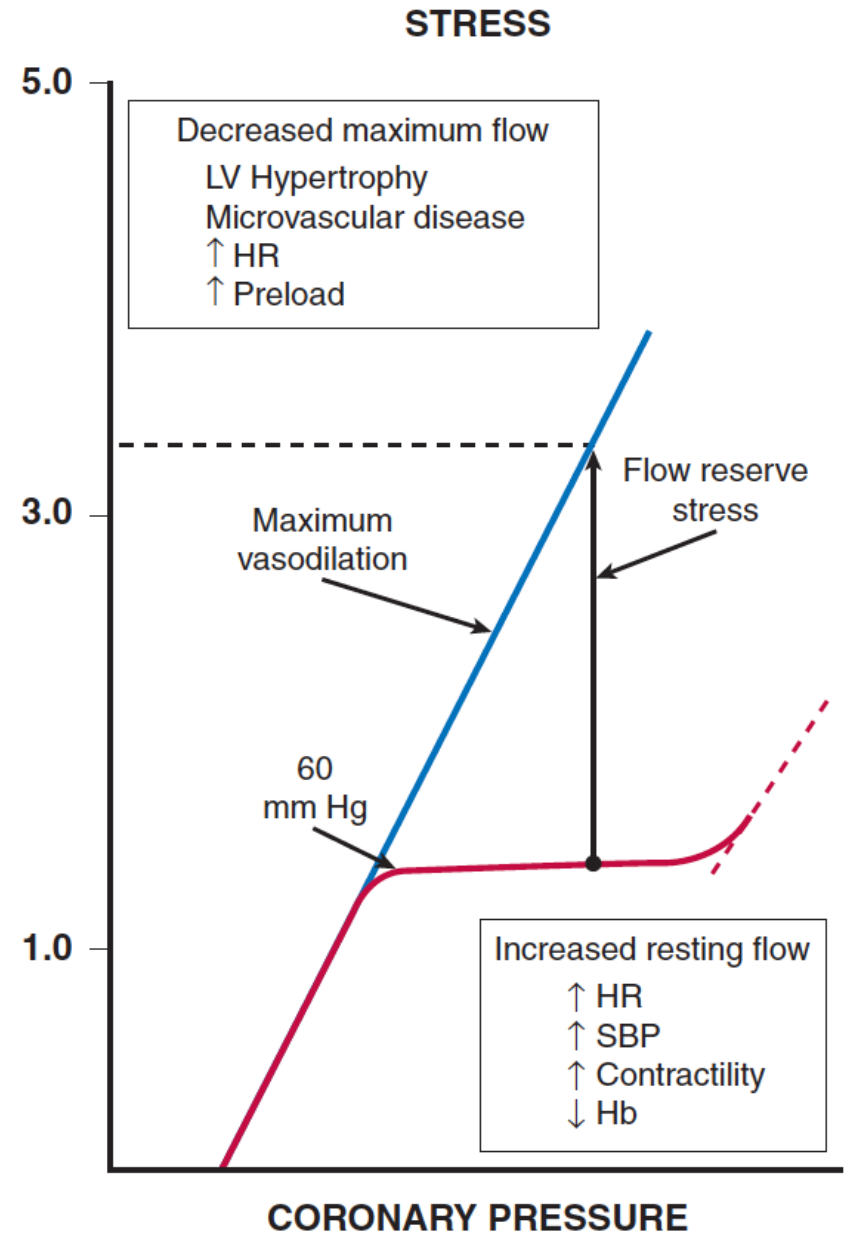
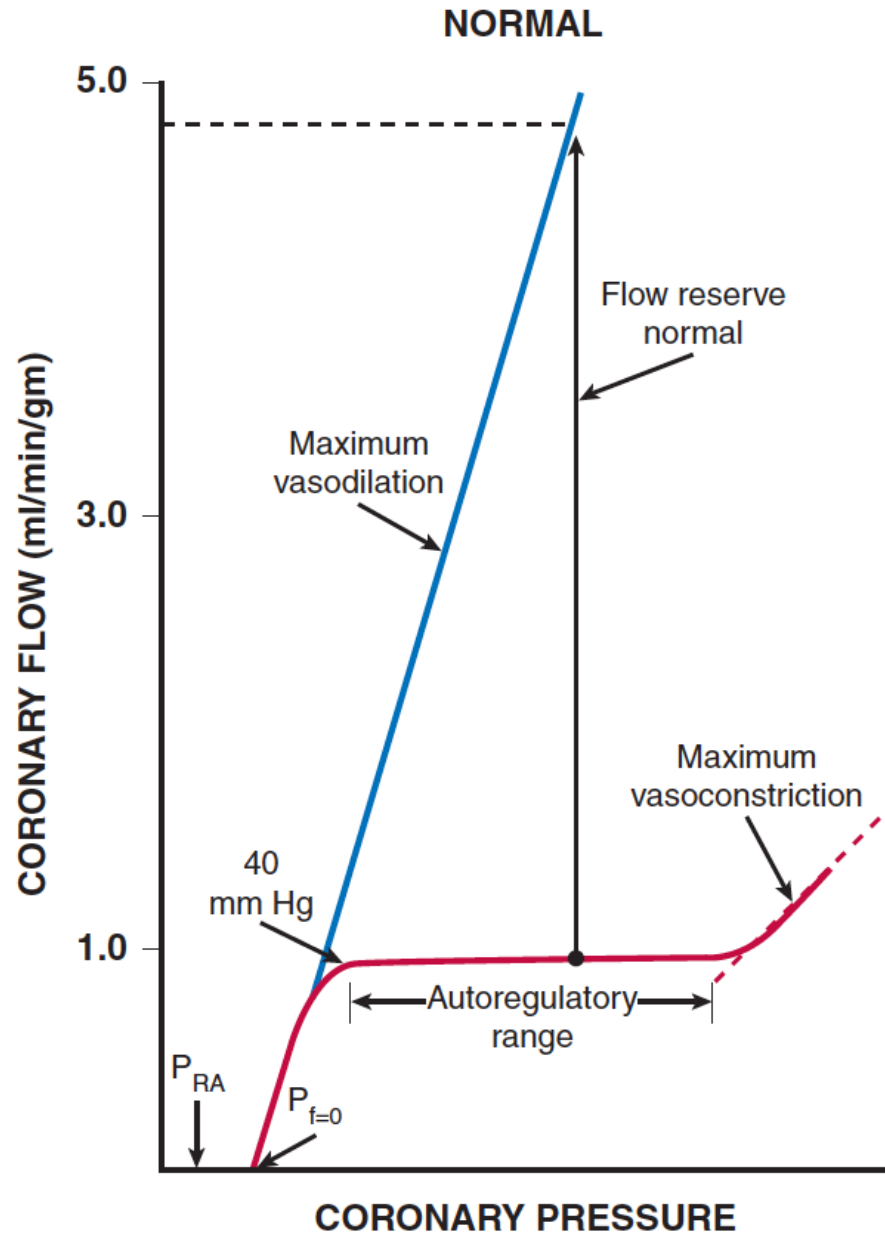
Coronary Pressure-Flow Relation



Coronary Pressure-Flow Relation



Coronary Pressure-Flow Relation



Regulation of Coronary Blood Flow

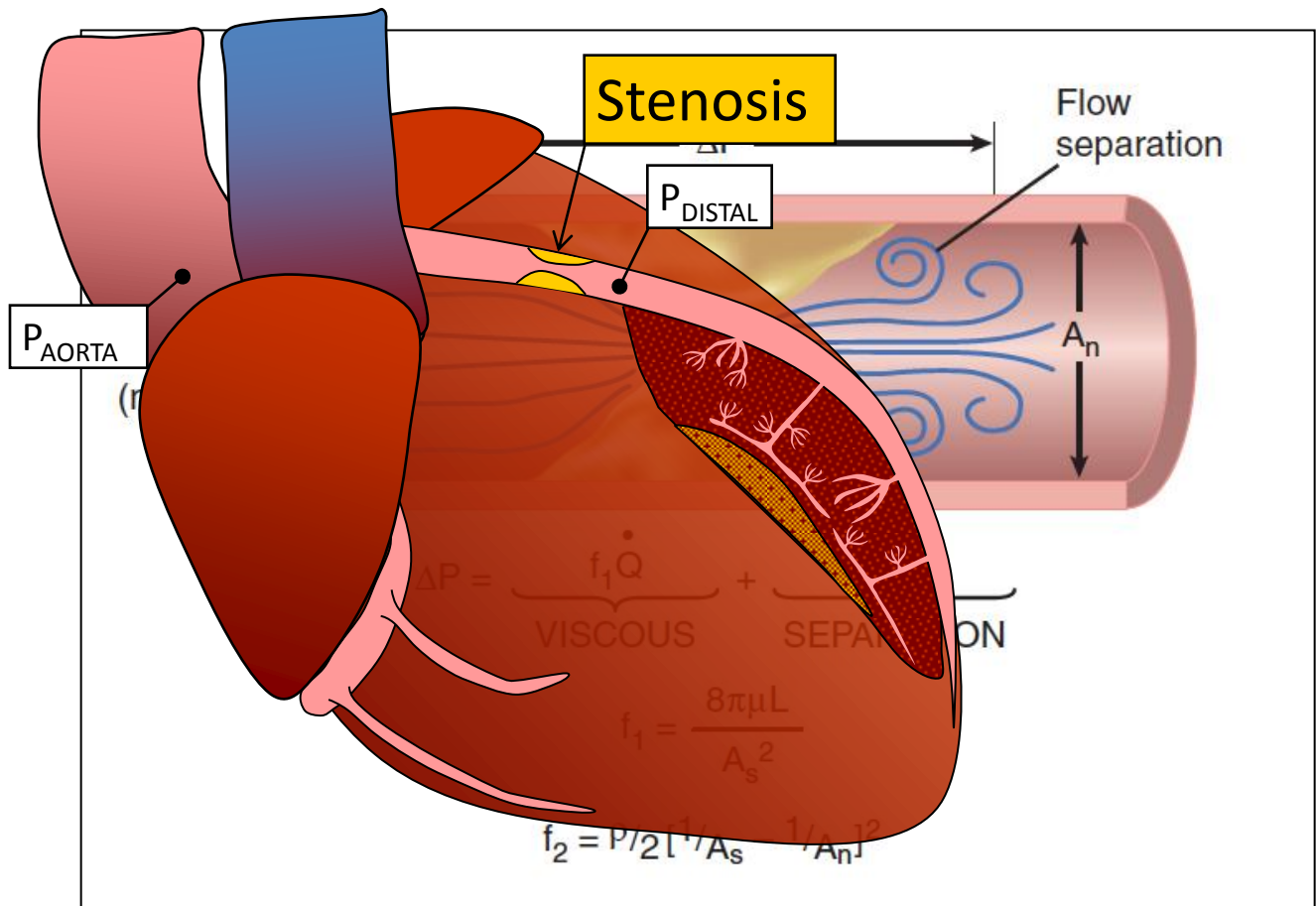
- Introduction
- Control of Coronary Resistance Vessels
- Autoregulation: Pressure Flow Relations
- *Hemodynamic Effects of a Coronary Stenosis*

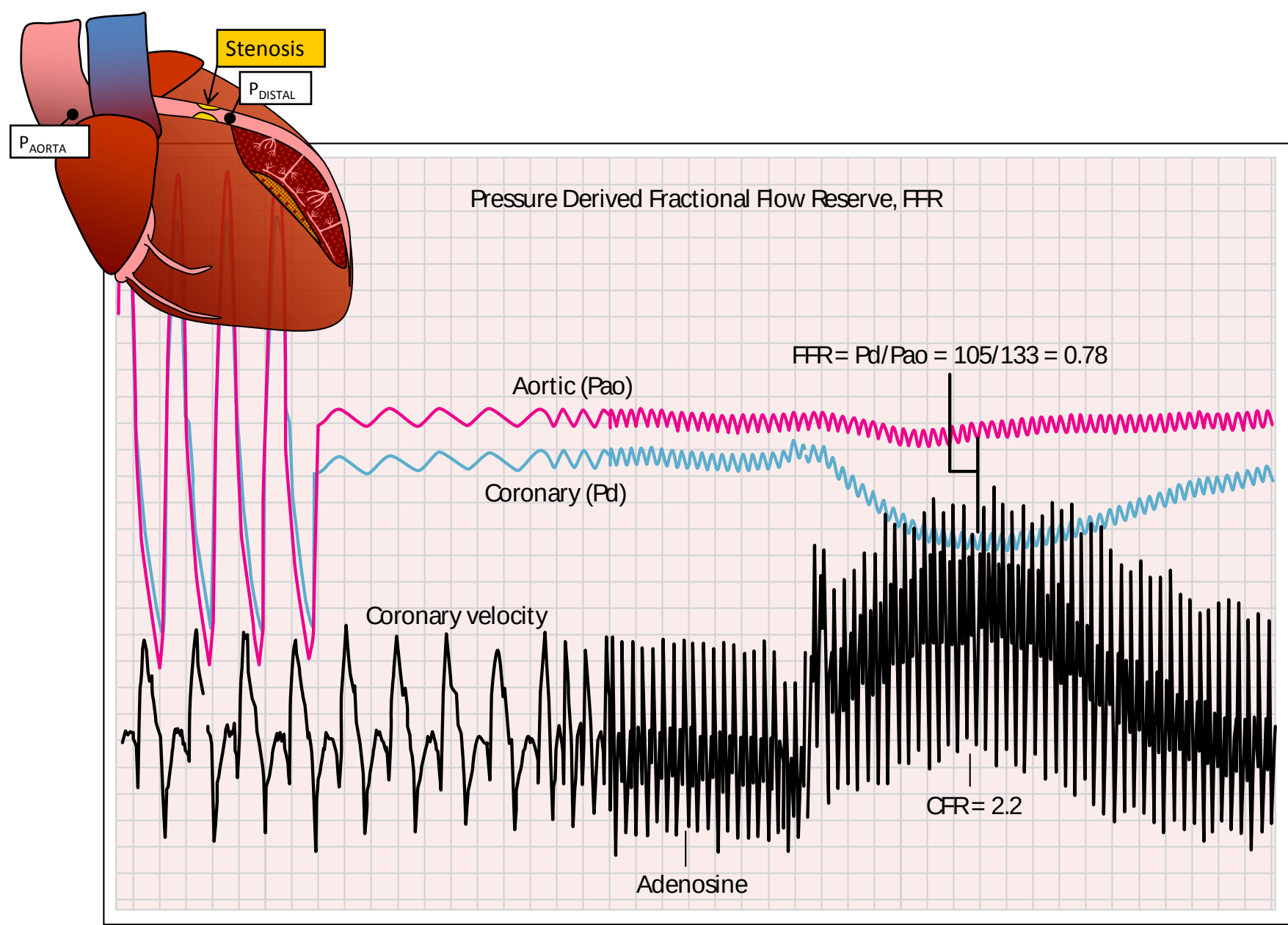
Duncker & Bache *Physiol Rev* 2008

Van de Hoeff et al *J Mol Cell Cardiol* 2012

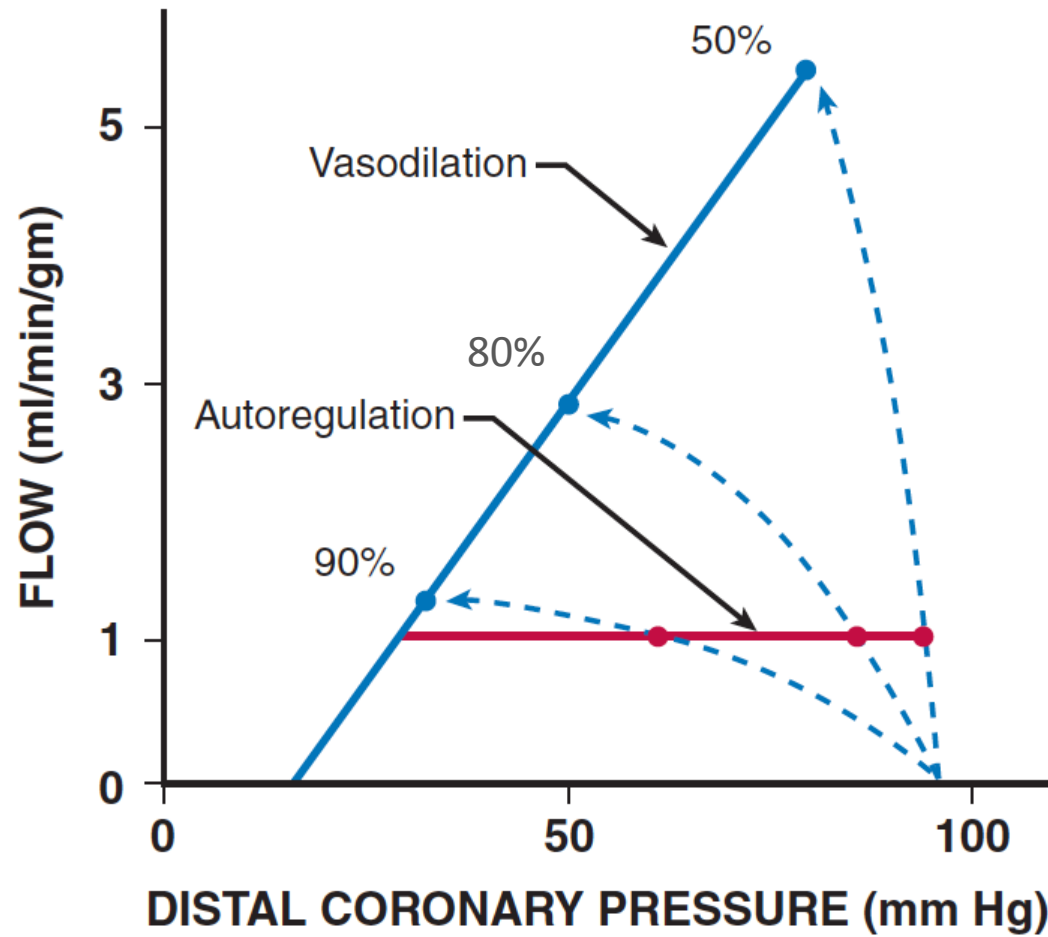
Laughlin et al *Compr Physiol* 2012

Duncker et al *Prog Cardiovasc Dis* 2015

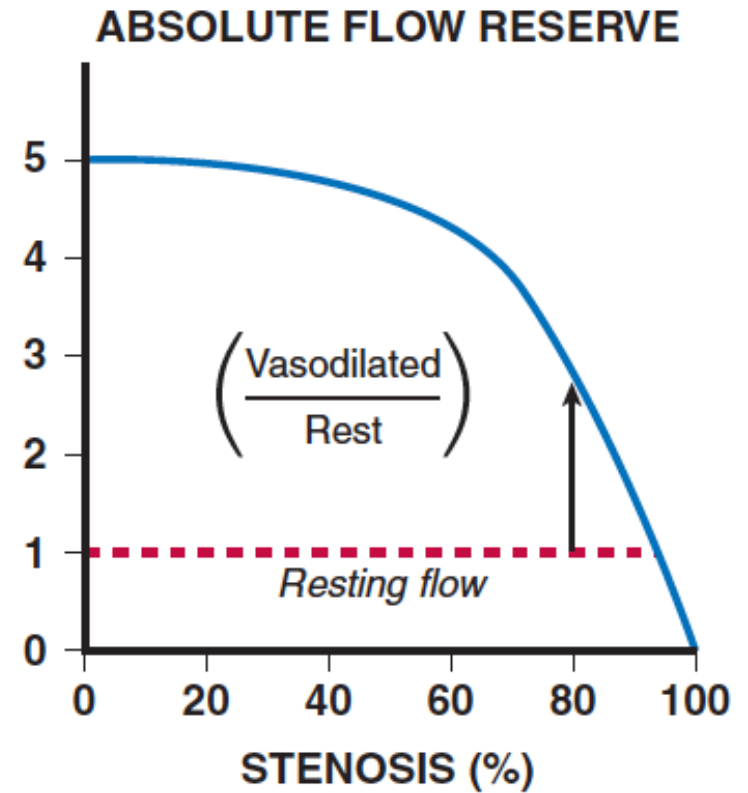
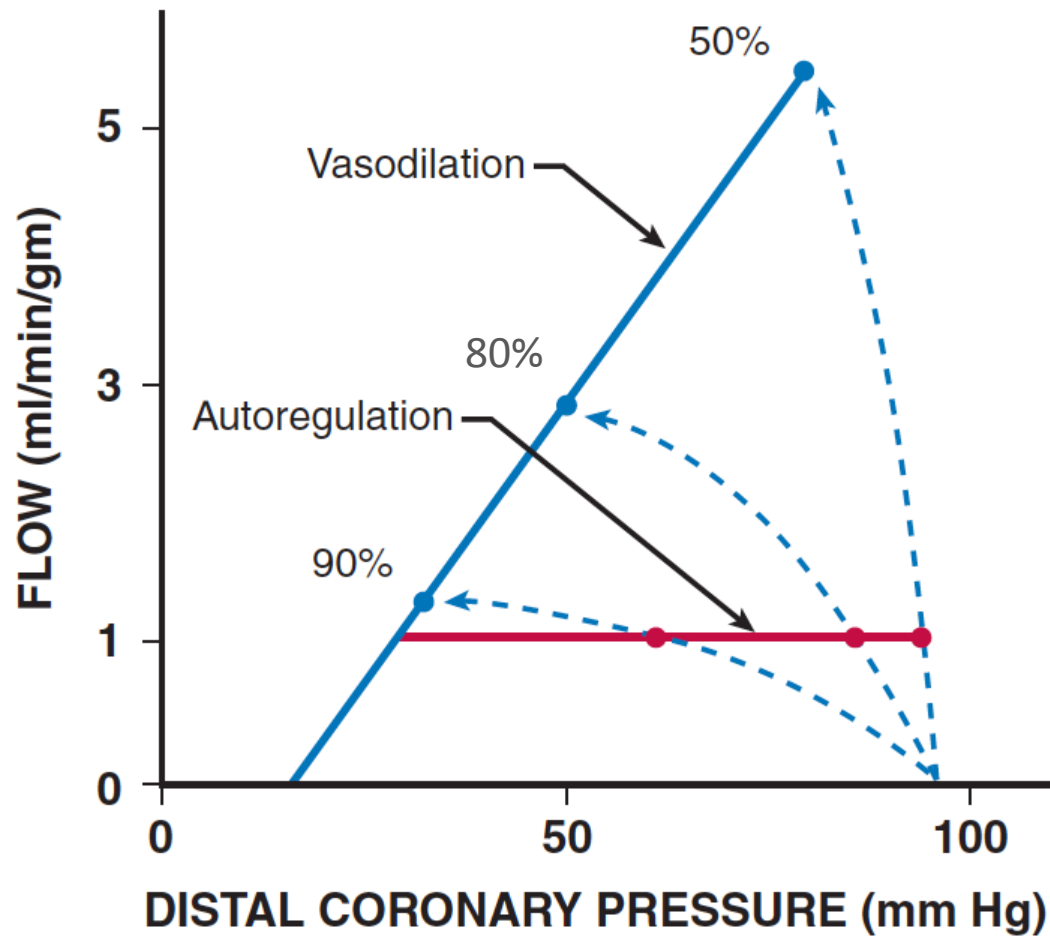




Assessment of Coronary Reserve

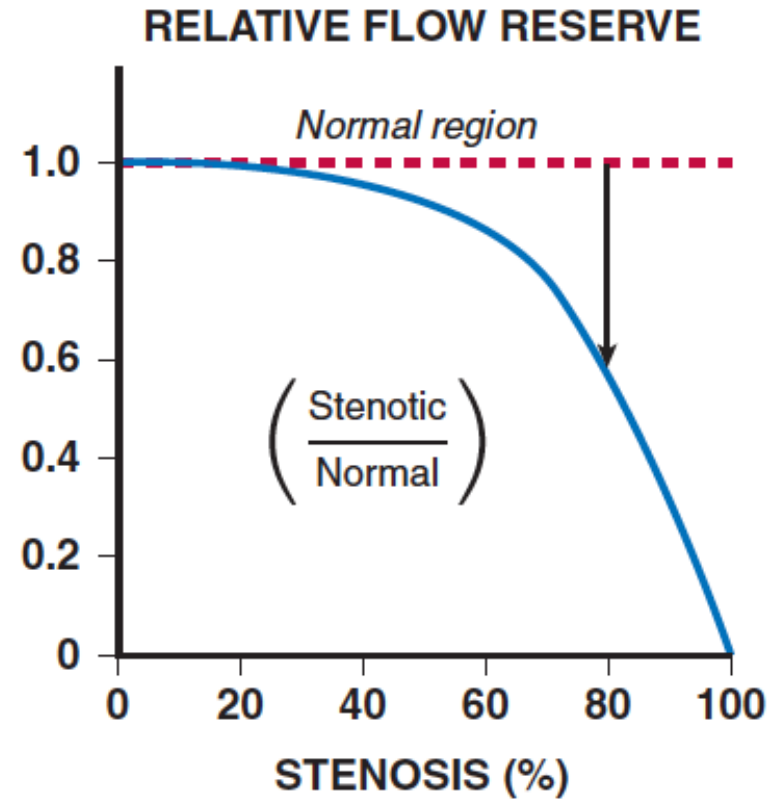
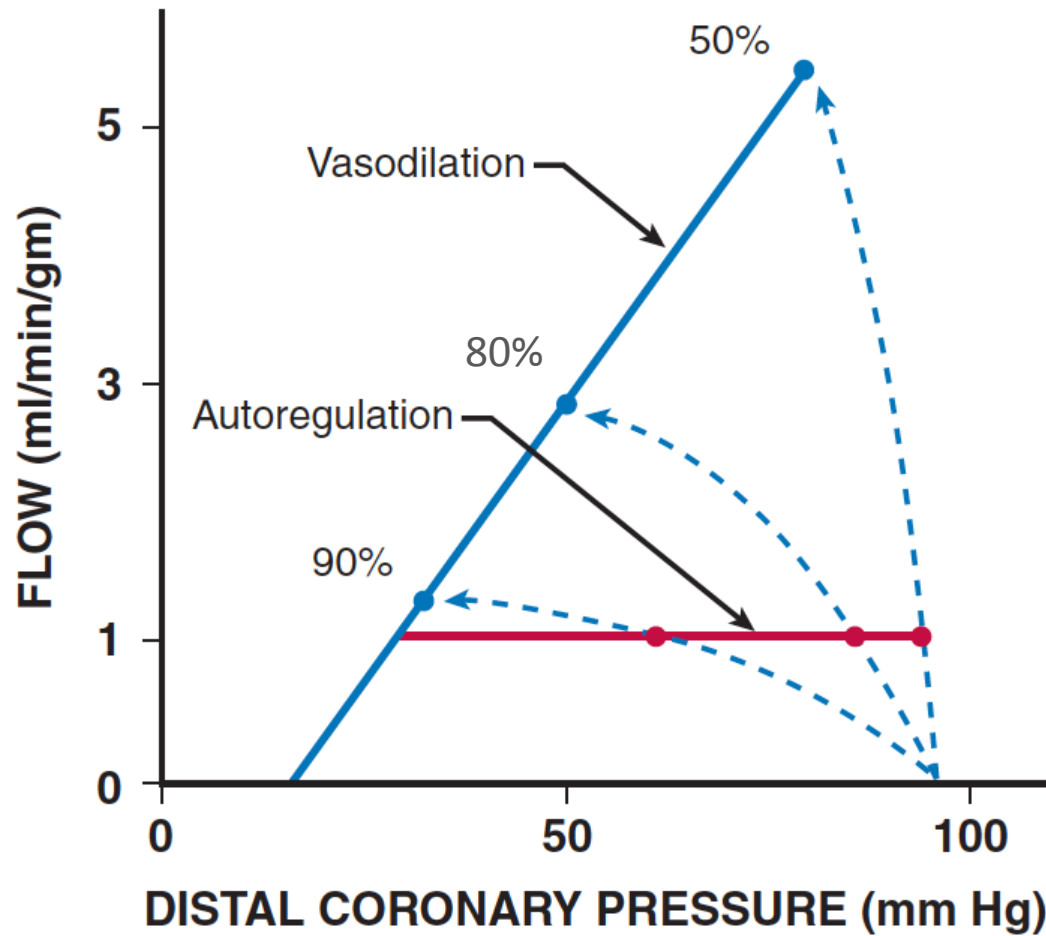


Assessment of Coronary Reserve



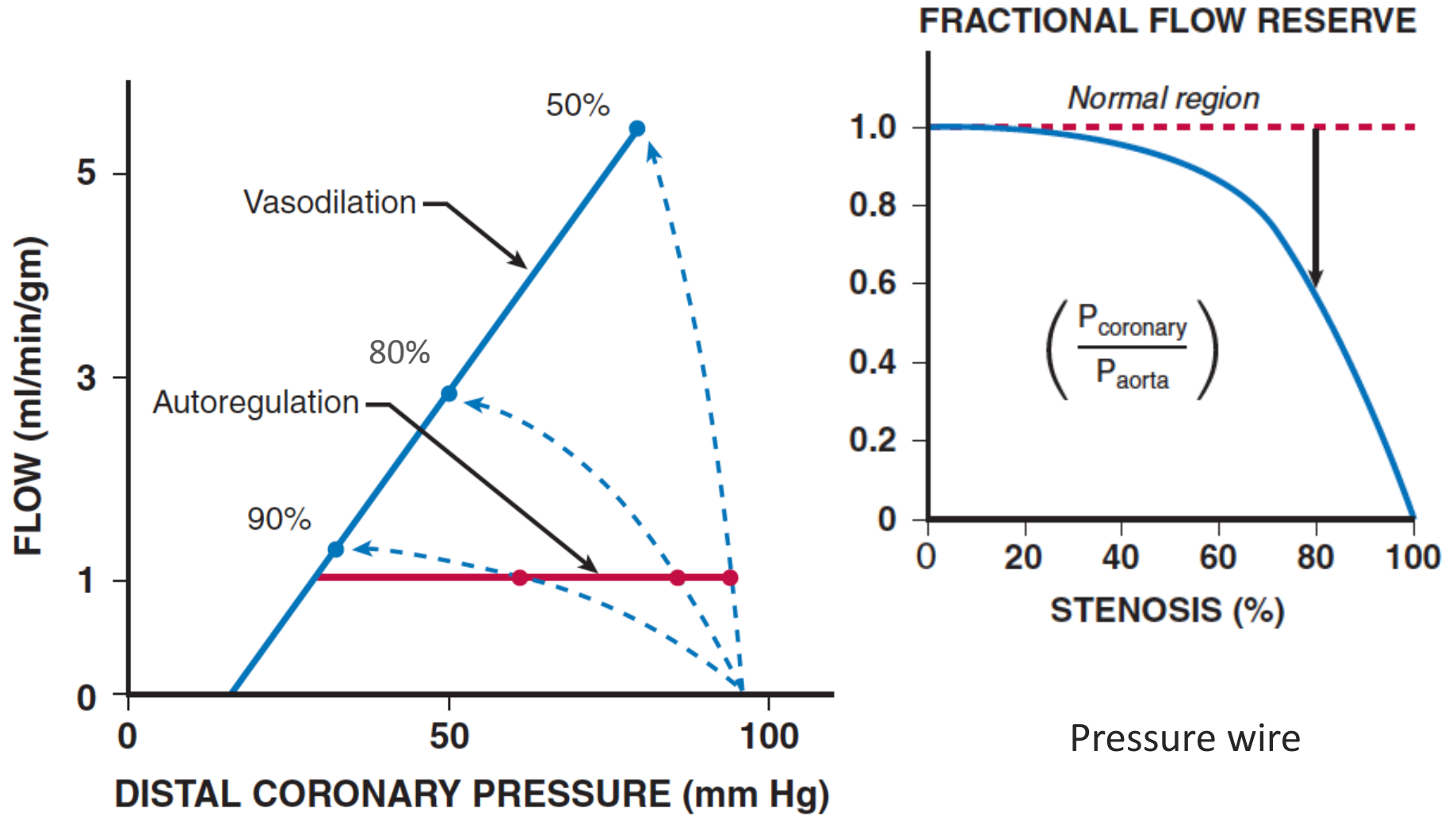
Flow velocity wire
PET/MRI/CT Perfusion

Assessment of Coronary Reserve

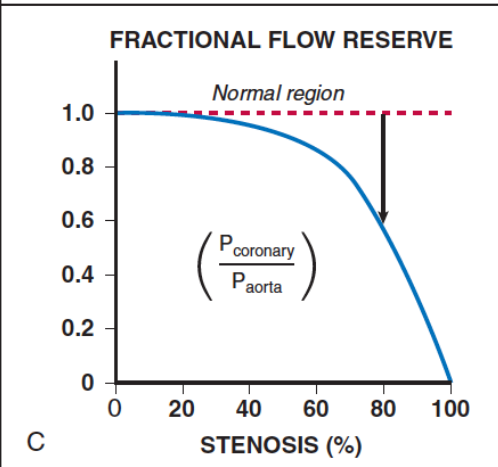
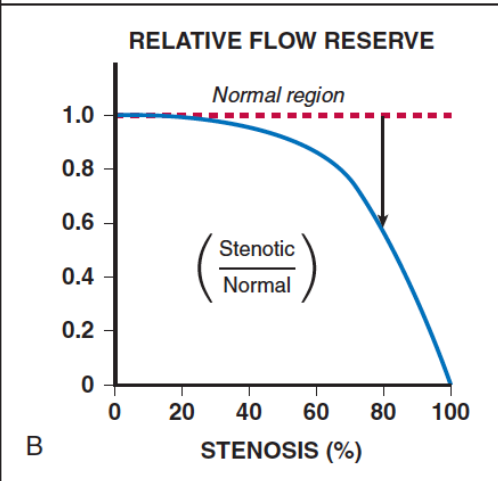
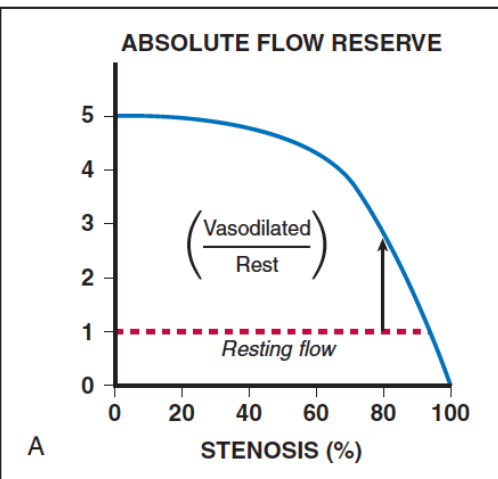
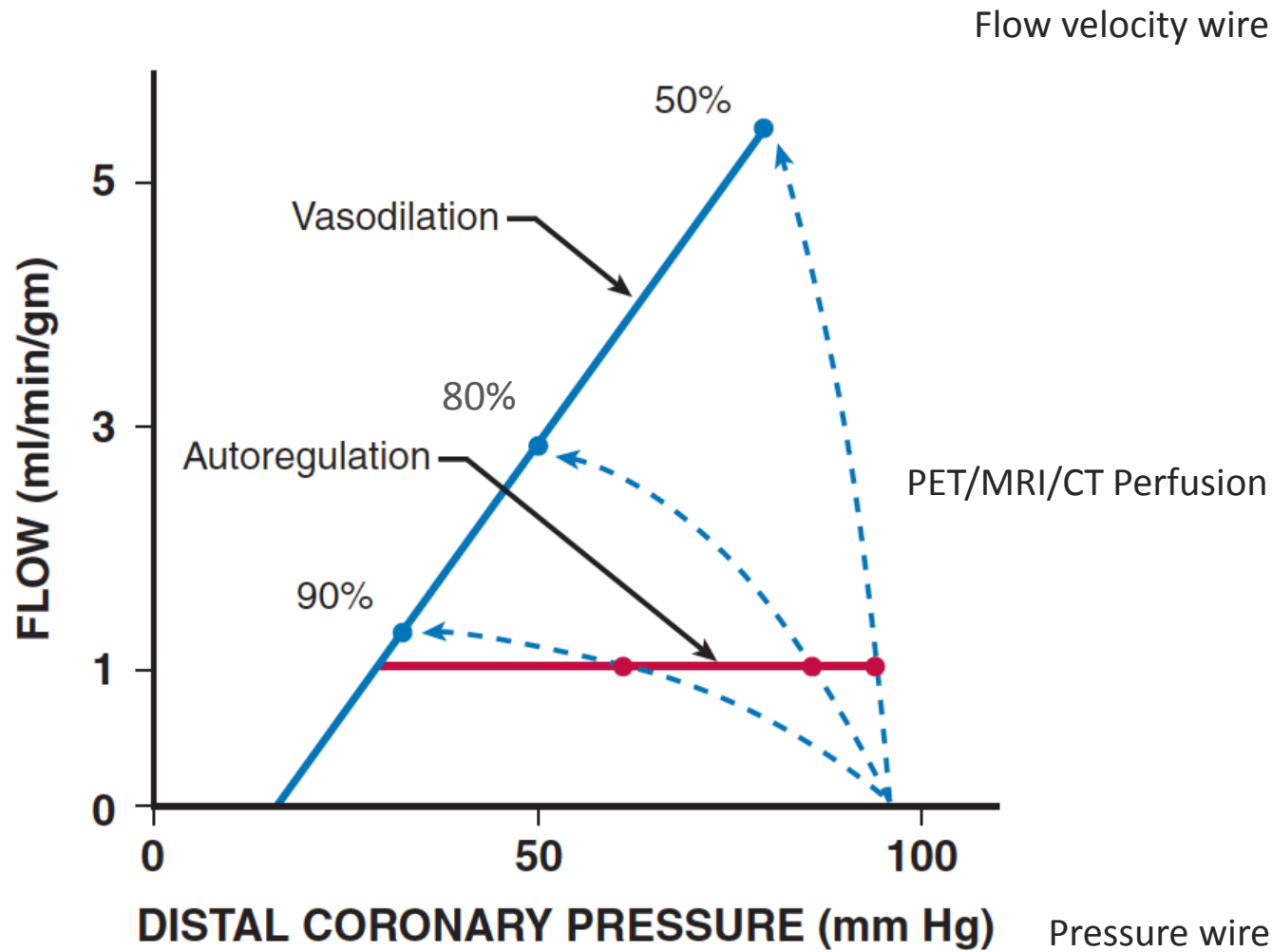


PET/MRI/CT Perfusion

Assessment of Coronary Reserve



Assessment of Coronary Reserve



Regulation of Coronary Blood Flow

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

Questions?

Duncker & Bache *Physiol Rev* 2008
Van de Hoeff et al *J Mol Cell Cardiol* 2012
Laughlin et al *Compr Physiol* 2012
Duncker et al *Prog Cardiovasc Dis* 2015