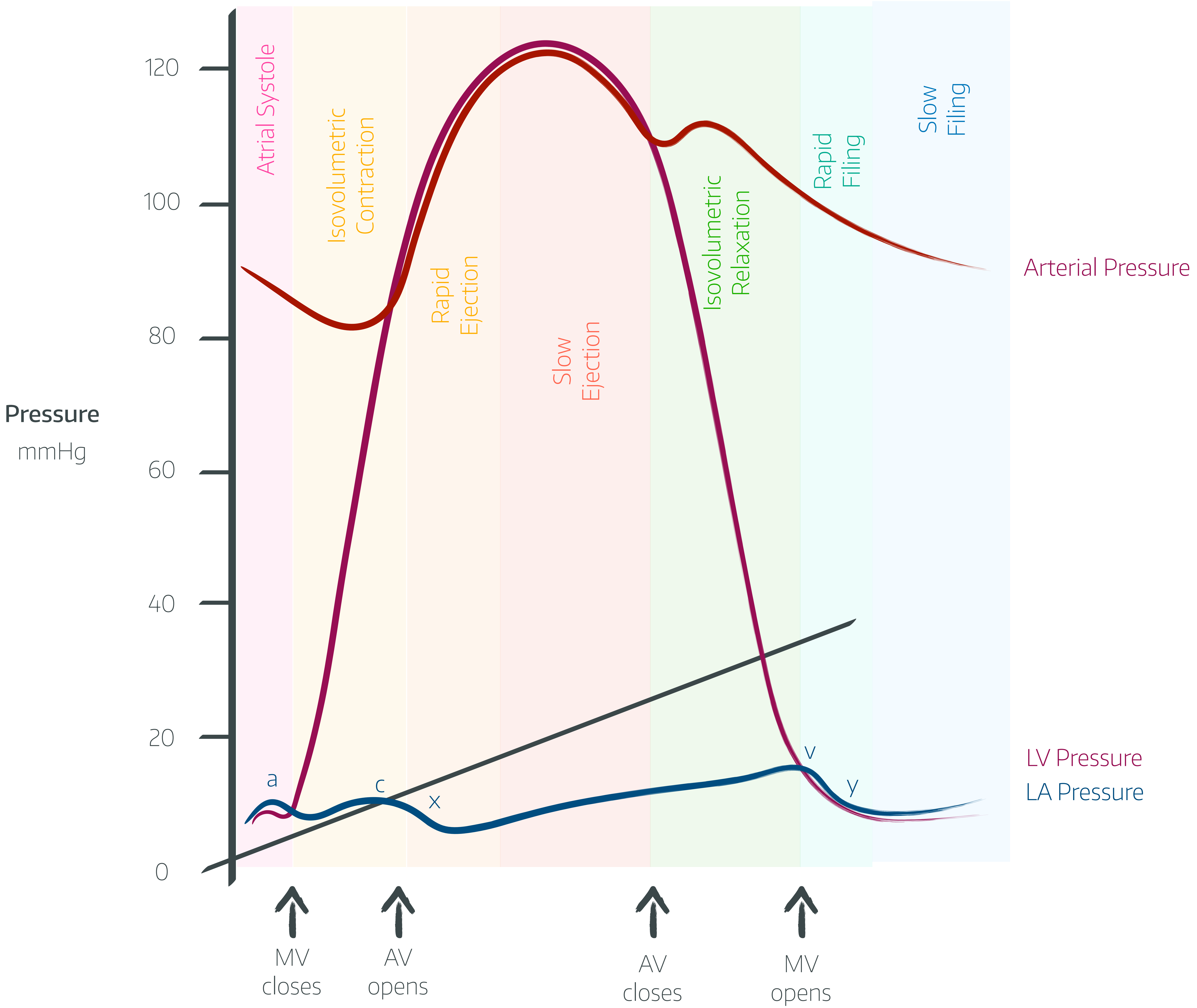
Anaestheasier

Graphical Flashcards

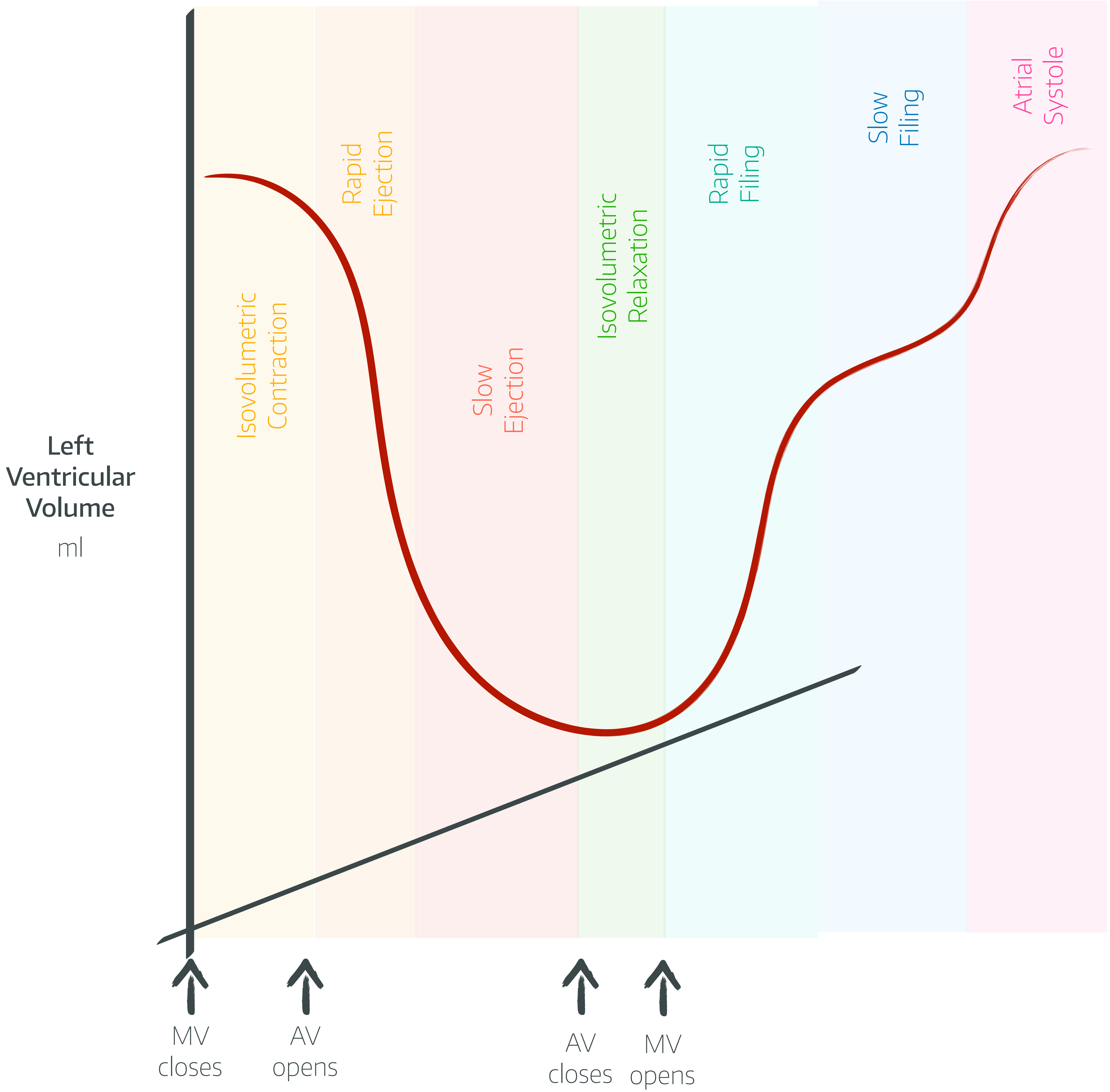
Physiology

For the Primary FRCA

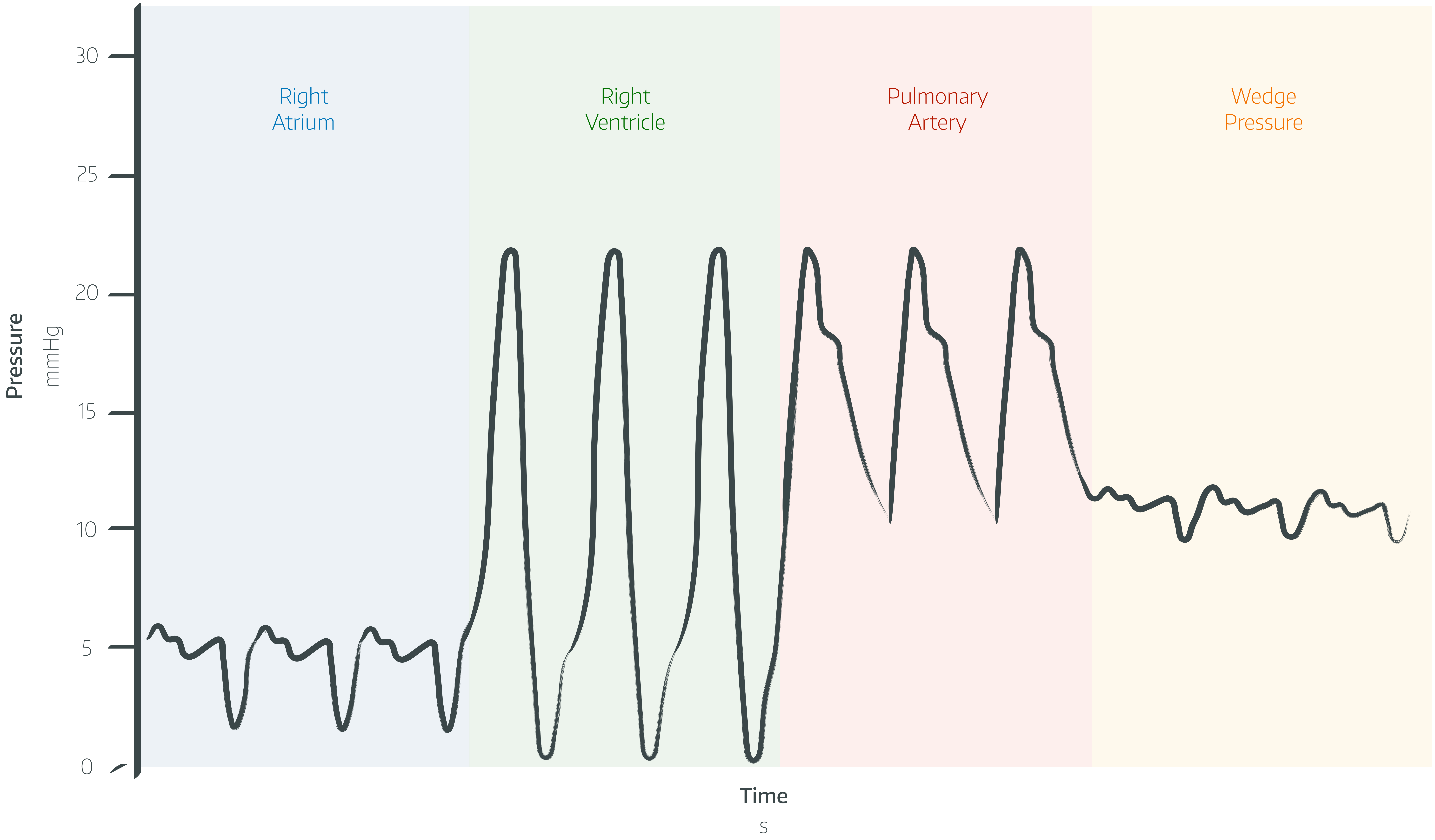
The Cardiac Cycle



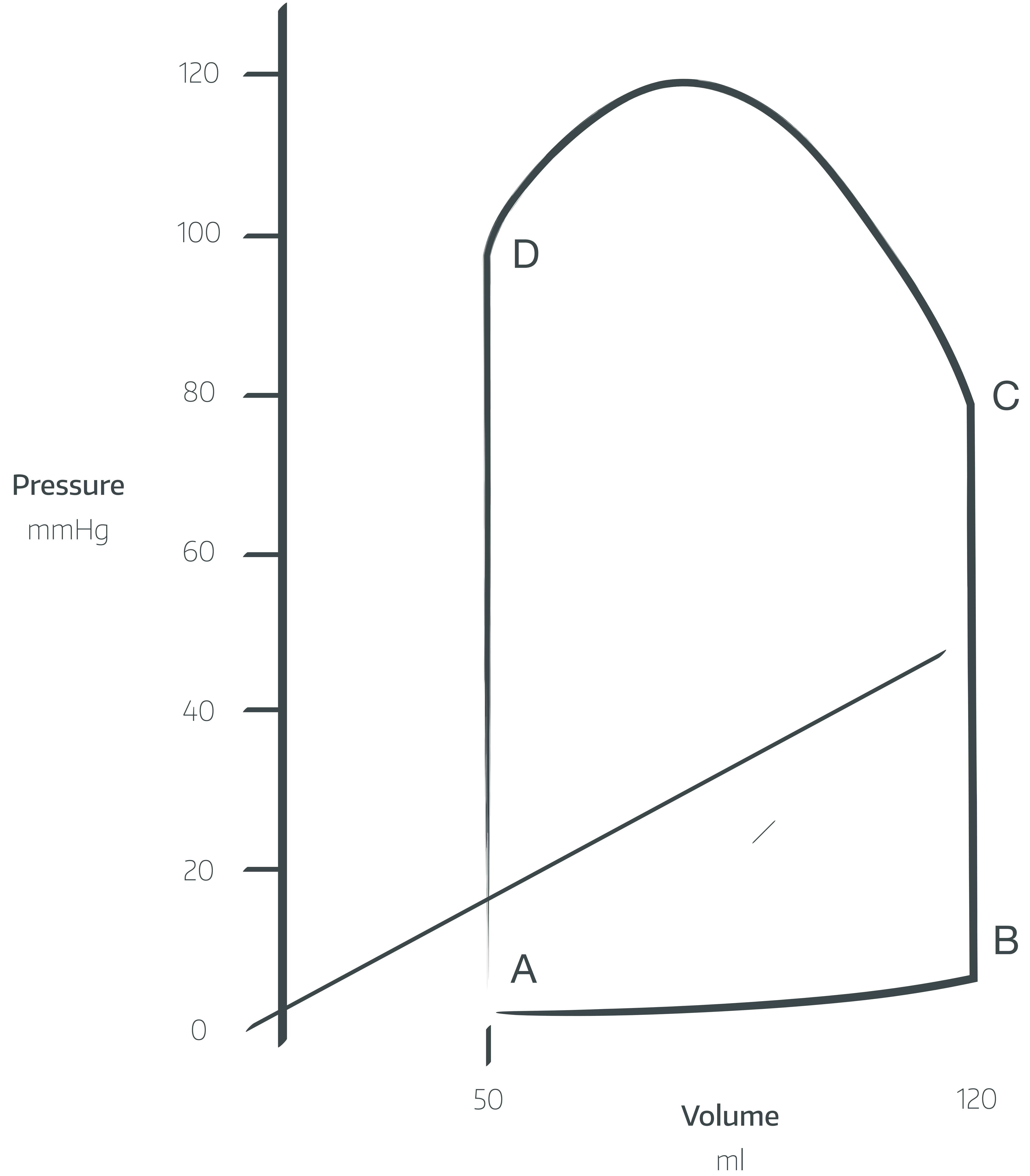
THE CARDIAC CYCLE



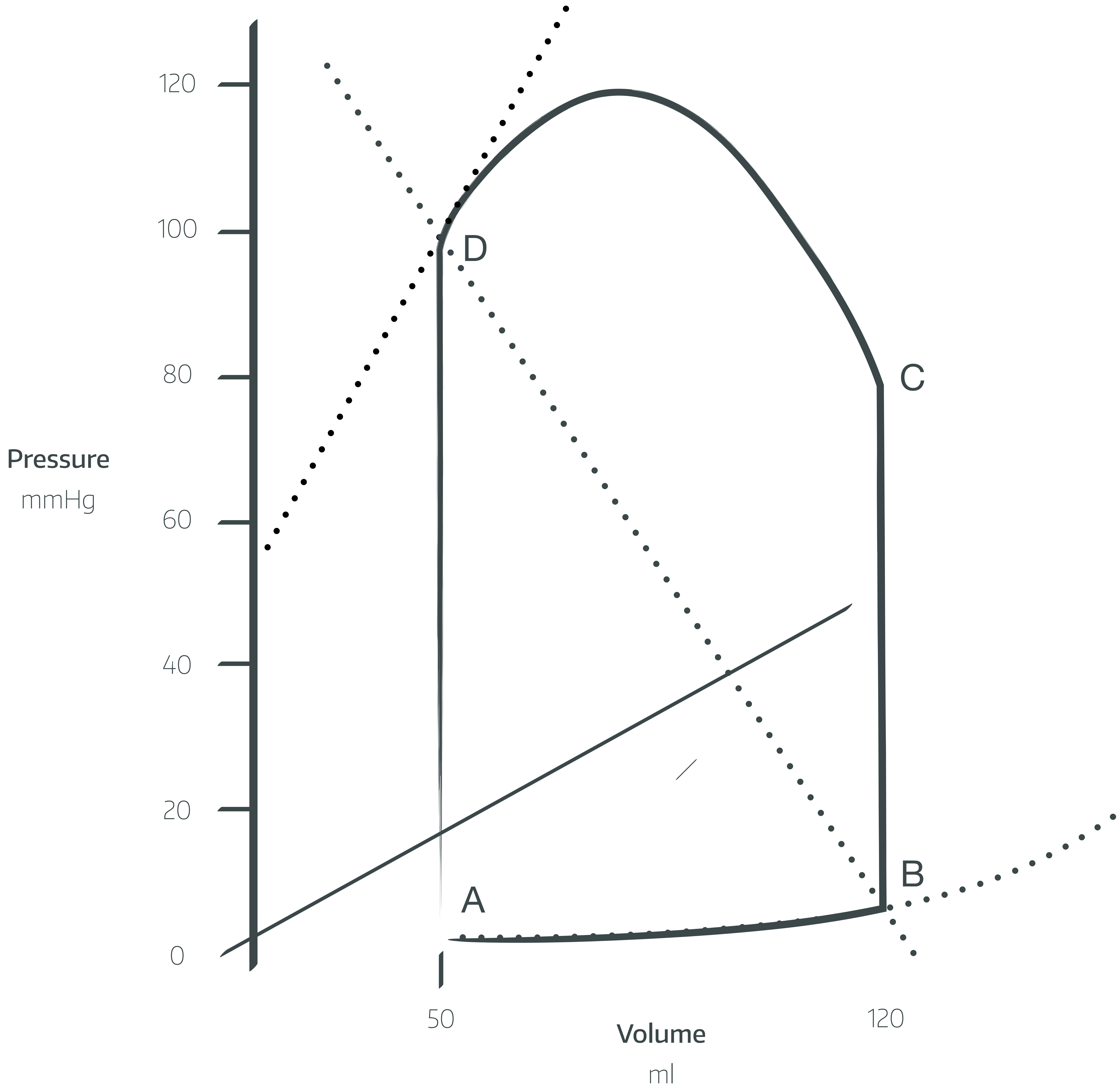
SWAN-GANZ CATHETER



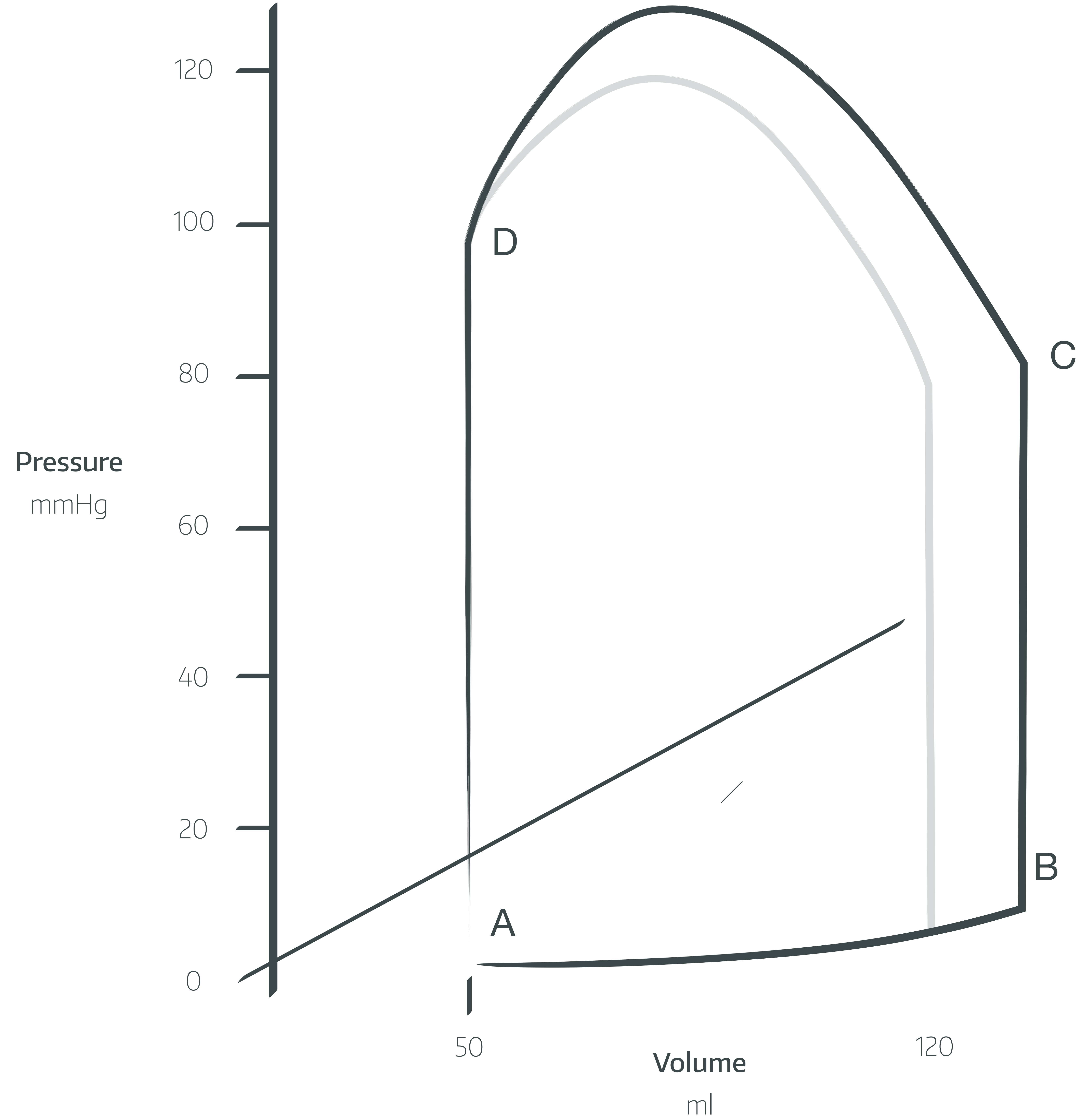
LV Pressure-Volume Loops



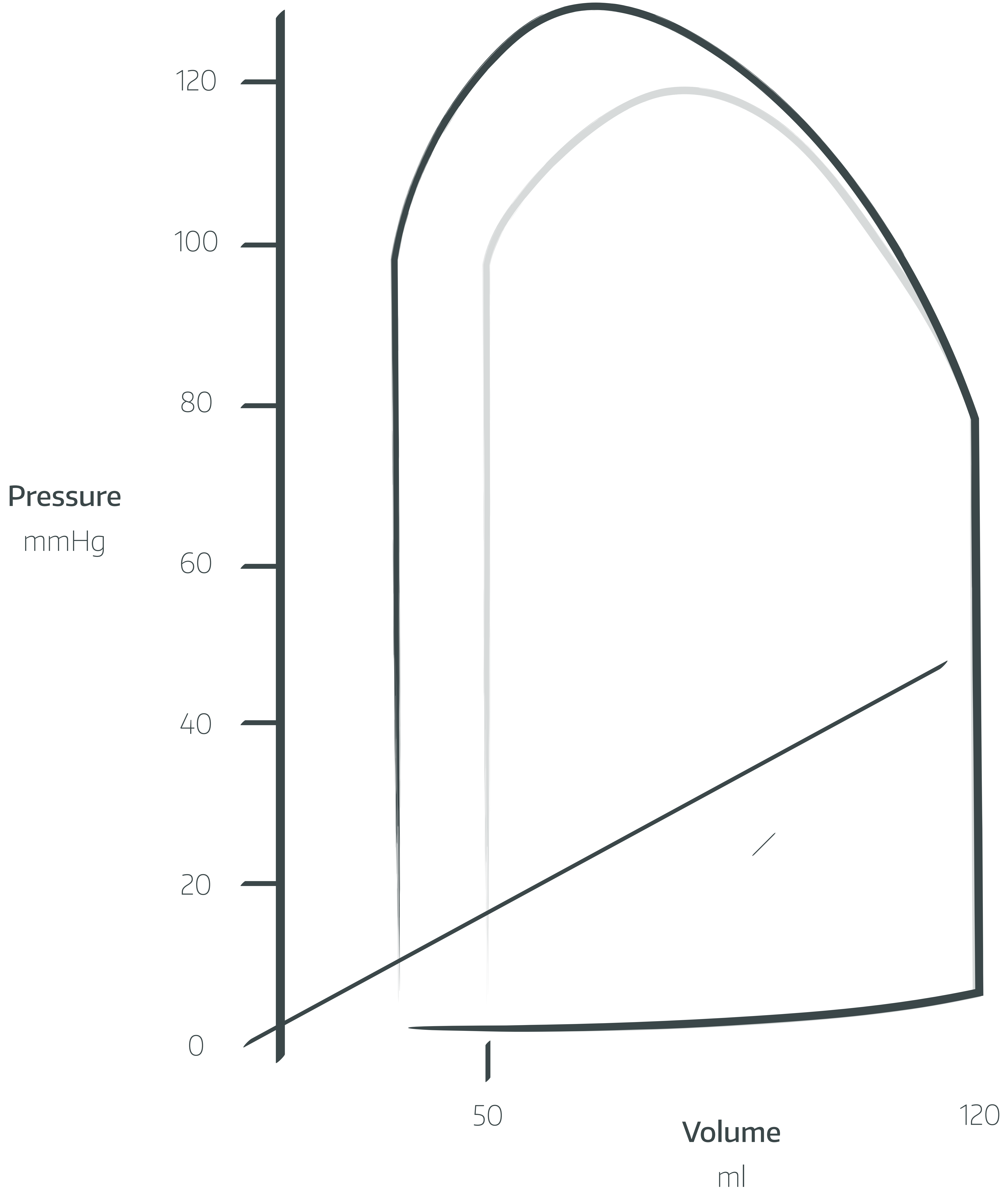
LV Pressure-Volume Loops



LV Pressure-Volume Loops



LV Pressure-Volume Loops



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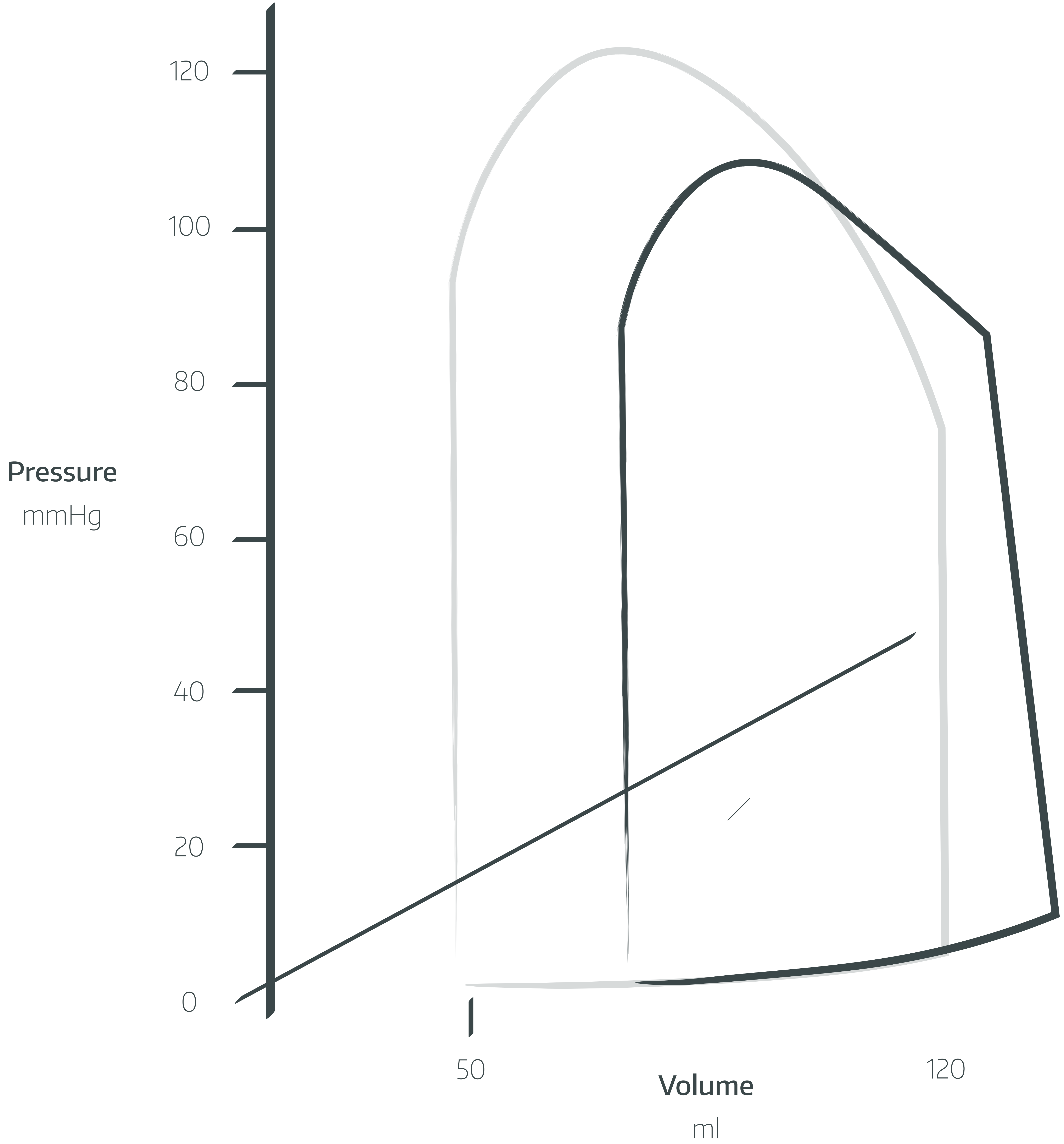

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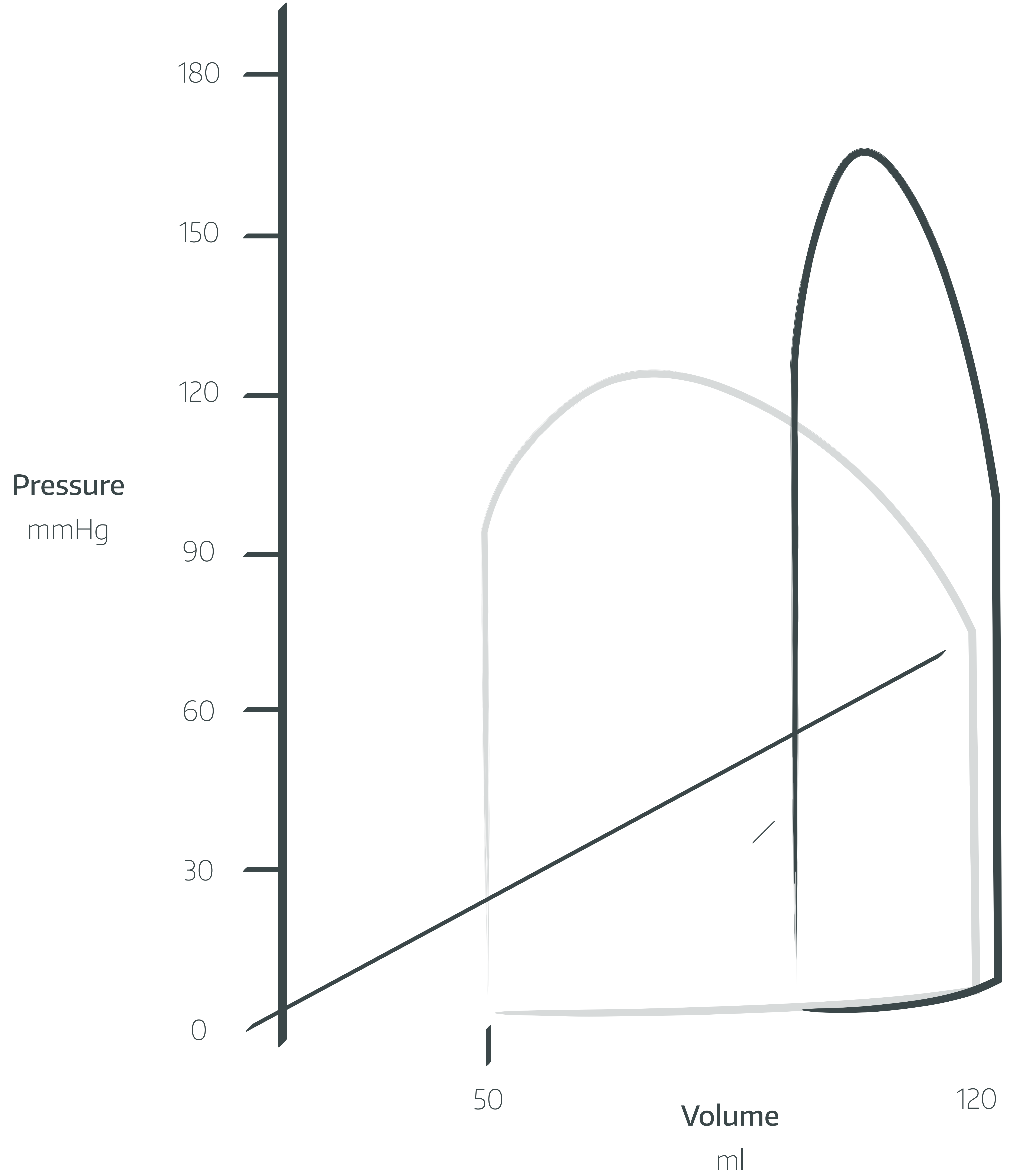
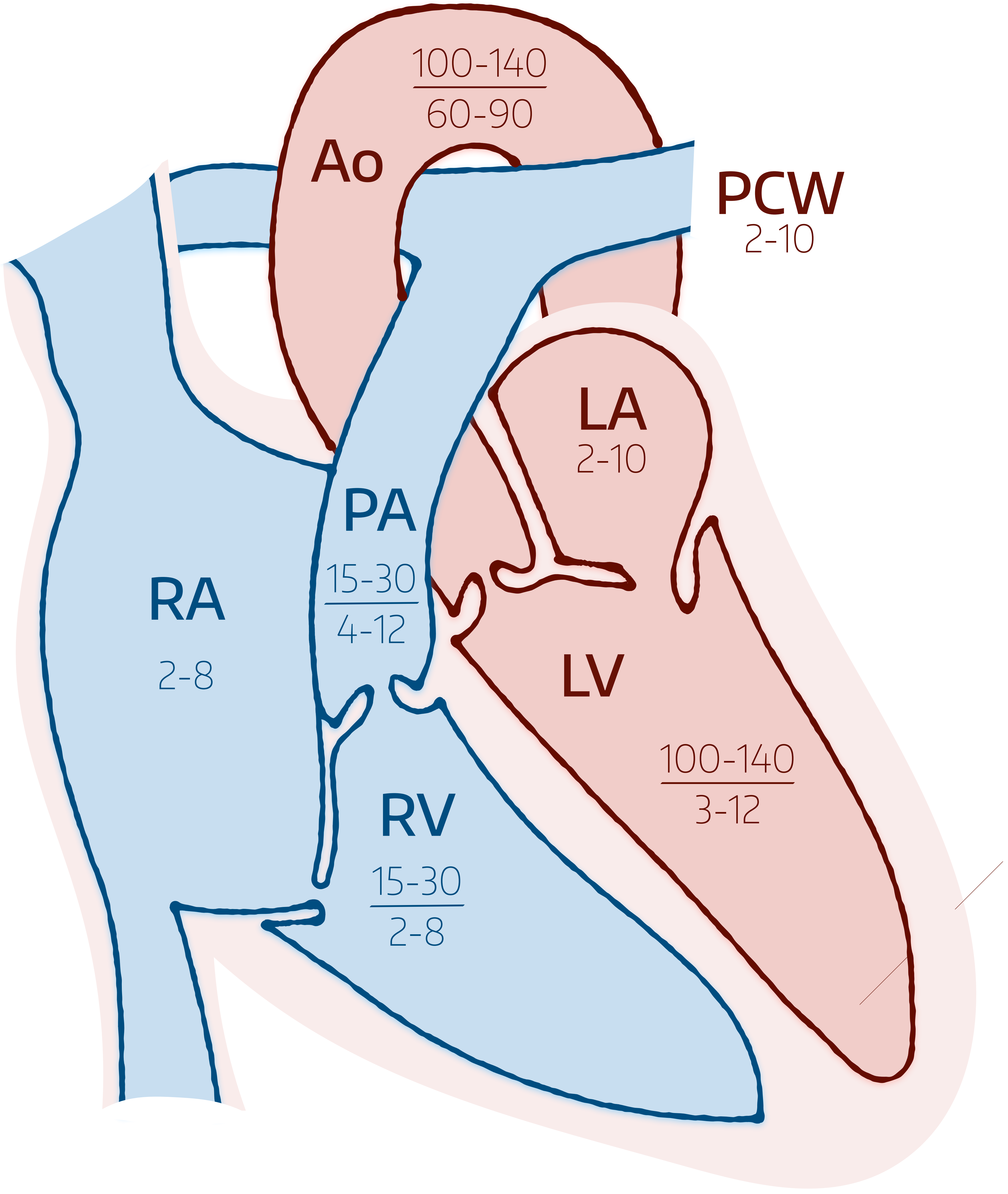
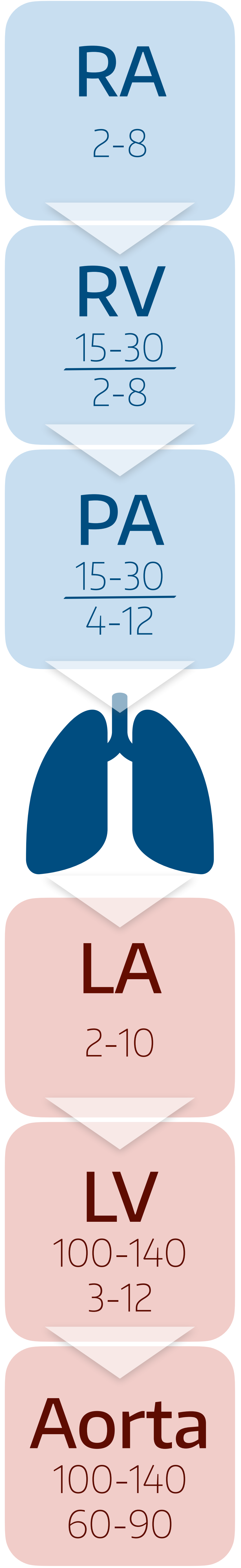
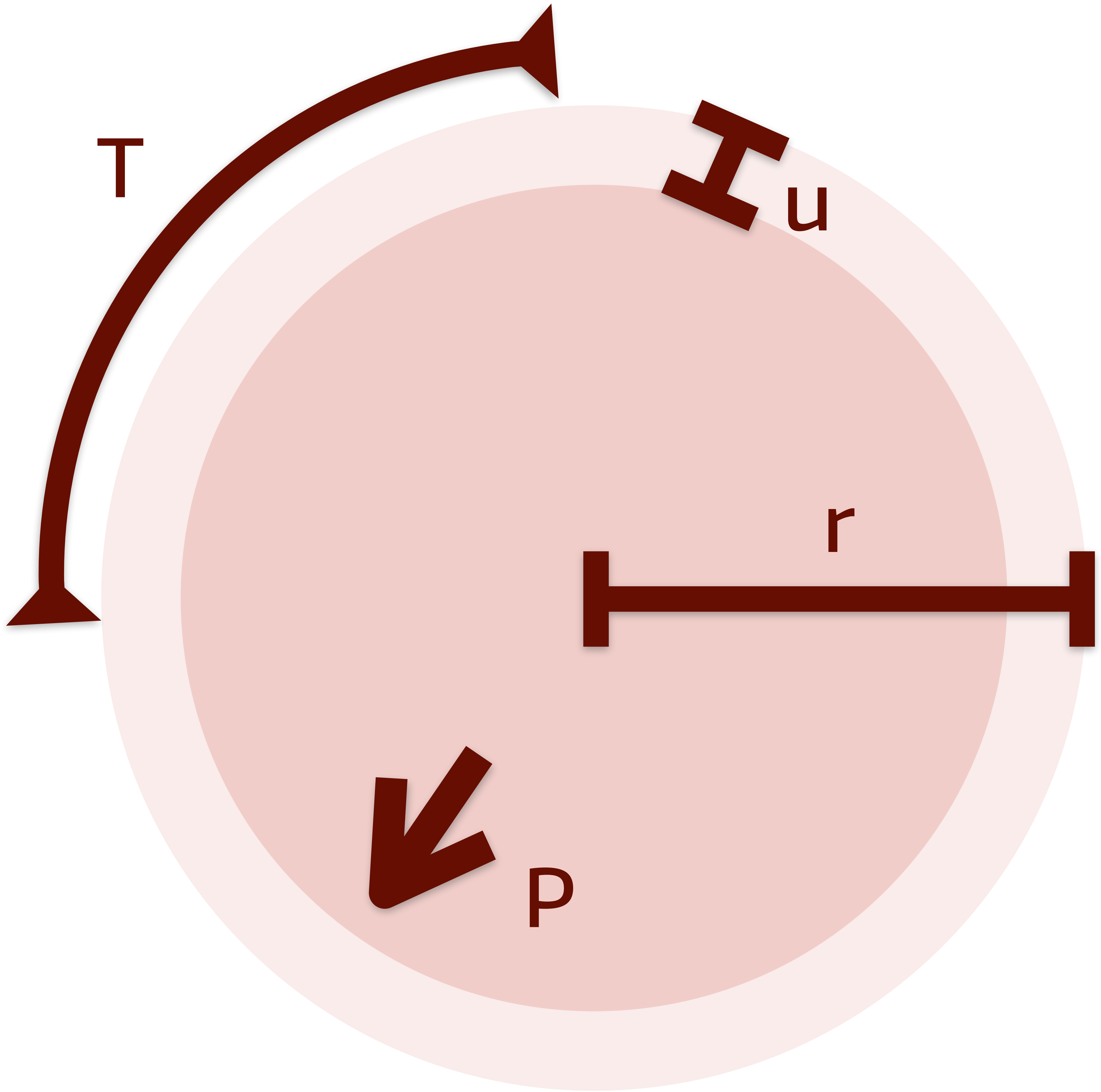


Intracardiac Pressures





LaPlace's Law



$$T = \frac{rP}{2u}$$

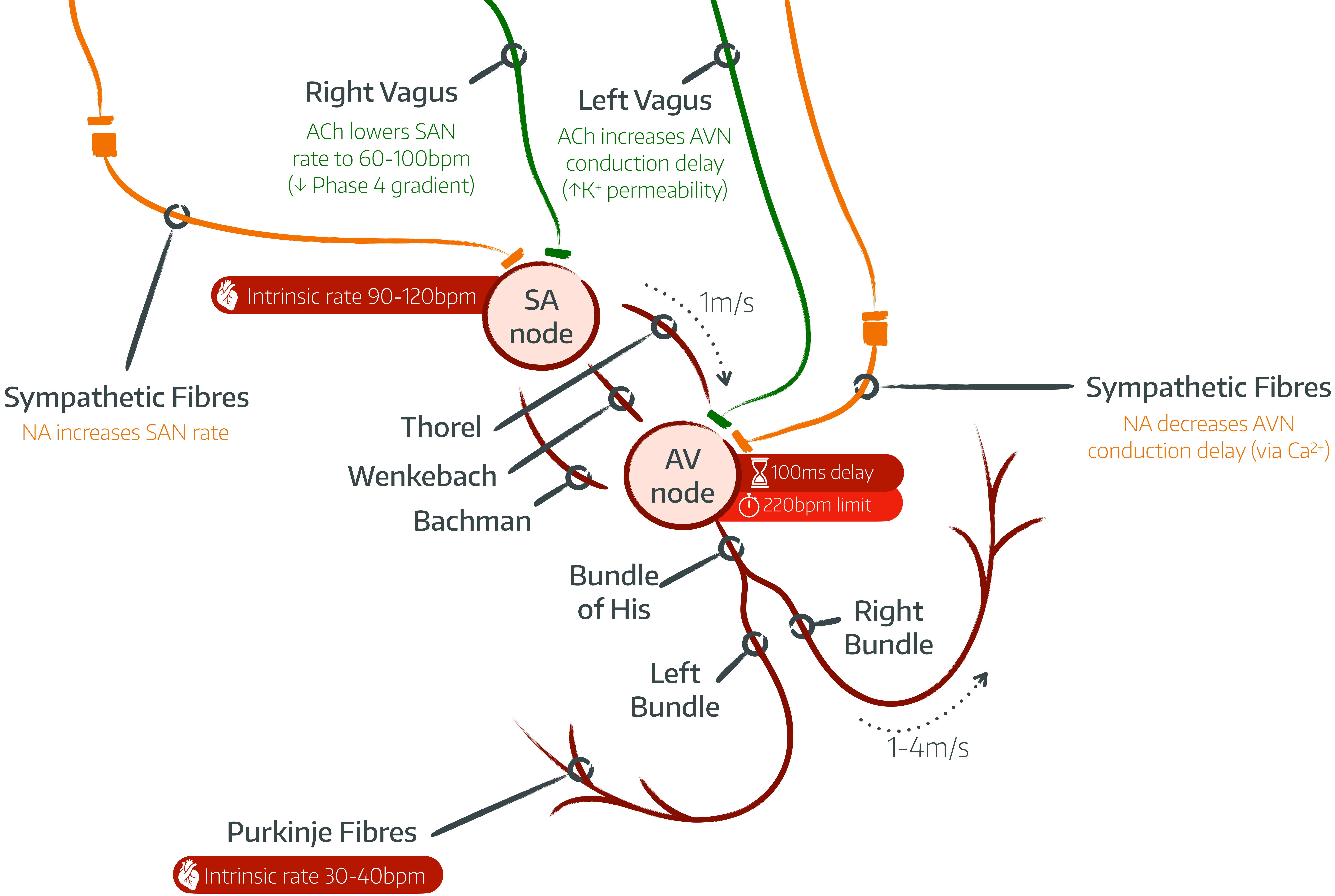
Radius

Transmural Pressure

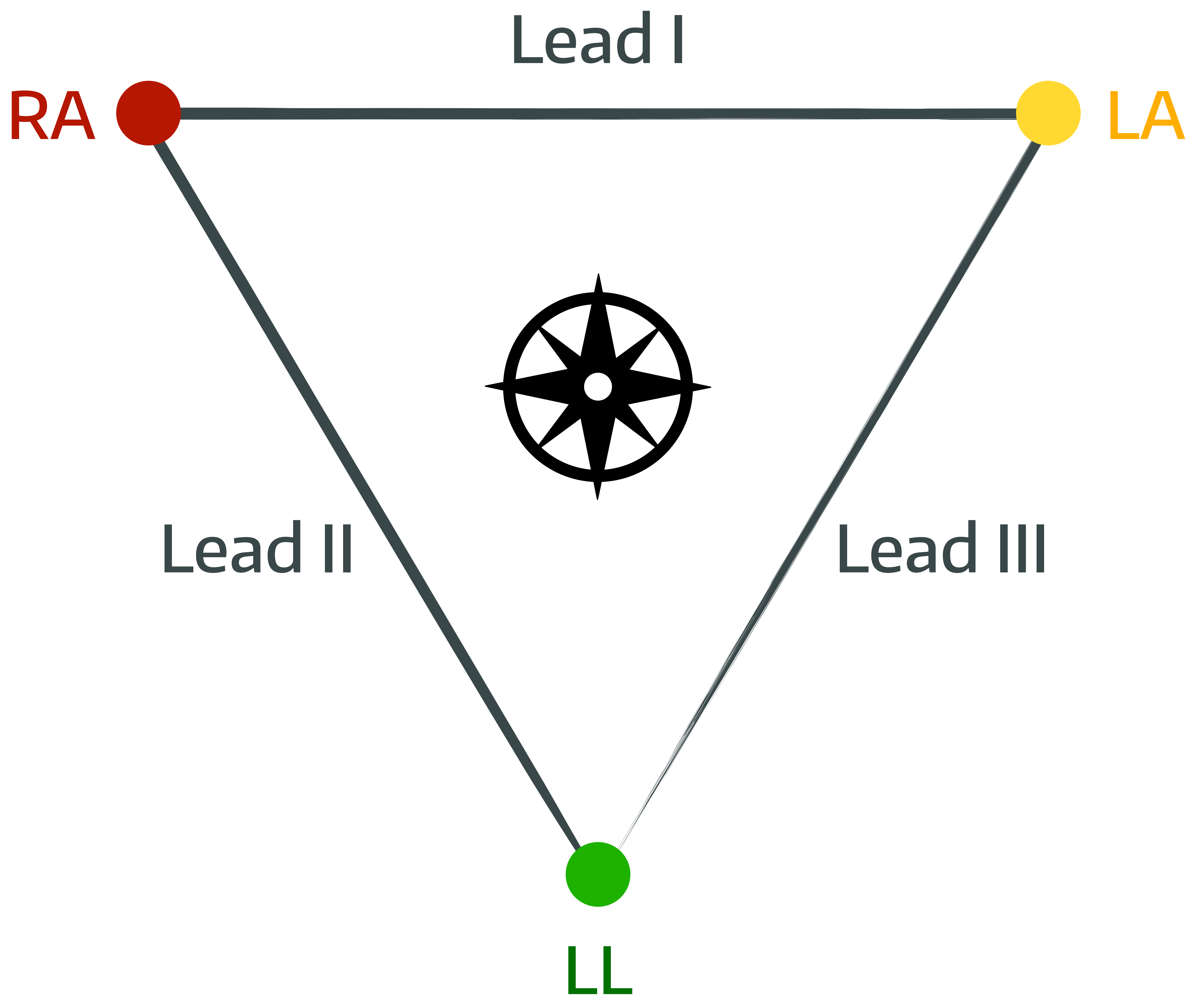
Wall tension

Wall thickness

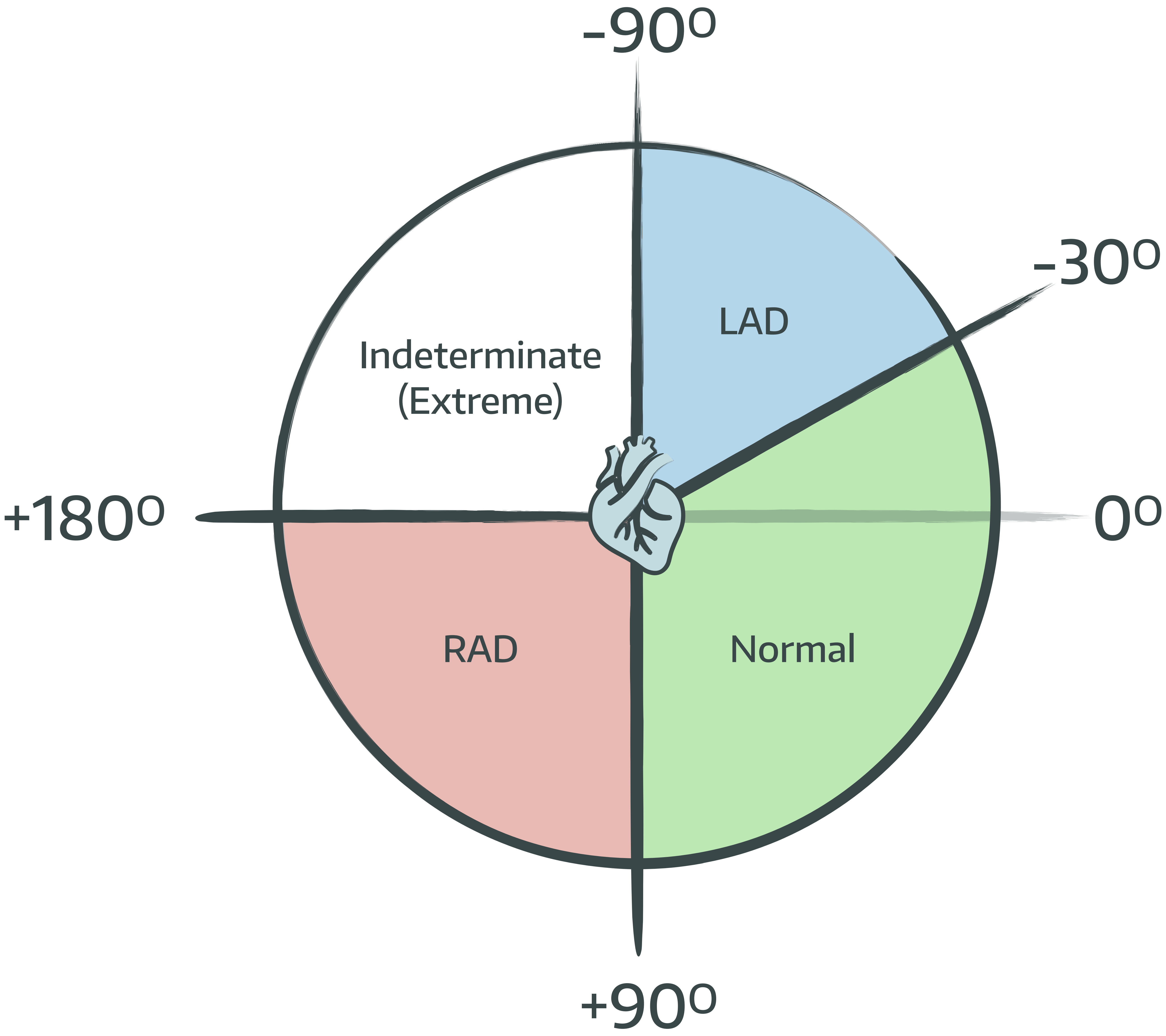
Heart Rate Control



Einthoven's Law



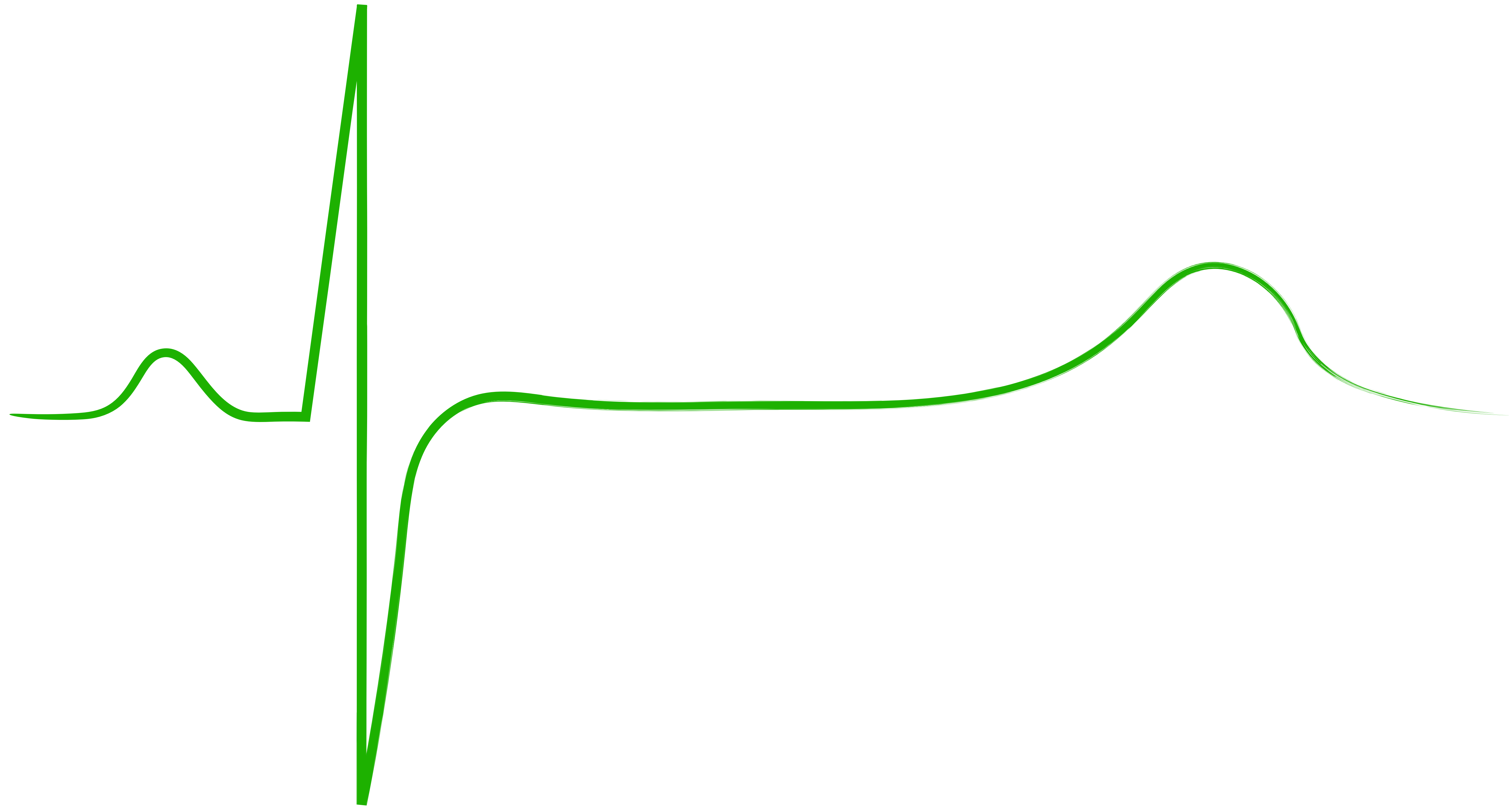
CARDIAC AXIS



ECG ABNORMALITIES

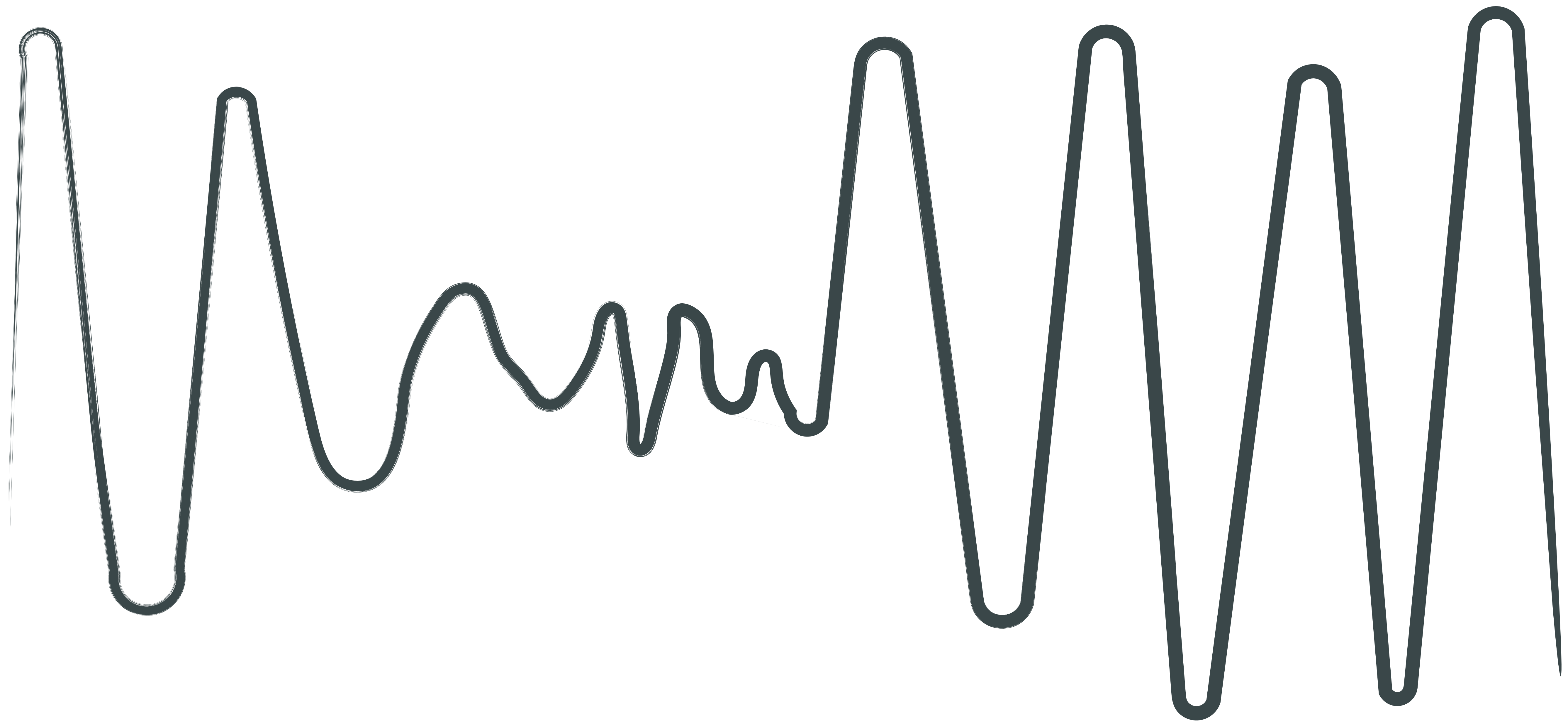
Ca^{2+}

Hypocalcaemia



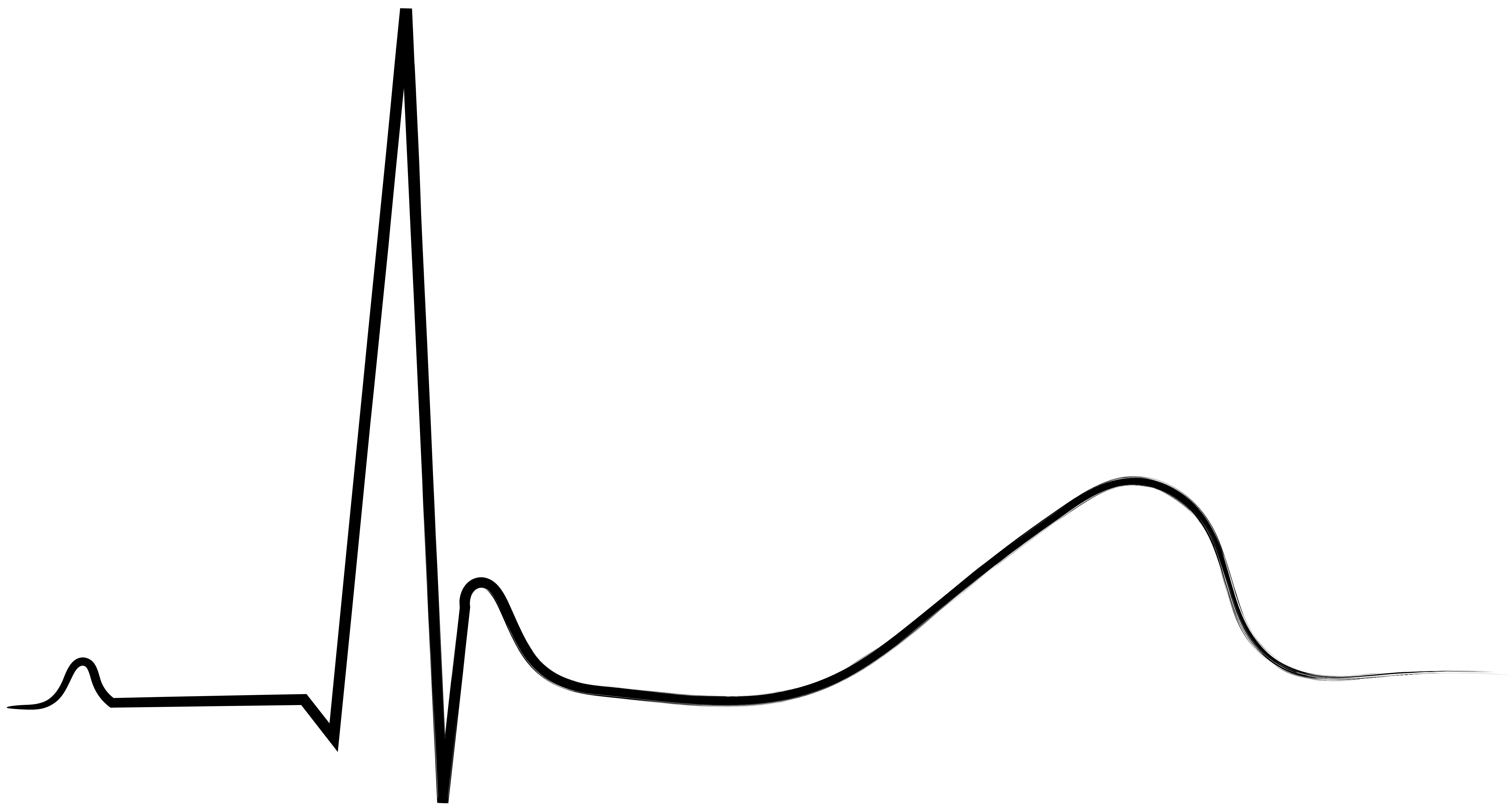
ECG ABNORMALITIES

Torsades de Pointes



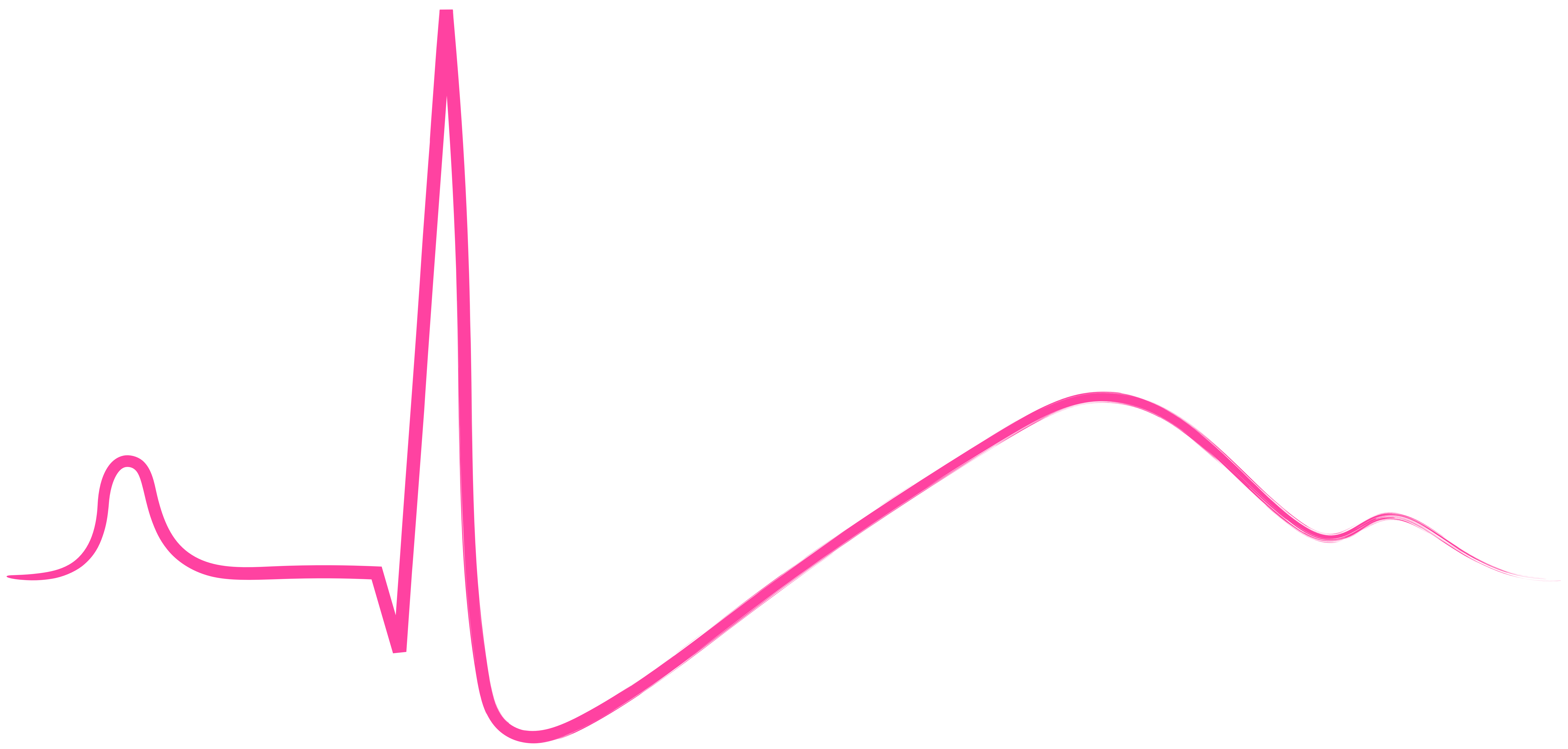
ECG ABNORMALITIES

Hypothermia

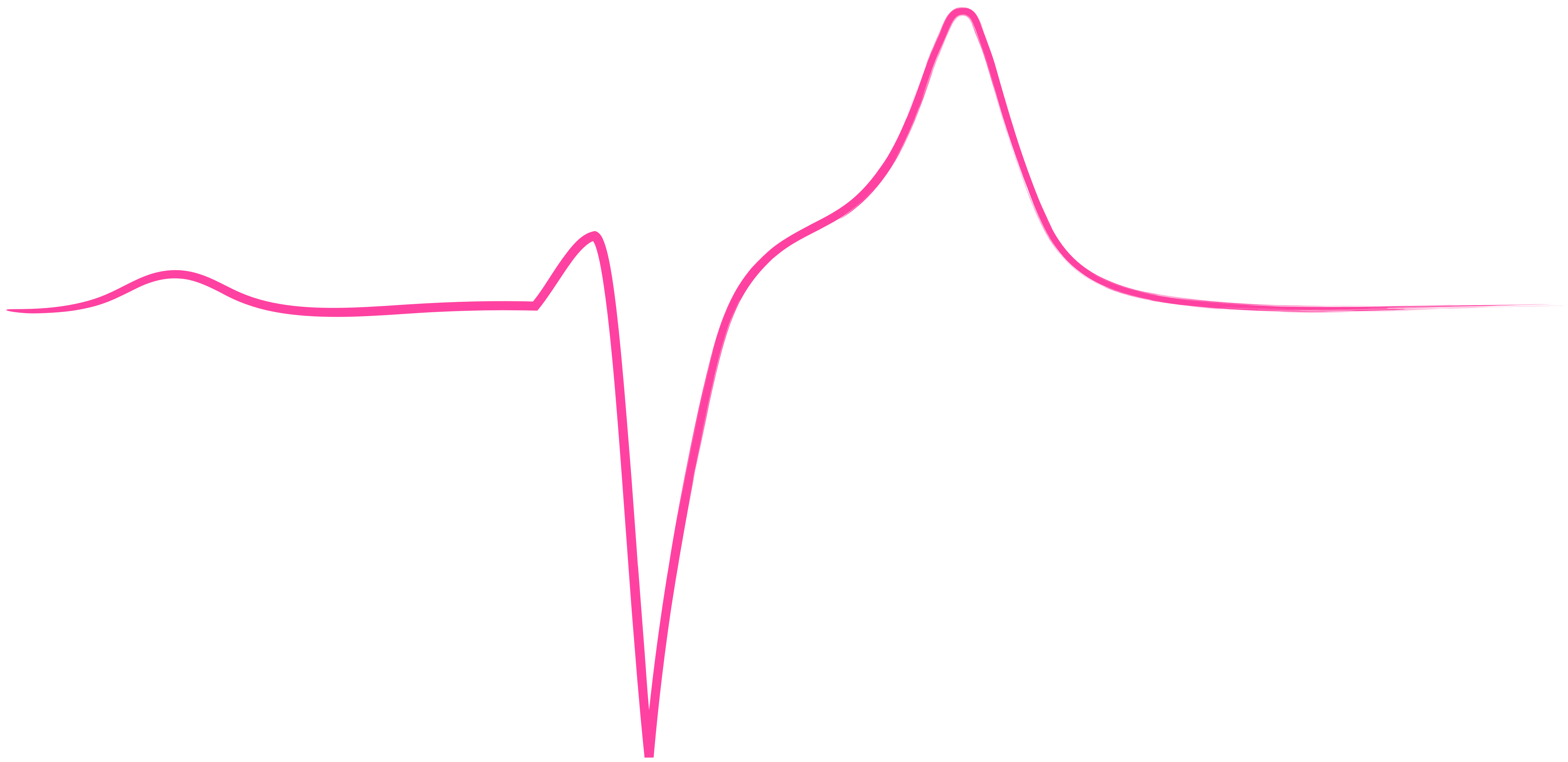


ECG ABNORMALITIES

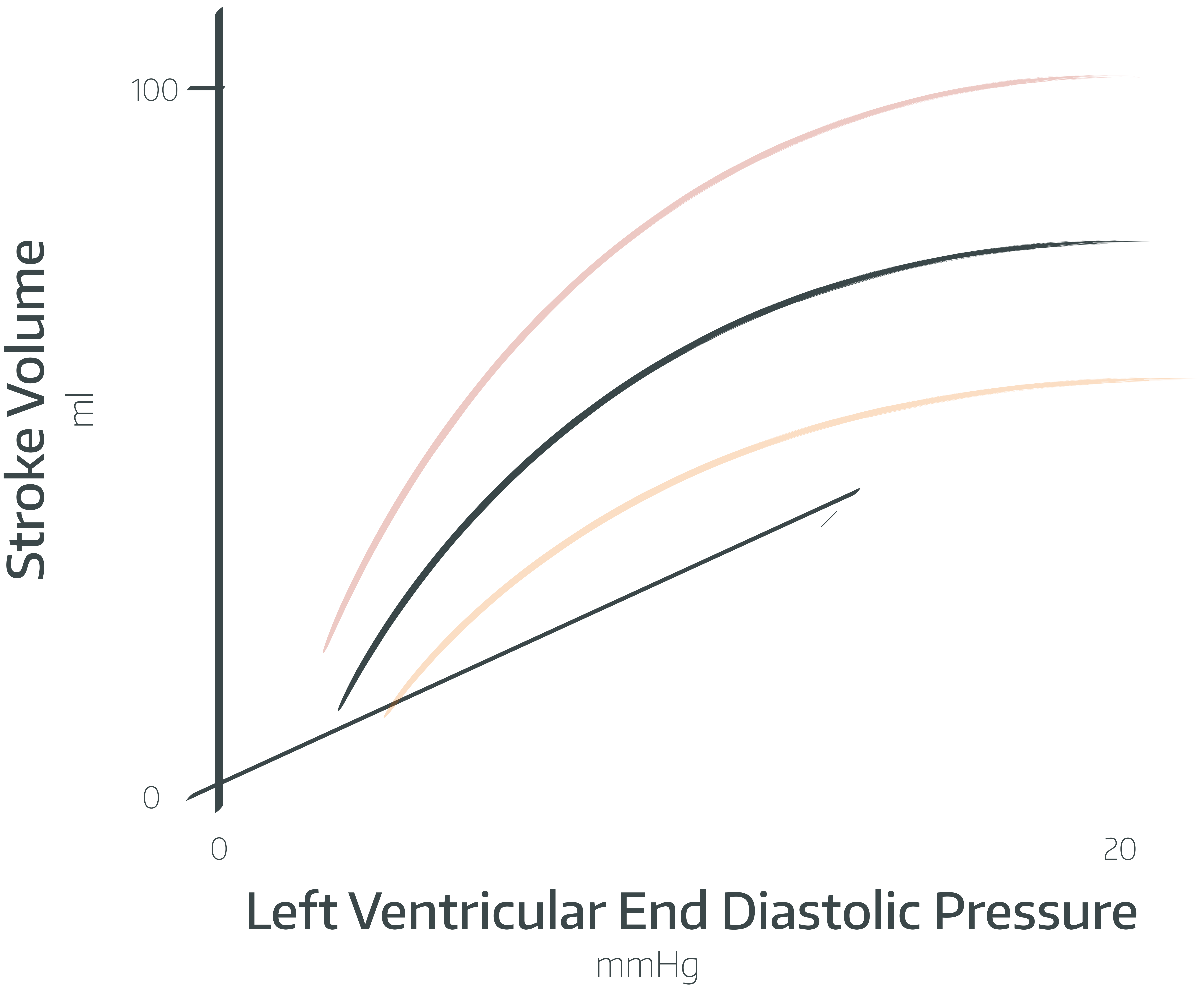
Hypokalaemia



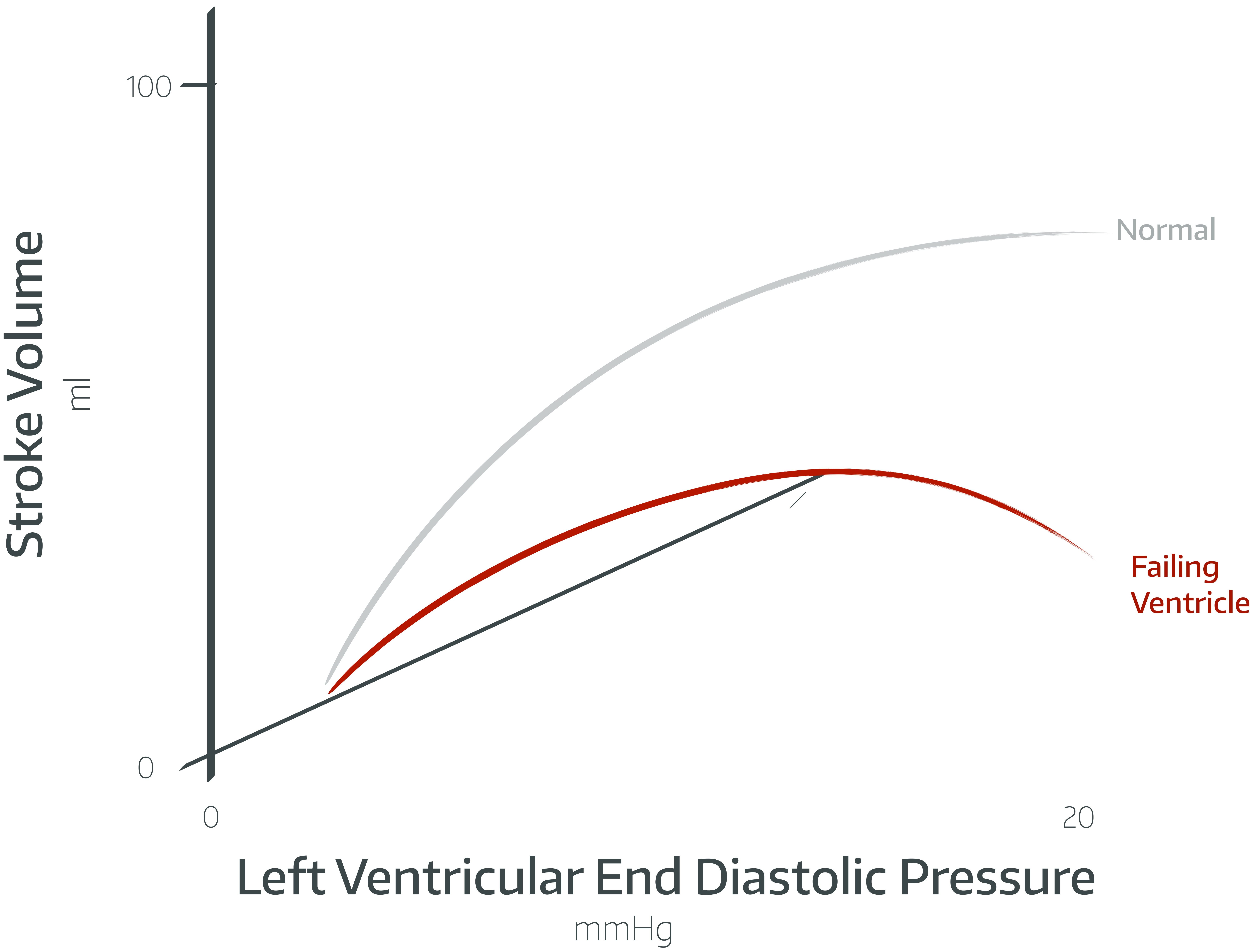
Hyperkalaemia



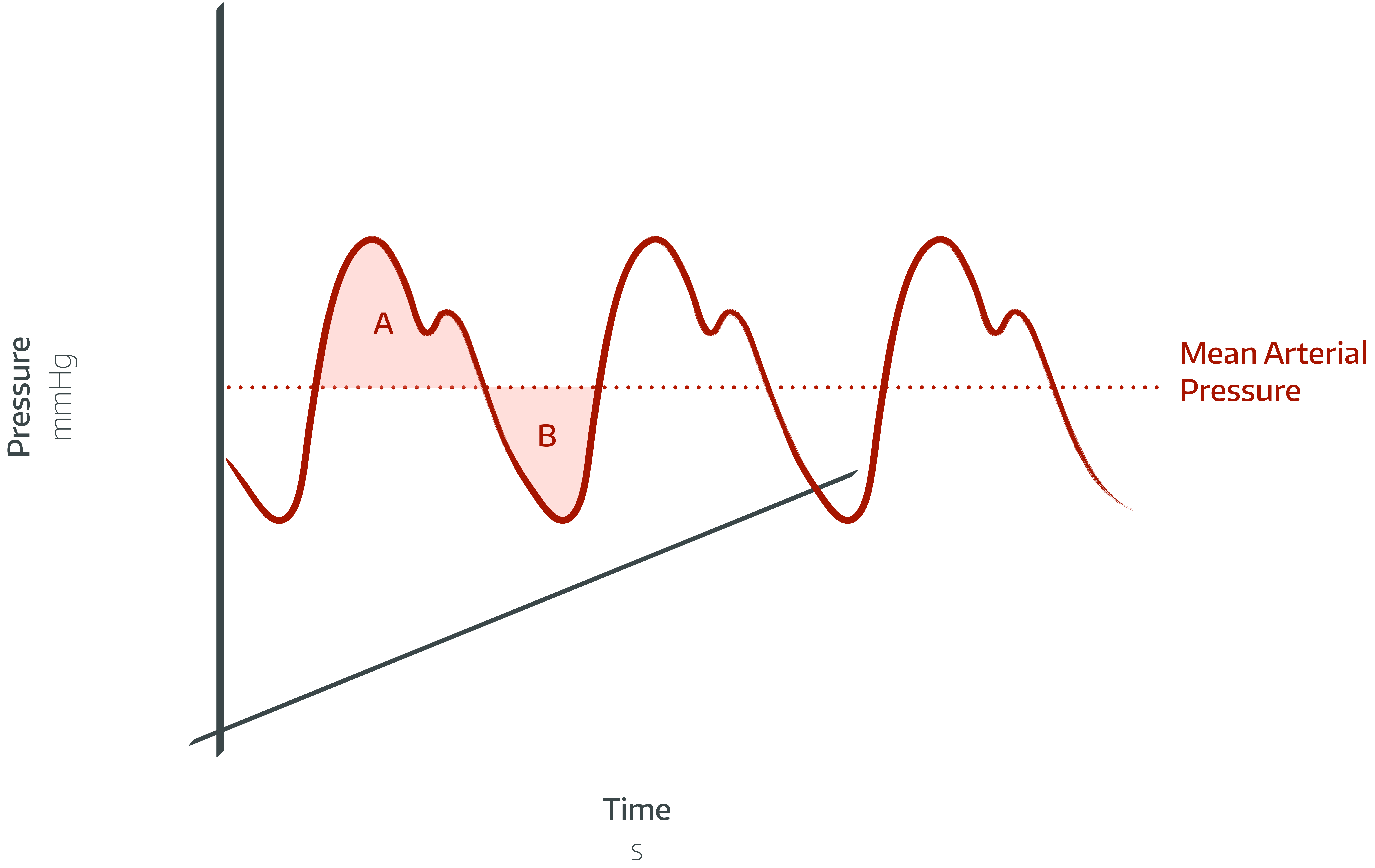
Frank-Starling Curve



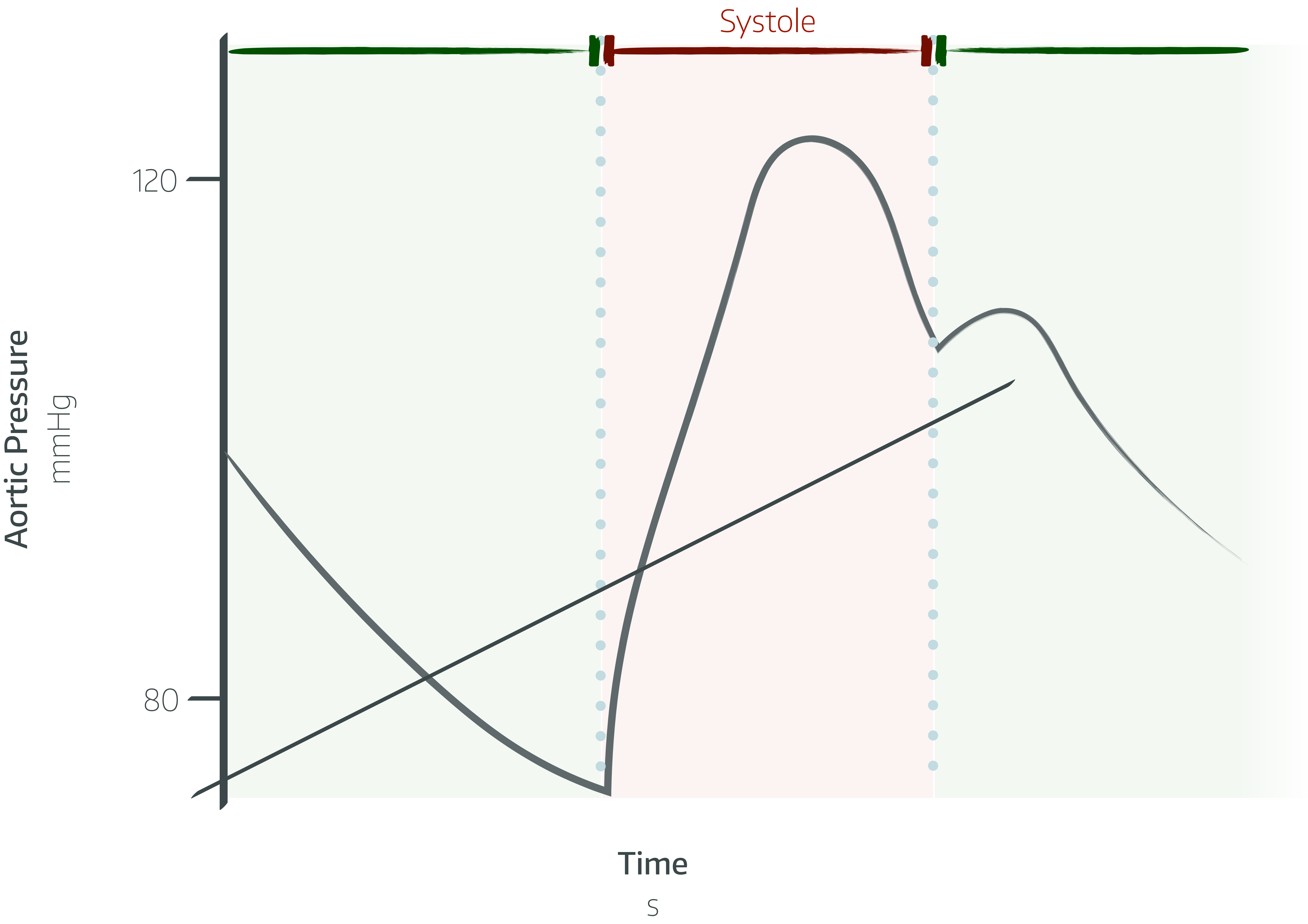
Frank-Starling Curve



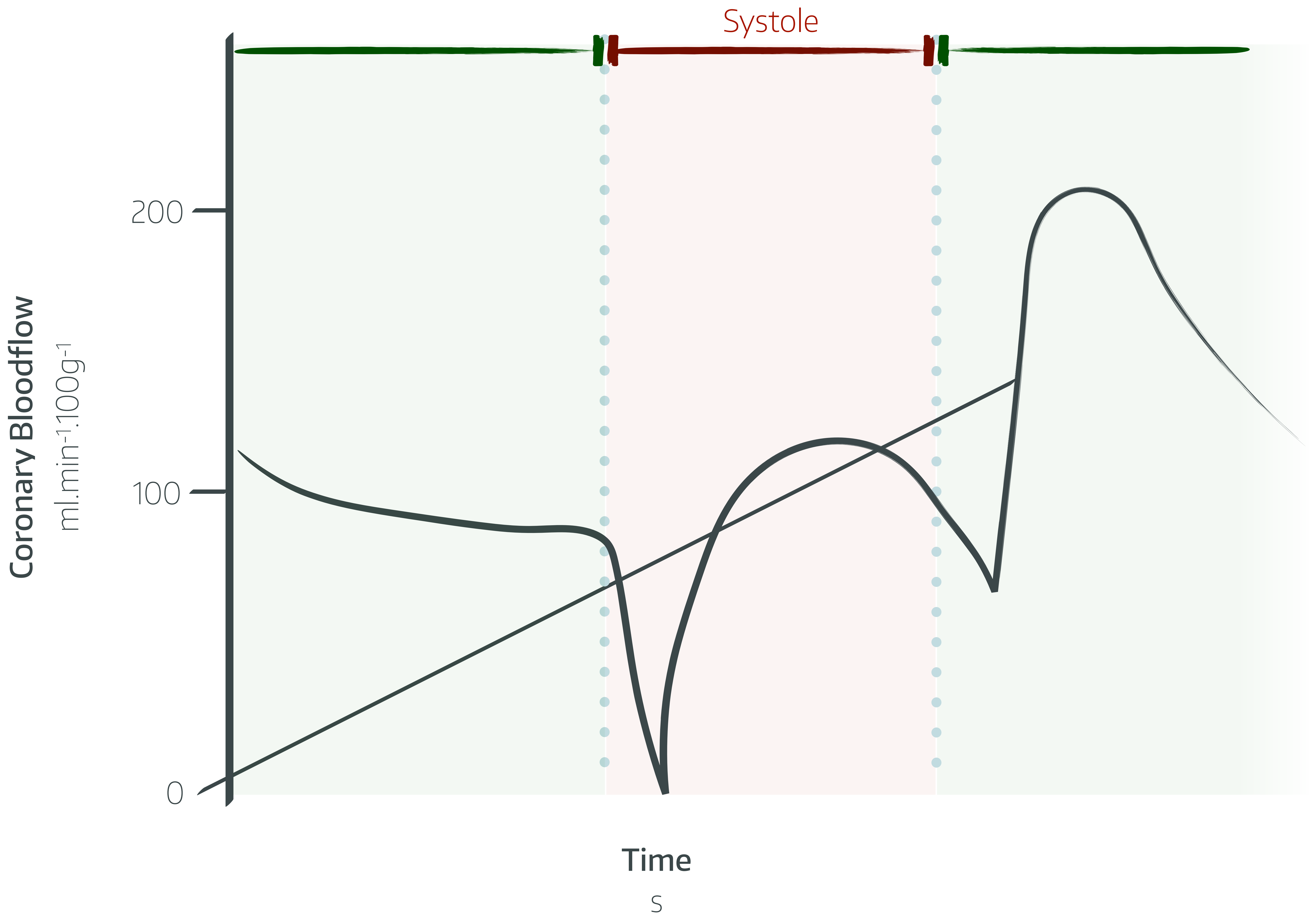
Blood Pressure



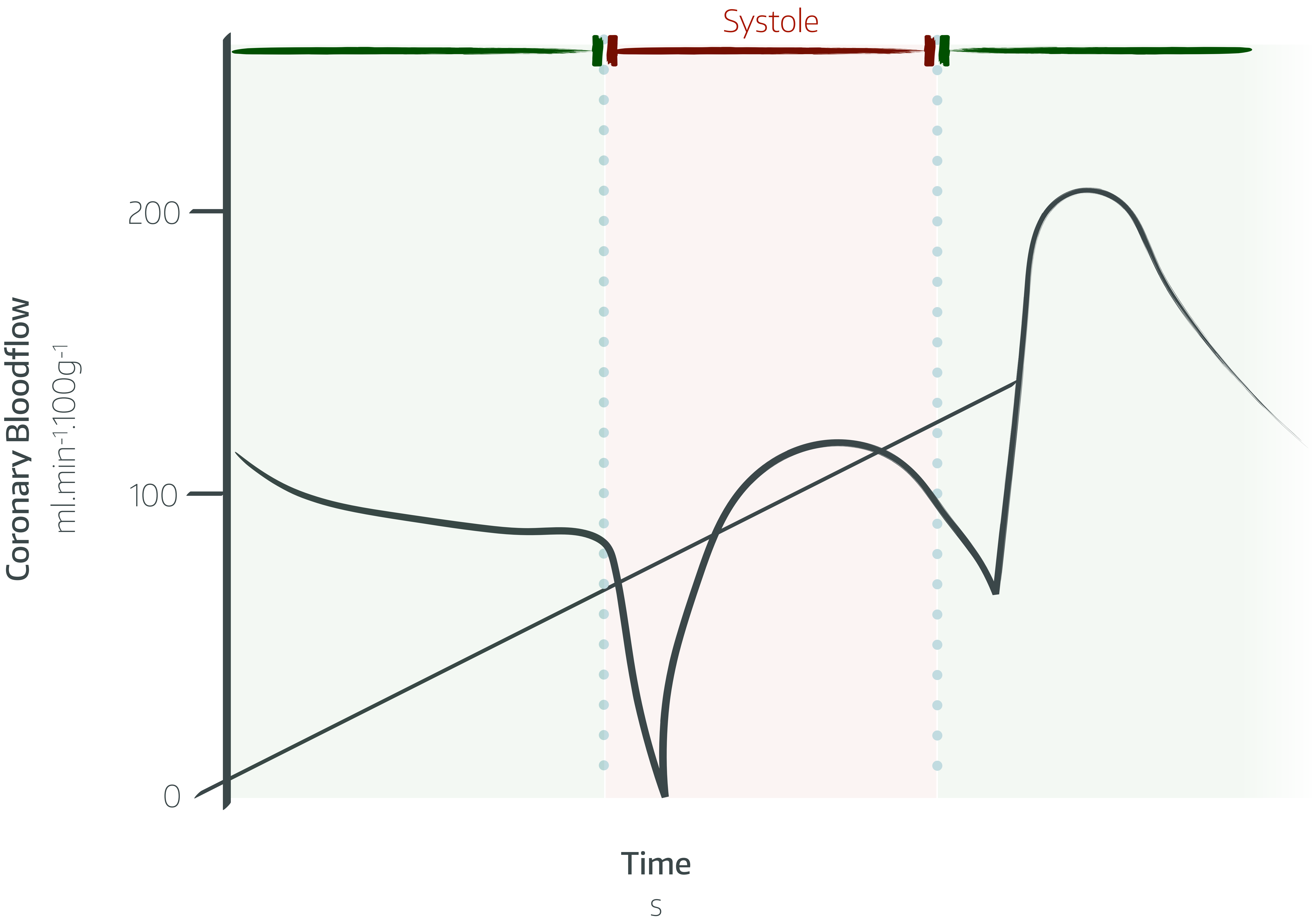
Blood Pressure



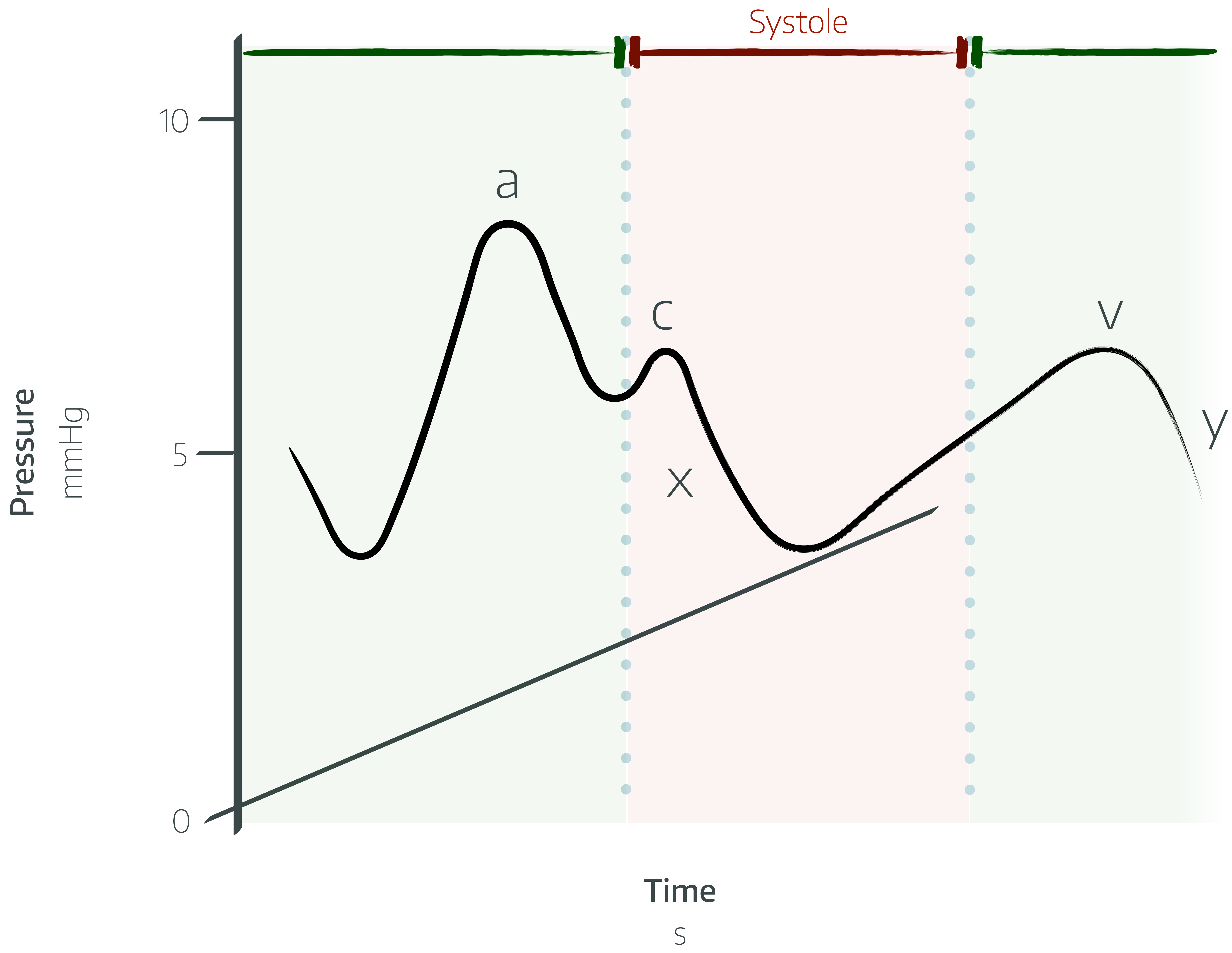
Blood Pressure



Blood Pressure



Central Venous Pressure



VALSALVA MANŒUVRE

Forced expiration against a closed glottis

Phase 1

Onset of Pressure

Compression of Pulmonary Capacitance Vessels → Increased Venous Return → Raised BP → Reflex Bradycardia

Phase 2

Maintenance of Pressure

Reduced Venous Return → Reduced BP → Reflex Tachycardia → Eventually restores BP

Phase 3

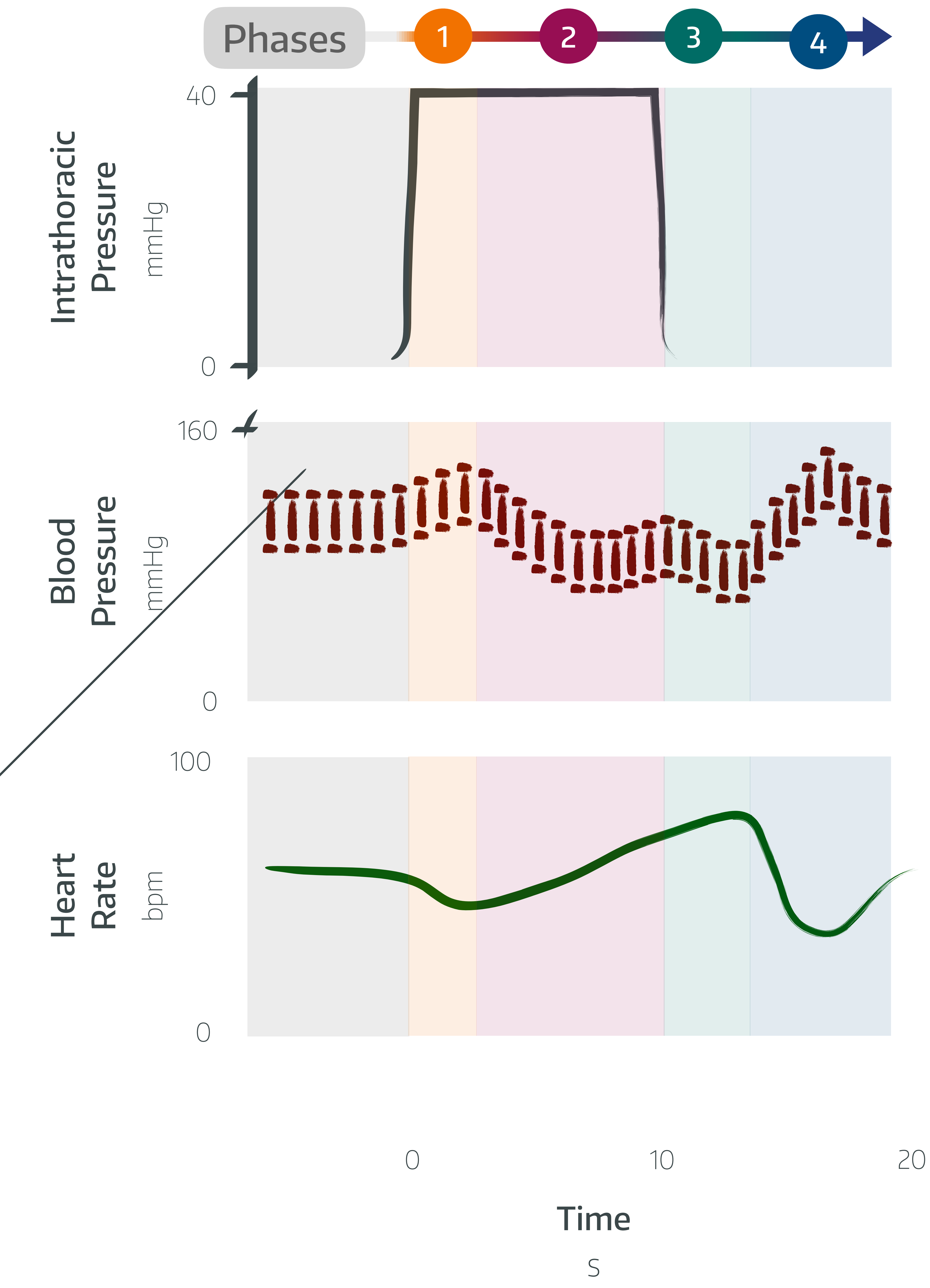
Release of Pressure

Large, empty Venous Reservoir → Low Venous Return → Reduced BP → Reflex Tachycardia

Phase 4

Until normal pressures reached

Venous Return Restored → Increased BP → Reflex Bradycardia.
All parameters then normalise.



SYSTEMIC VASCULAR RESISTANCE

$$SVR = \frac{MAP - RAP}{CO} \times 80$$

SVR: Systemic Vascular Resistance

~1,000 - 1,500 dynes.s.cm^{-5}

MAP: Mean Arterial Pressure

RAP: Right Atrial Pressure

CO: Cardiac Output

80: Unit Conversion Coefficient

BLOOD PRESSURE

PULMONARY VASCULAR RESISTANCE

Pulmonary Vascular Resistance

Mean Pulmonary Artery Pressure

Left Atrial Pressure

$$PVR = \frac{MPAP - LAP}{CO} \times 80$$

~100 - 150 dynes.s.cm^{-5}

Cardiac Output

Unit Conversion Coefficient

Venous Return

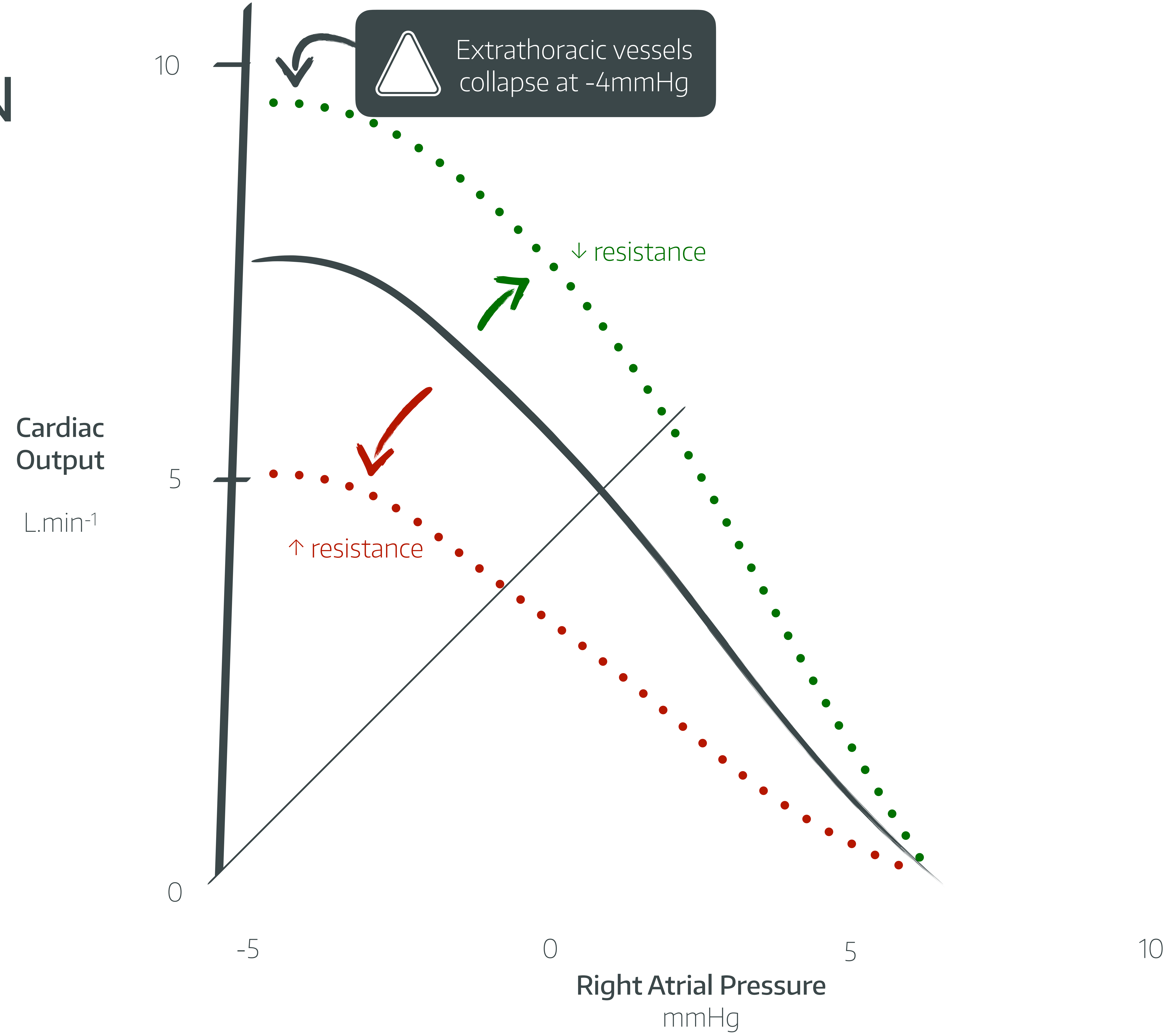
$$= \frac{\color{red}{MSFP} - \color{blue}{RAP}}{R_{ven}} \times 80$$

Mean Systolic Filling Pressure

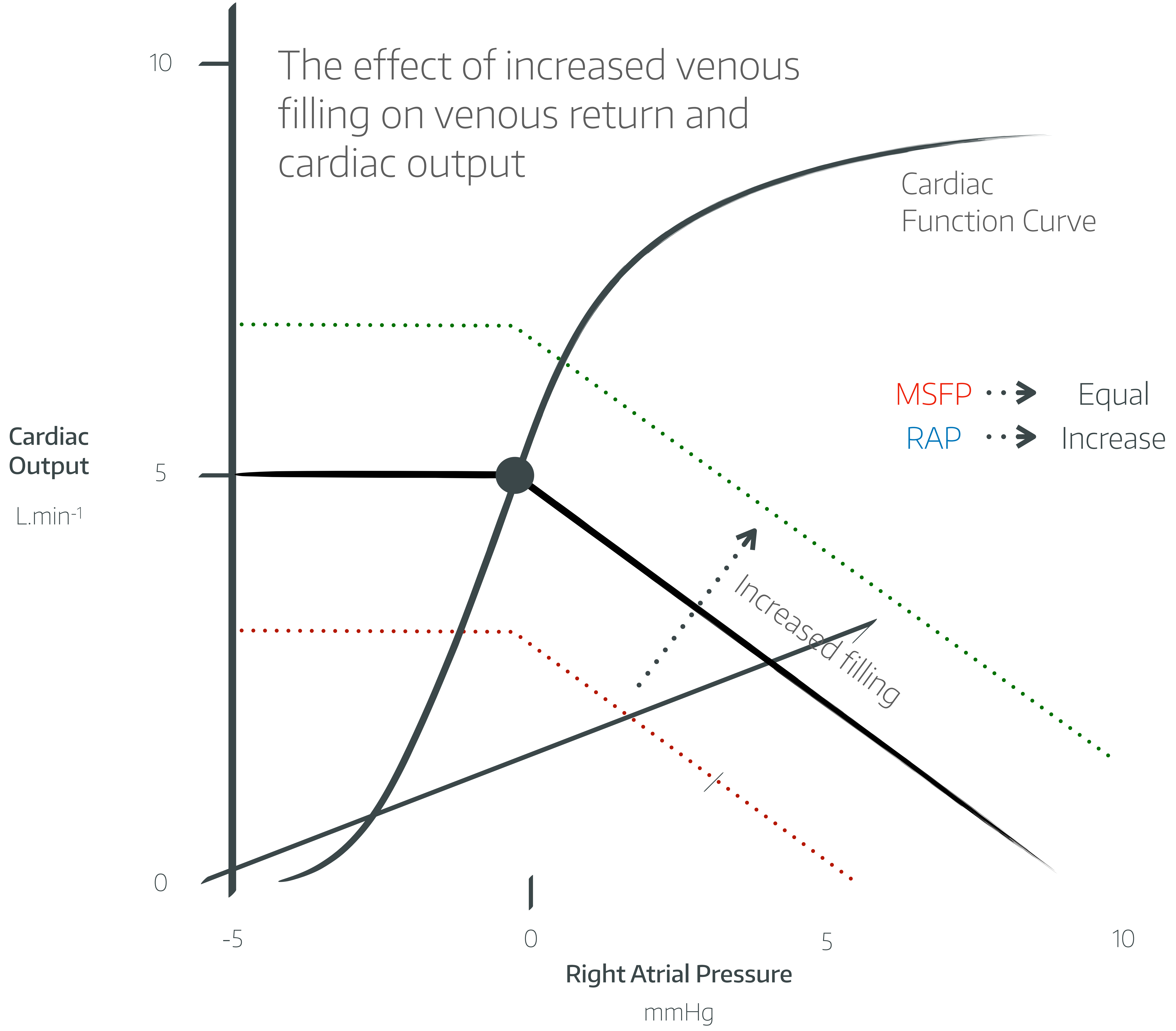
= weighted average of systemic circulation pressures

Right Atrial Pressure

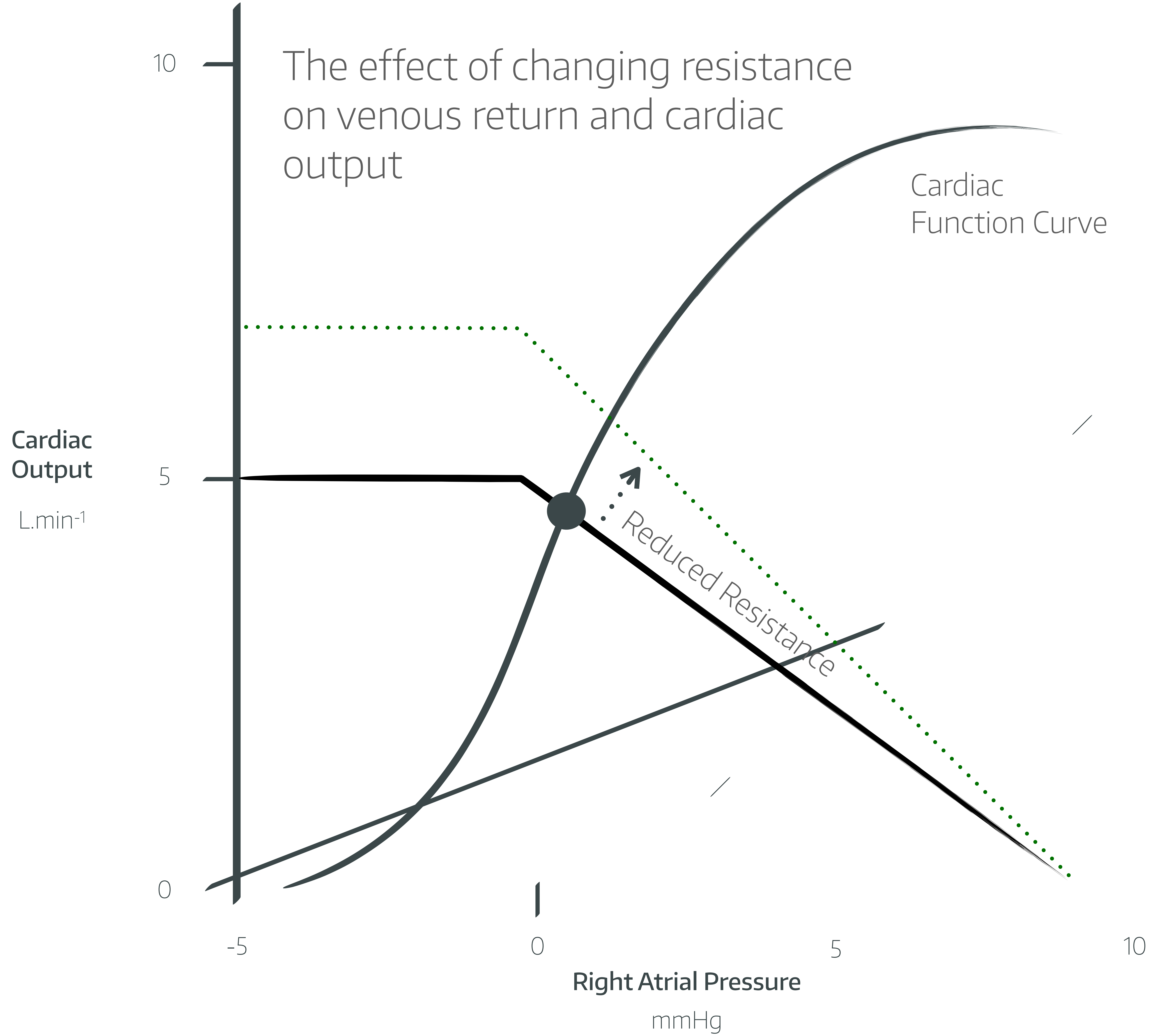
Venous Resistance



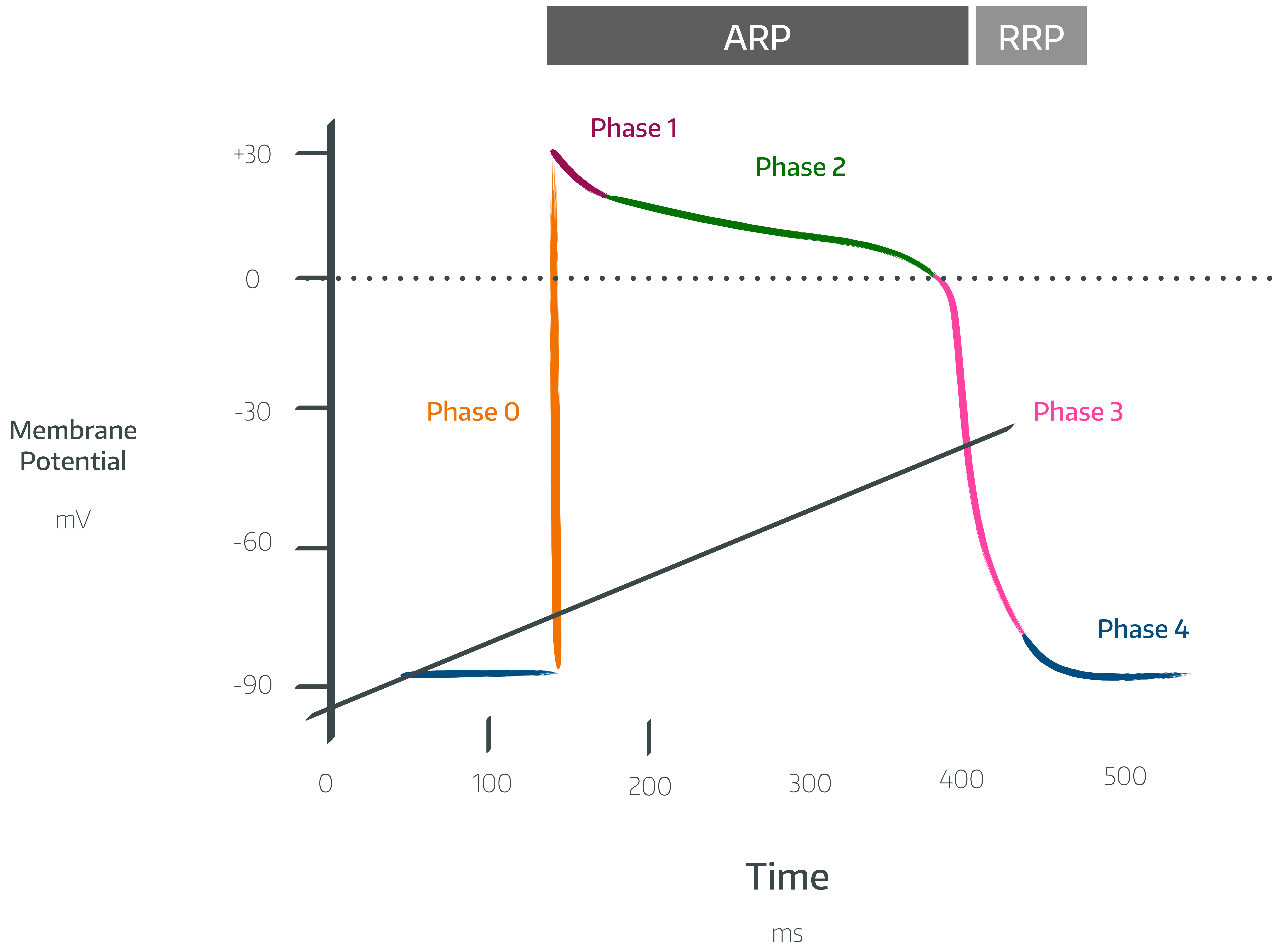
Cardiac Physiology



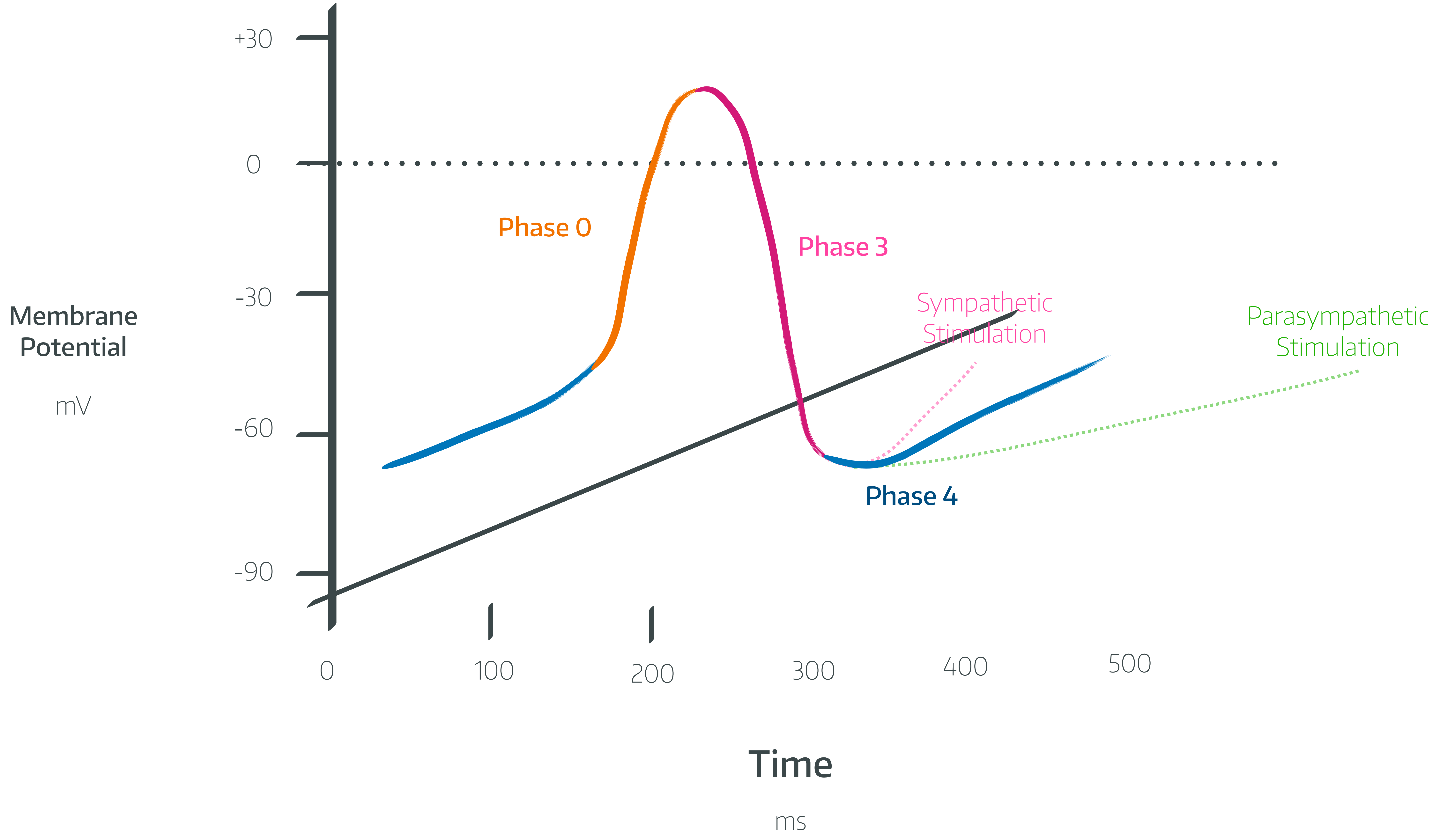
Cardiac Physiology



Cardiac Action Potential



Cardiac Action Potential

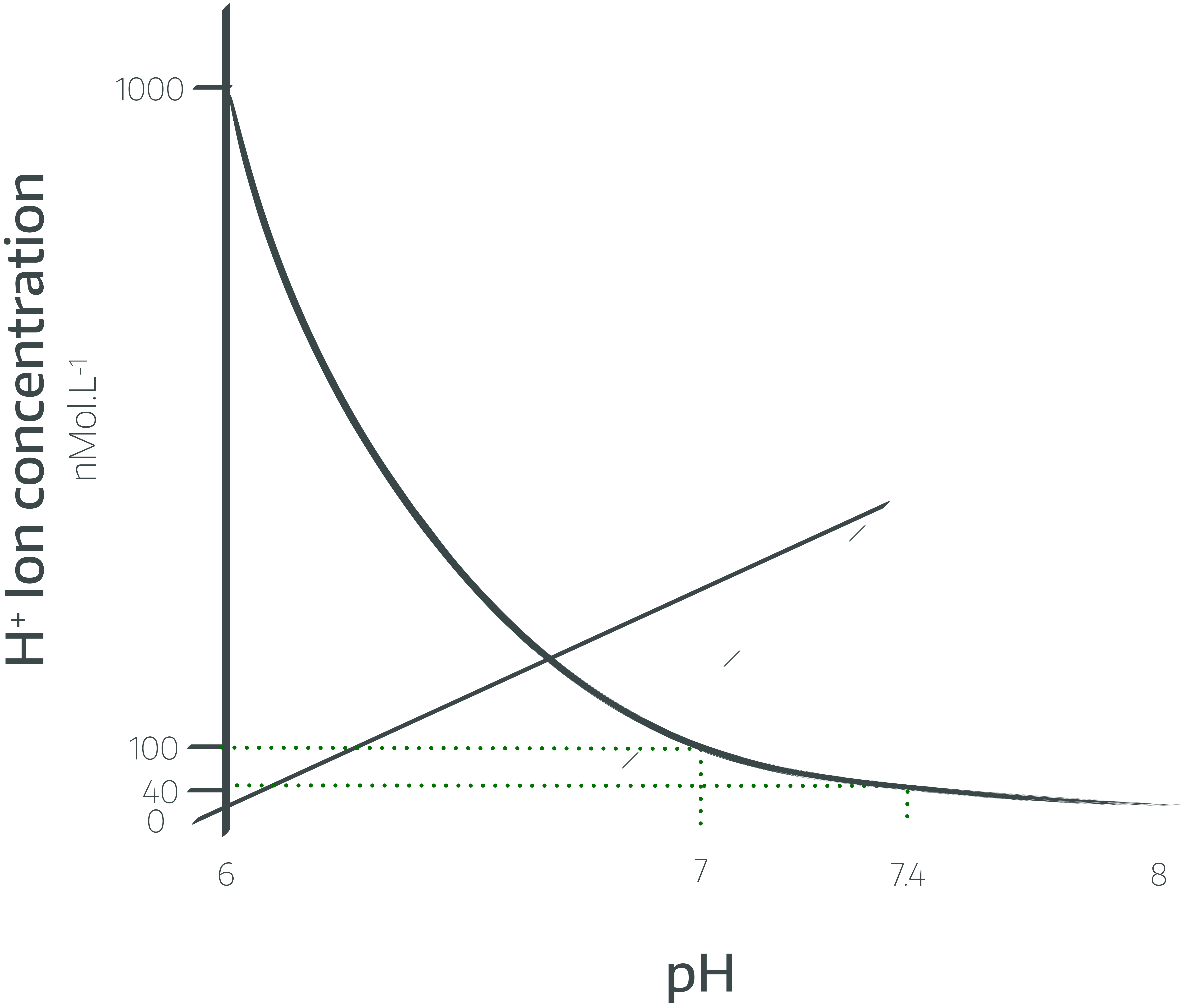


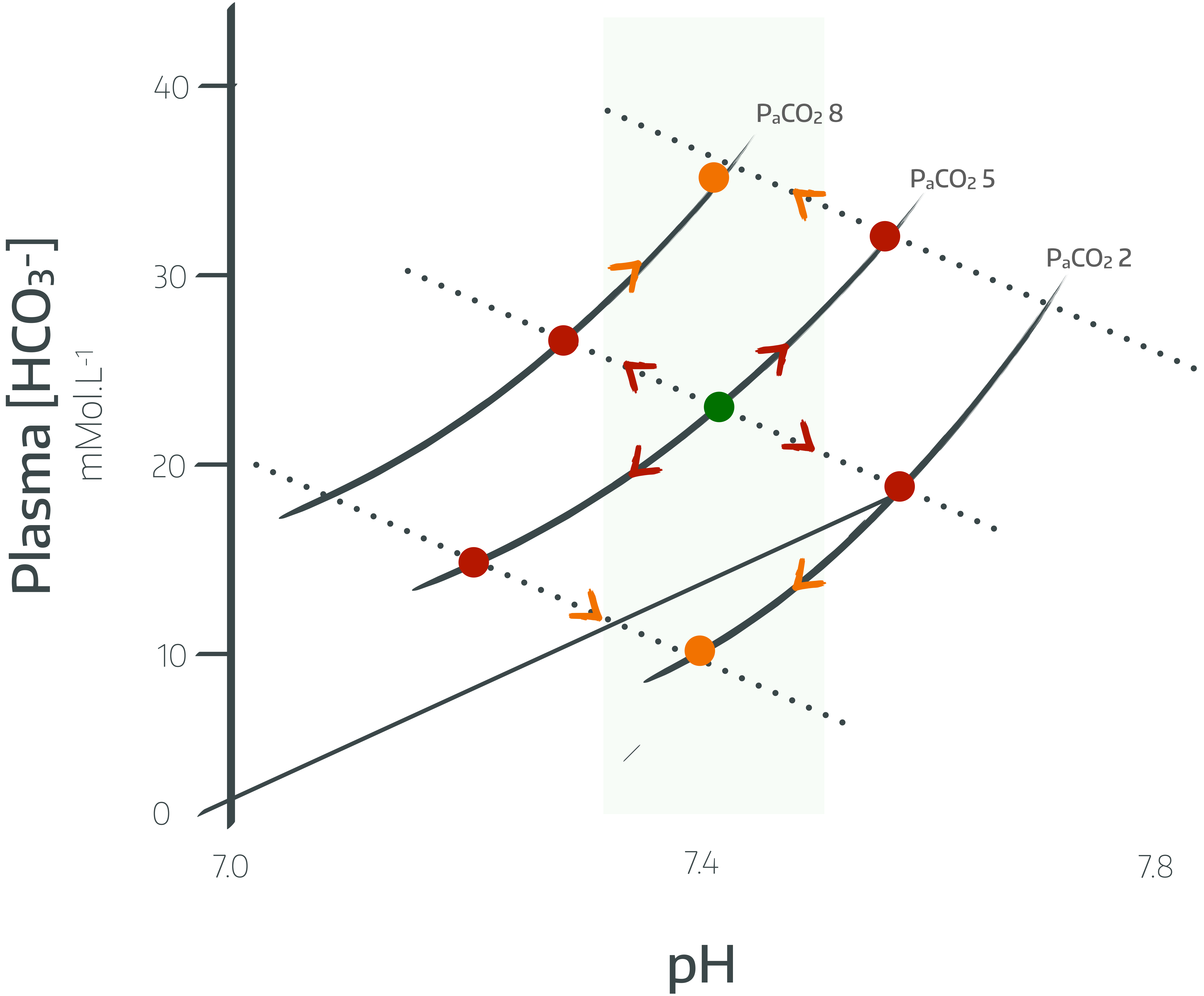
HAEMORRHAGE CLASSIFICATION

Traditional Classes according to **ATLS**

	1	2	3	4
Blood Loss	< 15% Blood volume	15-30% Blood volume	30-40% Blood volume	> 40% Blood volume
Heart Rate	< 100 bpm	> 100 bpm	> 120 bpm	> 140 bpm
Blood Pressure	↔	↔	↓	↓
Respiratory Rate	14 - 20 /min	20 - 30 /min	30 - 40 /min	> 40 /min
Urine Output	> 30 ml/hr	20 - 30 ml/hr	5 - 15 ml/hr	Negligible
Mental Status	Slightly Anxious	Mildly Anxious	Confused	Lethargic

BIOCHEMISTRY




Plasma [HCO3-]
mMol.L-1
40
30
20
10
0
7.0
7.4
7.8
pH
PaCO2 8
PaCO2 5
PaCO2 2

'Raised Anion Gap' Metabolic Acidosis

C Carbon Monoxide / Cyanide
Congenital Heart Failure

A Aminoglycosides

T Toluene Glue
Theophylline

M Methanol

U Uraemia

D Diabetic Ketoacidosis

P Paraldehyde
Paracetamol

I Iron / Isoniazid
Inborn Errors of Metabolism

L Lactic Acidosis

E Ethylene Glycol
Ethanol

S Salicylates

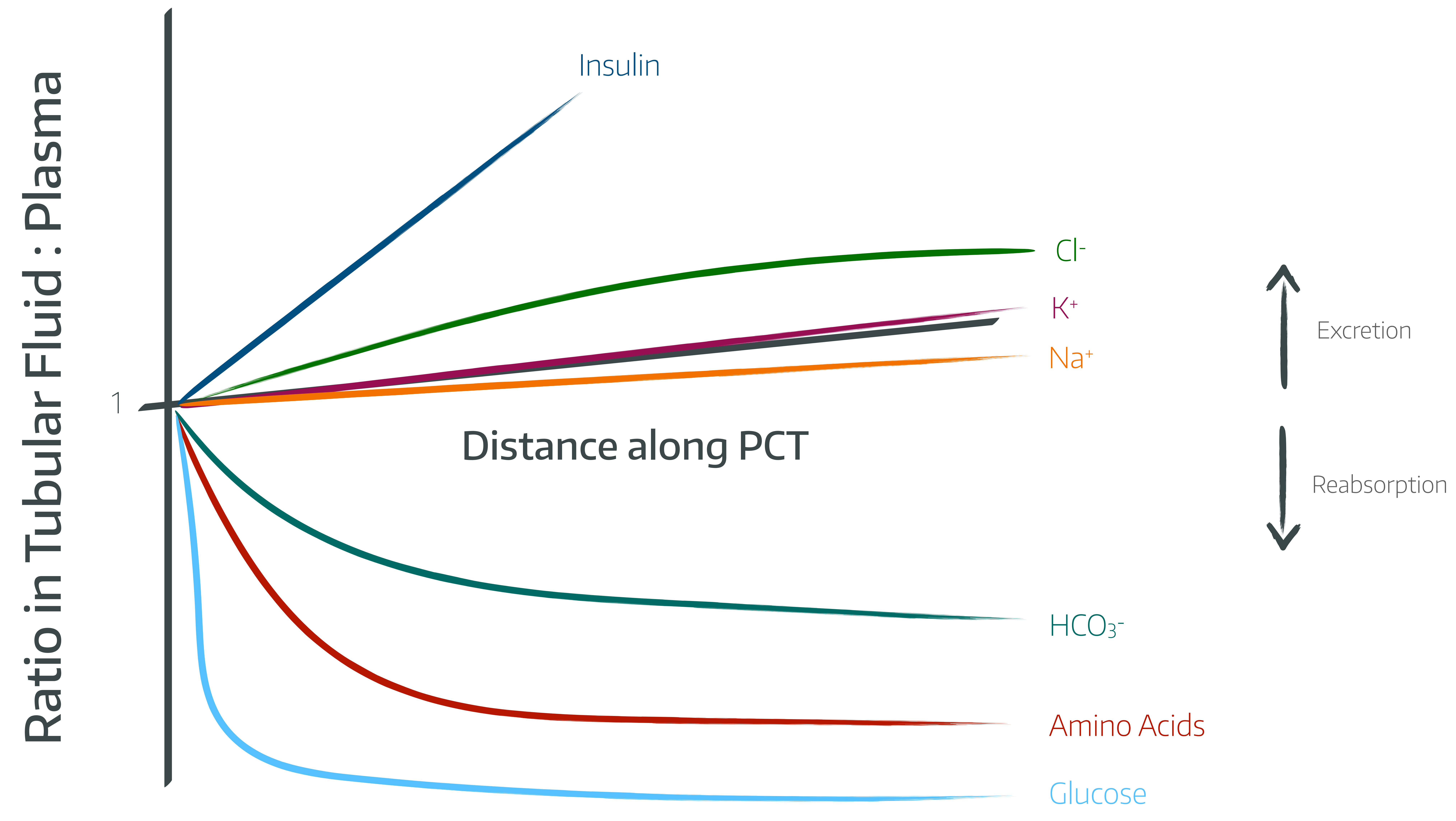
ANION GAP $= ([Na^+] + [K^+]) - ([Cl^-] + [HCO_3^-])$ 'Raised': > 12mmol

BIOCHEMISTRY

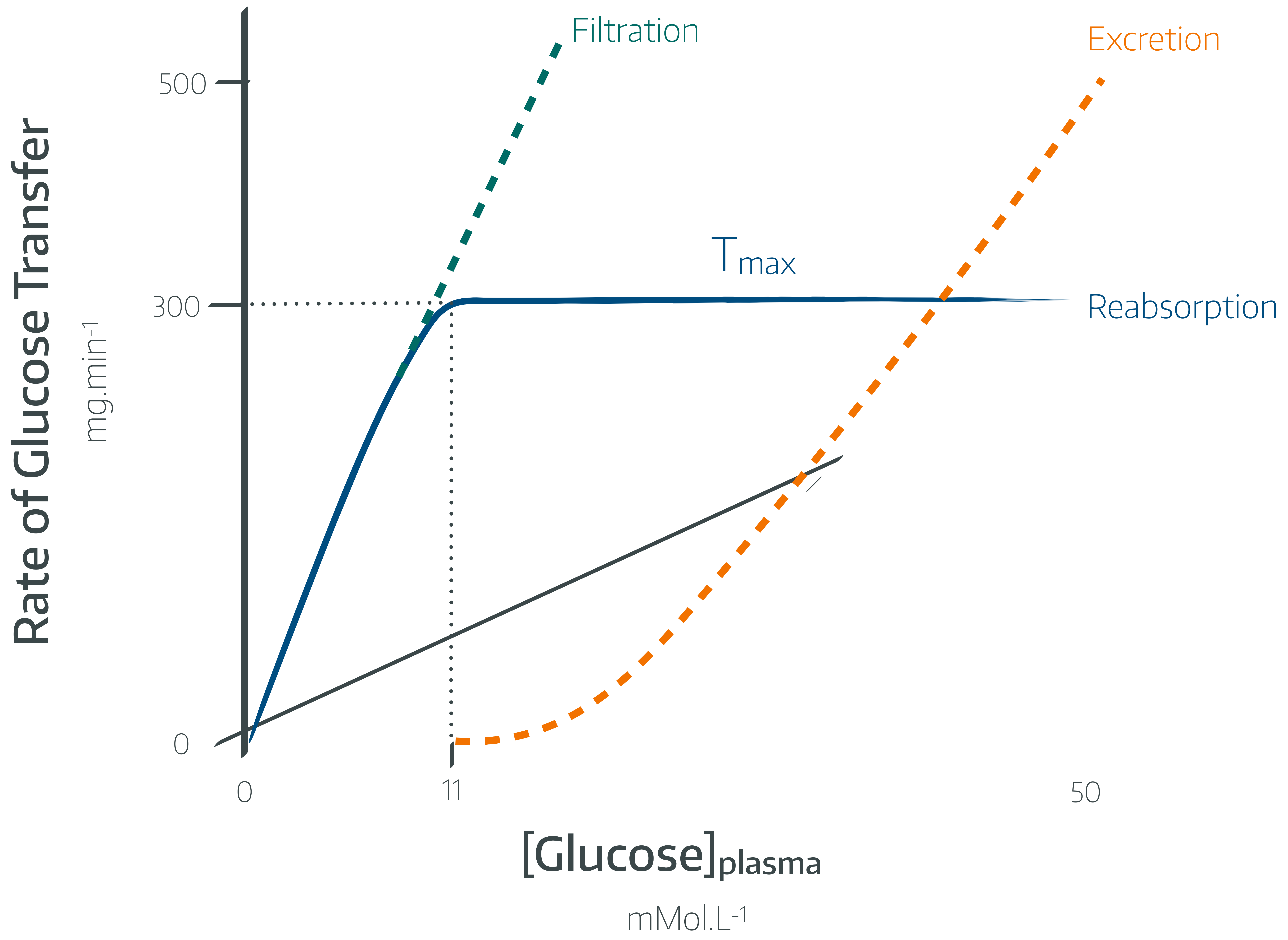
$$\text{Pyruvate} + \text{NADH} \overset{\text{Lactate Dehydrogenase}}{\rightleftharpoons} \text{Lactate} + H^{+} + NAD^{+}$$

pKa = 4
Strong Ion

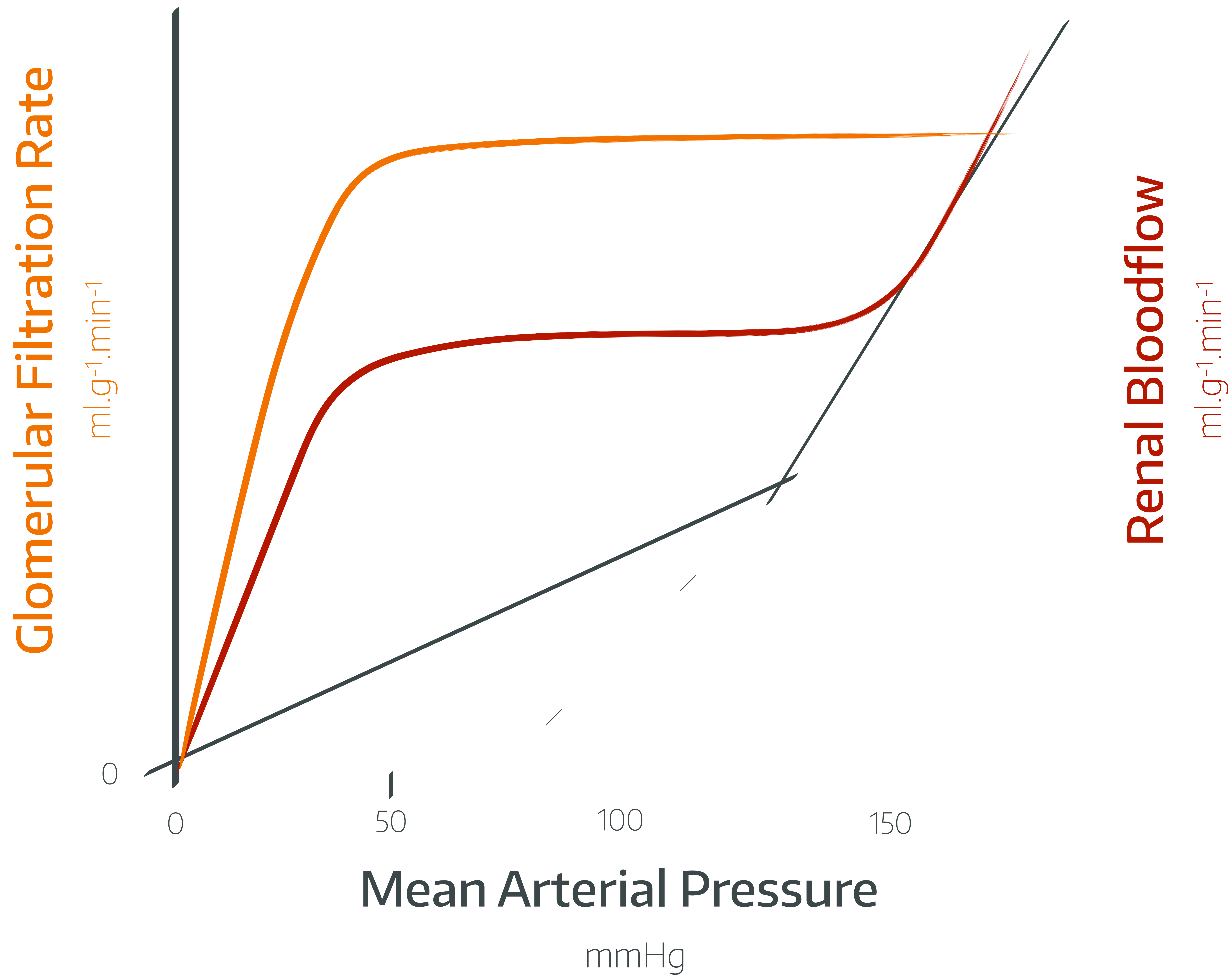
RENAL PHYSIOLOGY

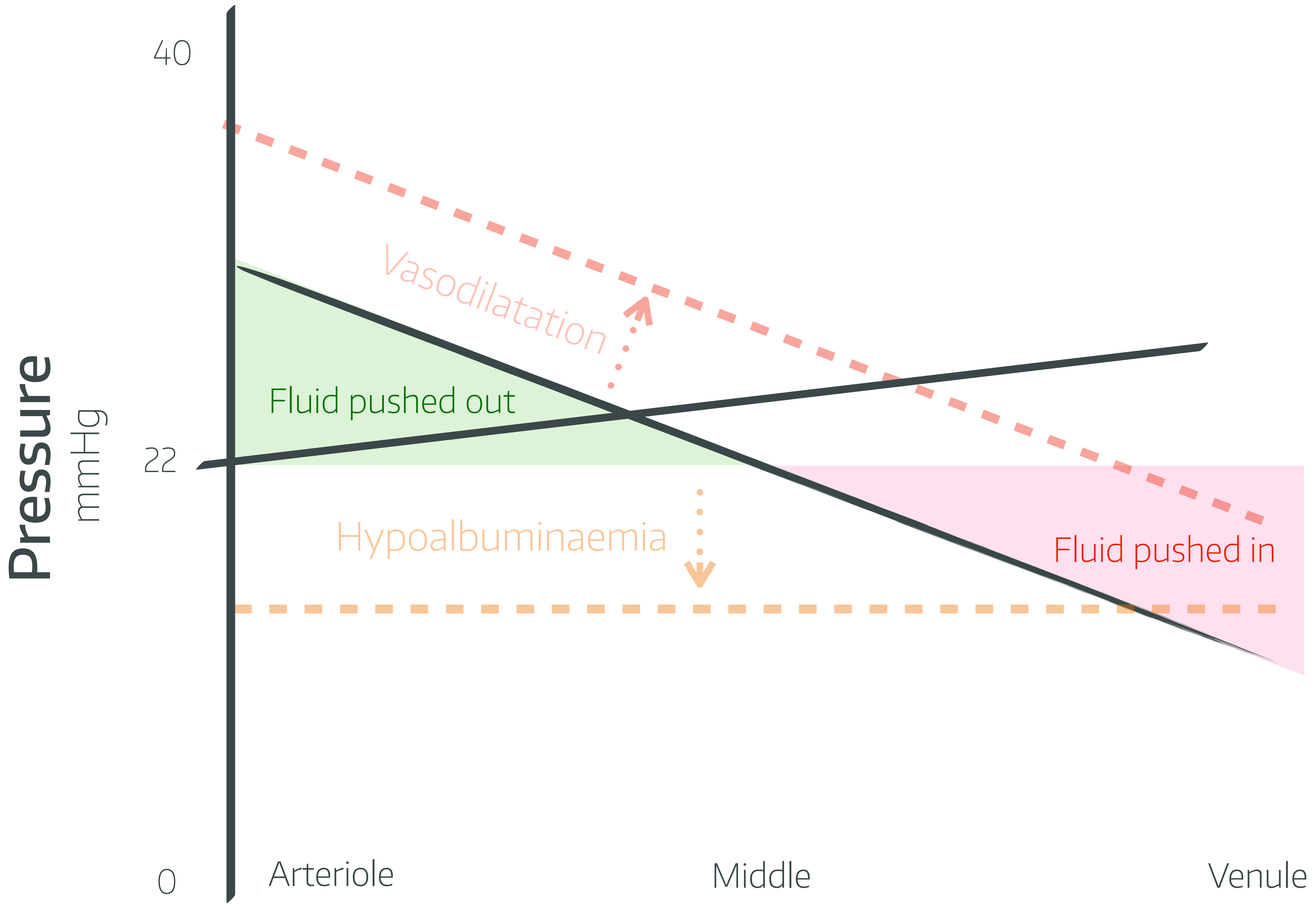


Renal Physiology



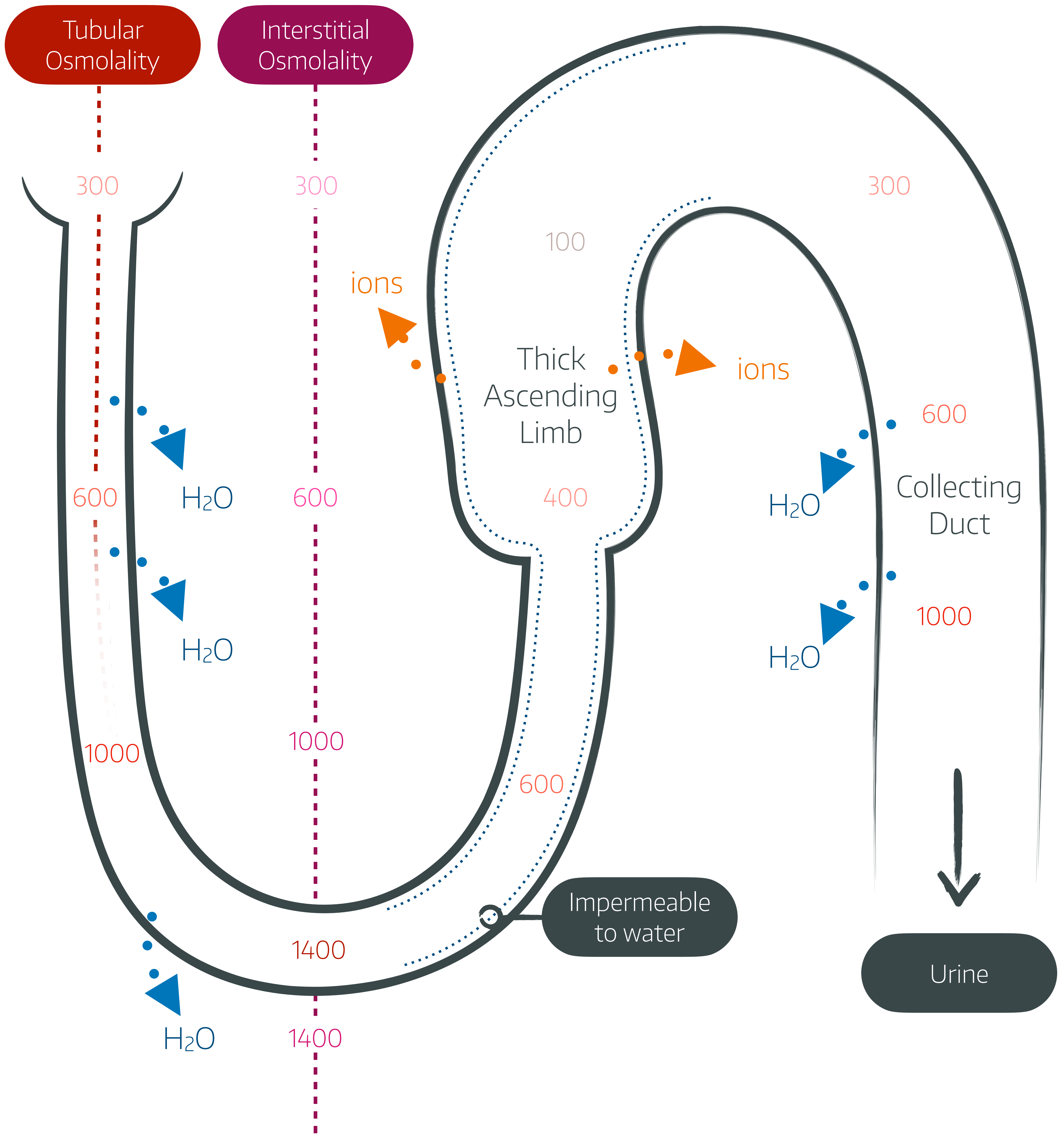
Renal Physiology



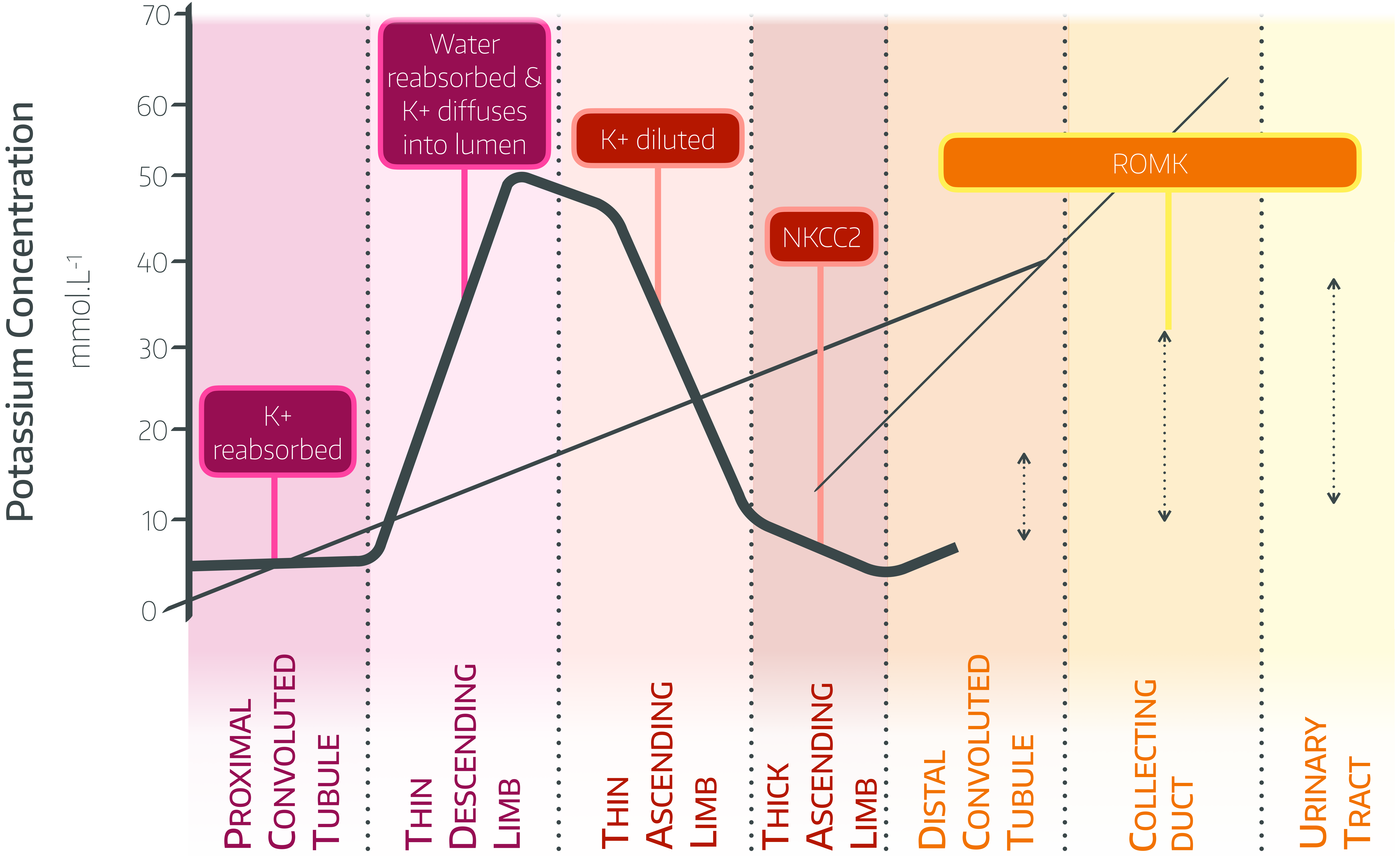


Pressure
mmHg
40
22
0
Vasodilatation
Fluid pushed out
Hypoalbuminaemia
Fluid pushed in
Arteriole
Middle
Venule

Renal Physiology

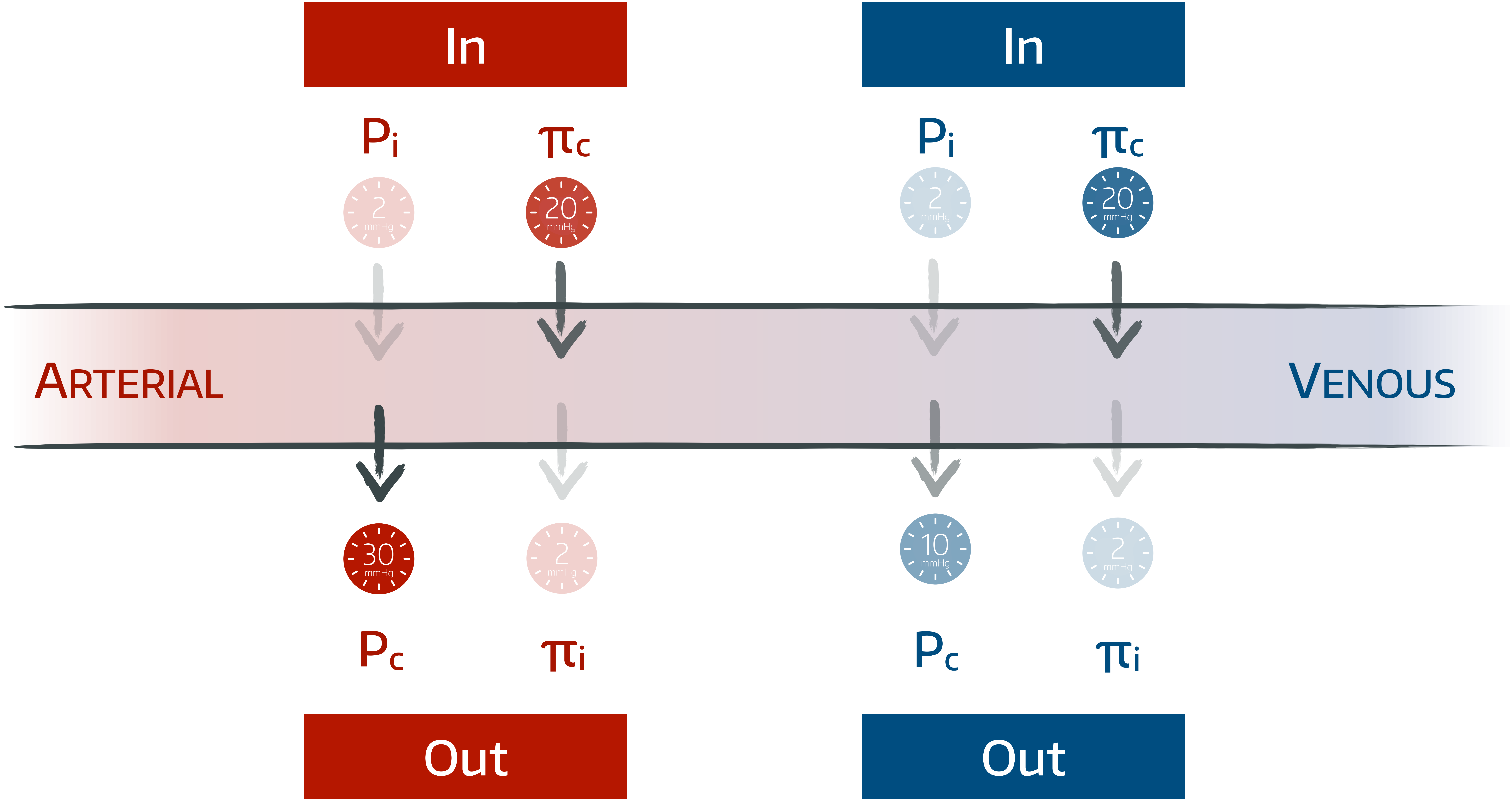


Renal Physiology




Renal Physiology
Blood
Tubule
H2CO3
HCO3-
H+
H+
HCO3-
Cl-
Cl-

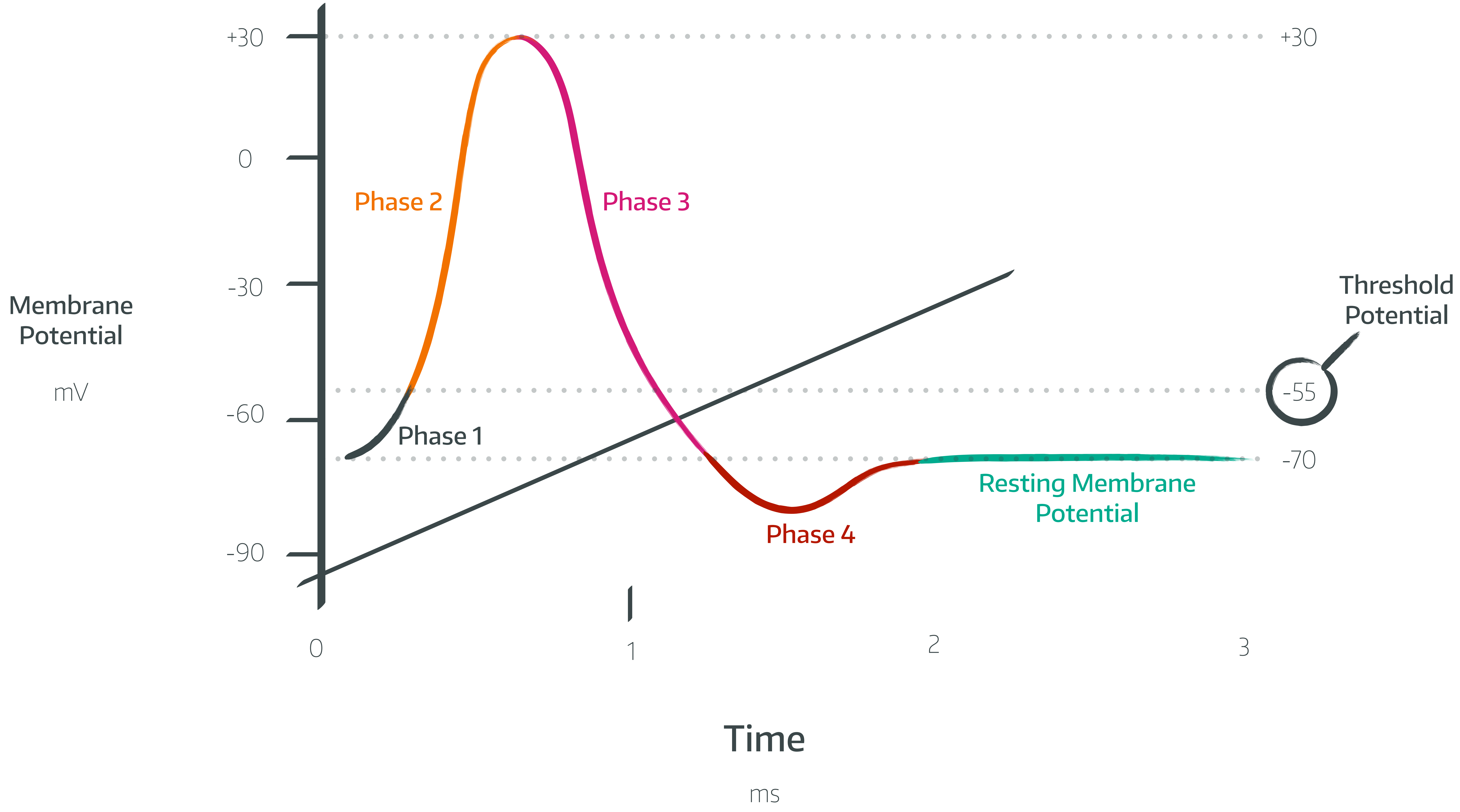
Starling Forces



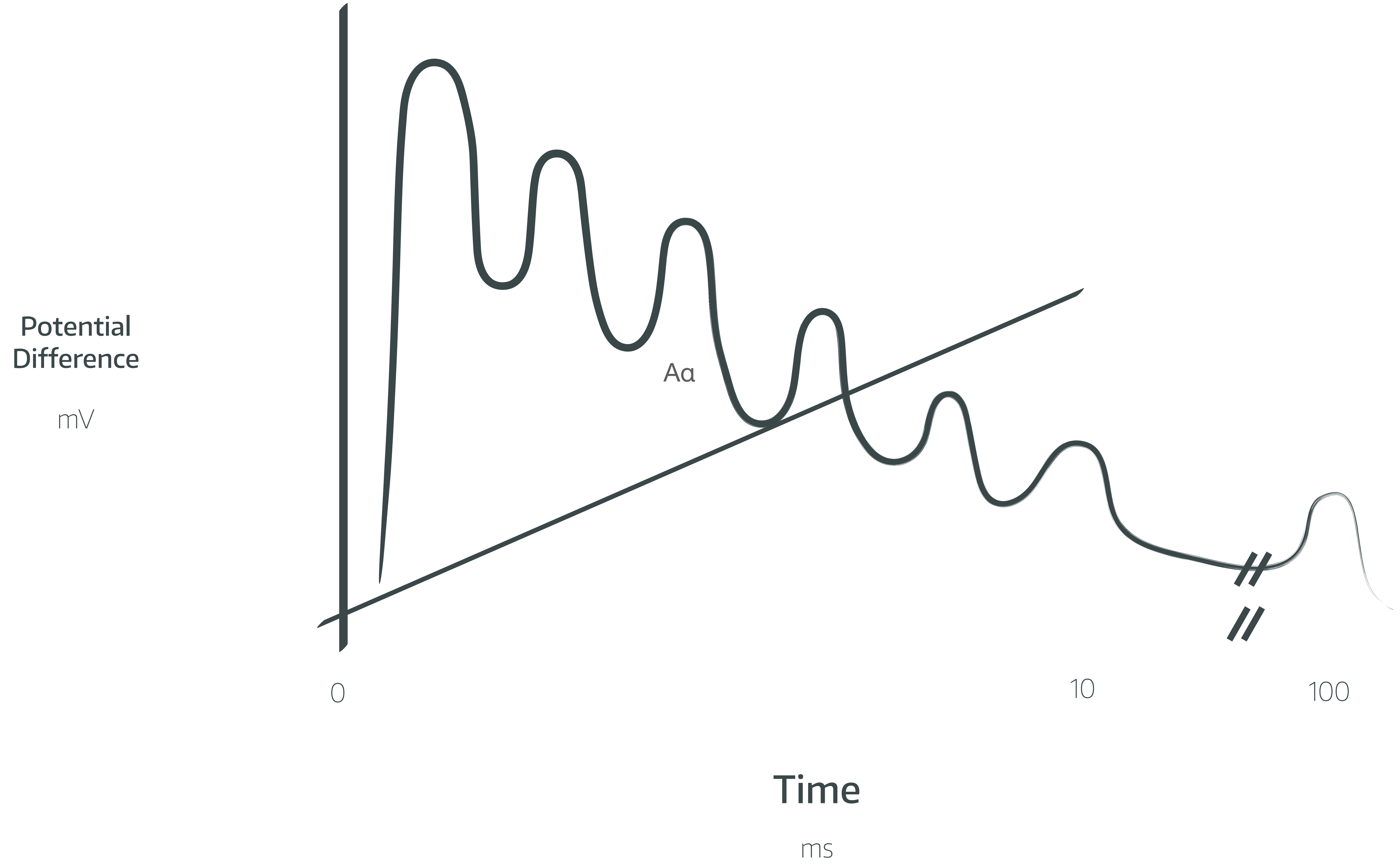
Net: 10mmHg out

Net: 10mmHg in

Neuronal Action Potential



Neuronal Action Potential



NERNST EQUATION

Membrane Potential

Gas Constant

Absolute Temperature

Inracellular Concentration

$$E = -\frac{R\,T}{z\,F}\ln\left(\frac{[in]}{[out]}\right)$$

Ion Valency

Faraday Constant

Extracellular Concentration

NERNST EQUATION

$$E = -\frac{RT}{zF}\ln\left(\frac{[in]}{[out]}\right)$$

E.G. FOR POTASSIUM (K^+)

$$= -\frac{8.314 \times 310.15}{(+1) \times 96{,}485}\ln\left(\frac{150}{4.5}\right)$$

$$\approx -0.09V = -90mV$$

E.G. FOR SODIUM (Na^+)

$$= -\frac{8.314 \times 310.15}{(+1) \times 96{,}485}\ln\left(\frac{12}{140}\right)$$

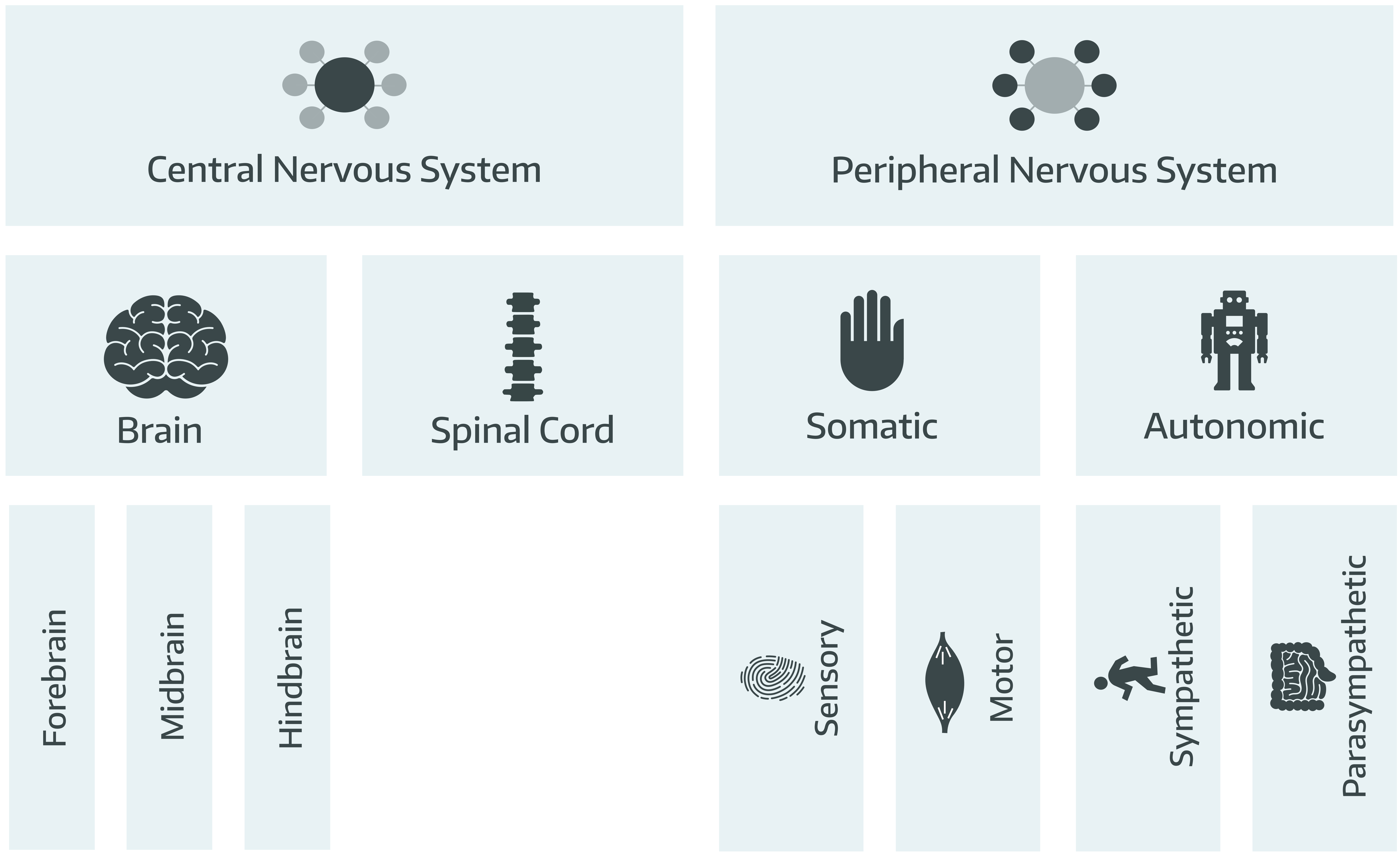
$$\approx +0.06V = +60mV$$

Neurone Physiology

Goldman Equation

$$\underbrace{E}_{\text{Membrane Potential}} = \frac{\overbrace{R}^{\text{Gas Constant}}\,\overbrace{T}^{\text{Absolute Temperature}}}{\underbrace{F}_{\text{Faraday Constant}}} \ln\left(\frac{P_{K^+}.[K^+]_o + \overbrace{P_{Na^+}}^{\text{Membrane Permeability to } Na^+}.\overbrace{[Na^+]_o}^{\text{Extracellular } Na^+ \text{ Concentration}} + P_{Cl^-}.[Cl^-]_i}{\underbrace{P_{K^+}}_{\text{Membrane Permeability to } K^+}.\underbrace{[K^+]_i}_{\text{Intracellular } K^+ \text{ Concentration}} + P_{Na^+}.[Na^+]_i + P_{Cl^-}.[Cl^-]_o}\right)$$

Nervous System



Thoracolumbar Outflow

T1 - L2

Systemic Effects

- Mydriasis
- Sweating
- ↑HR & ↑Contractility
- Bronchodilatation
- ↓Digestive Function
- Ejaculation
- Bladder Relaxation
- Vasoconstriction

Nervous System

Forebrain

Thalamus	Hypothalamus	Basal Ganglia	Amygdala	Hippocampus	Cortex
Sleep	Metabolism Homeostasis	Voluntary Motor Control	Emotion Fear Memory	Memory	Higher thought Language Memory

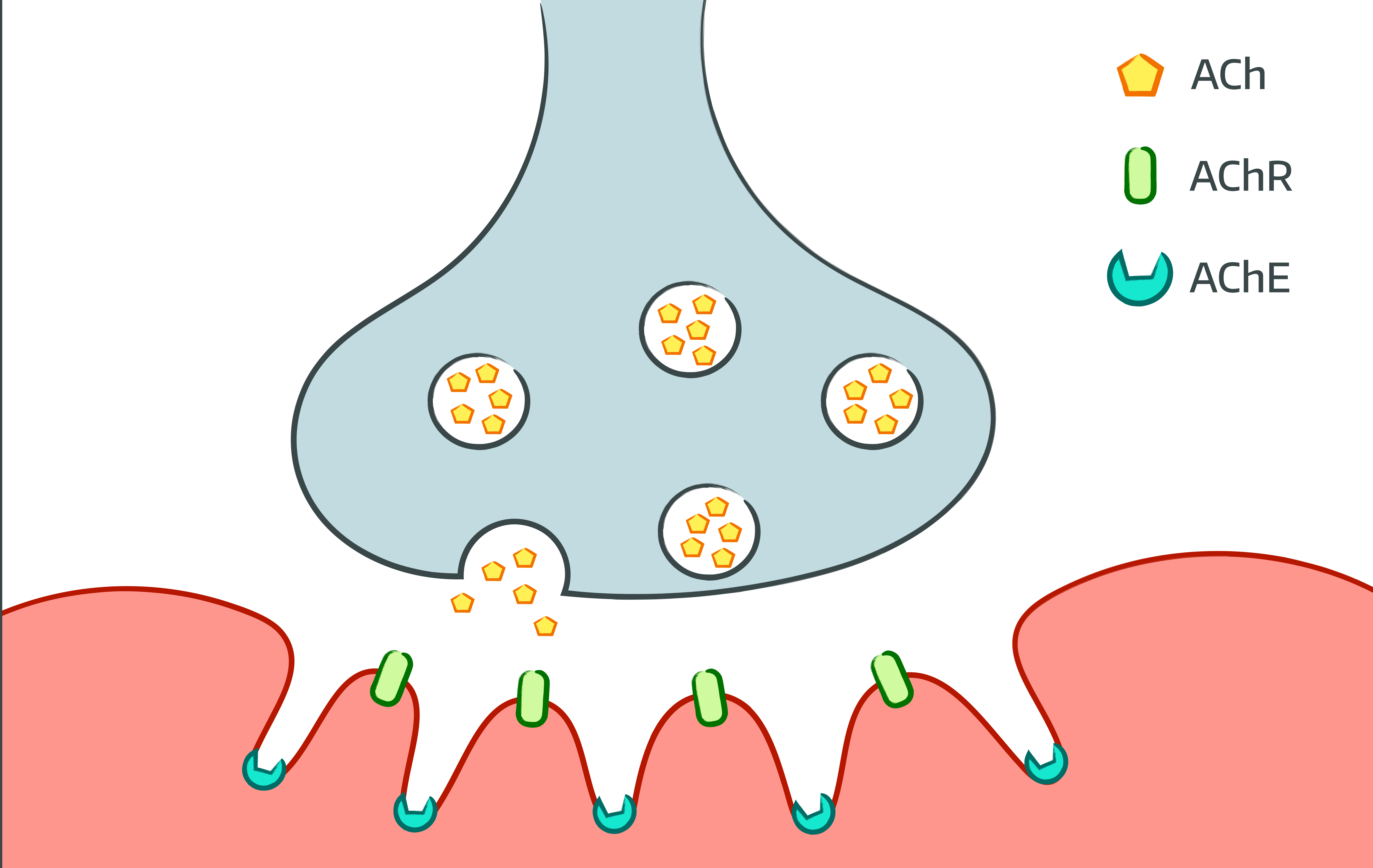
Midbrain

Tectum	Tegmentum
Eye & Ear Reflexes	Movement Cranial Nerve Nuclei

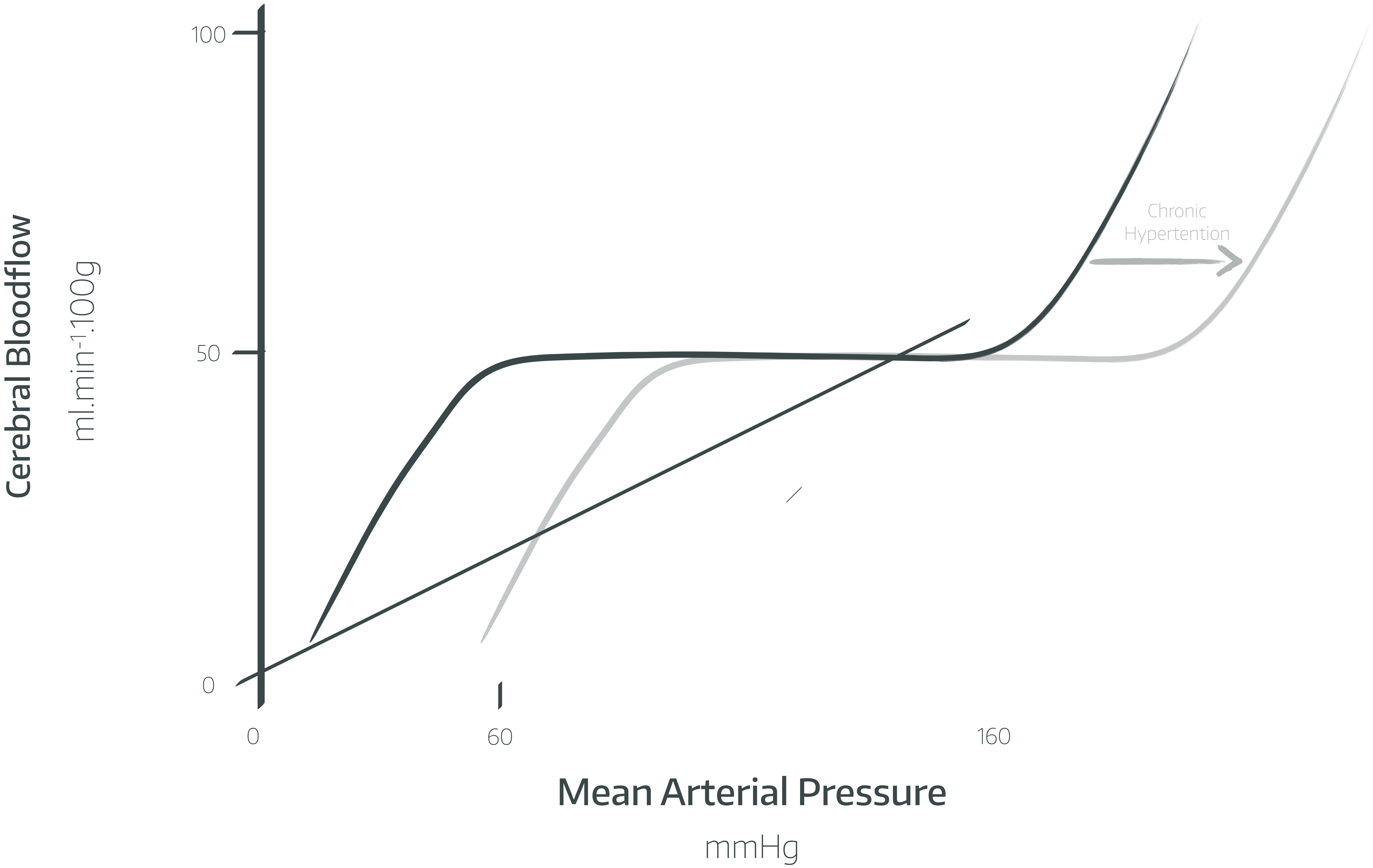
Hindbrain

Pons	Medulla	Cerebellum
Bladder Sleep Breathing Swallowing	Breathing Heart & Circulation Vomiting	Balance Co-ordination

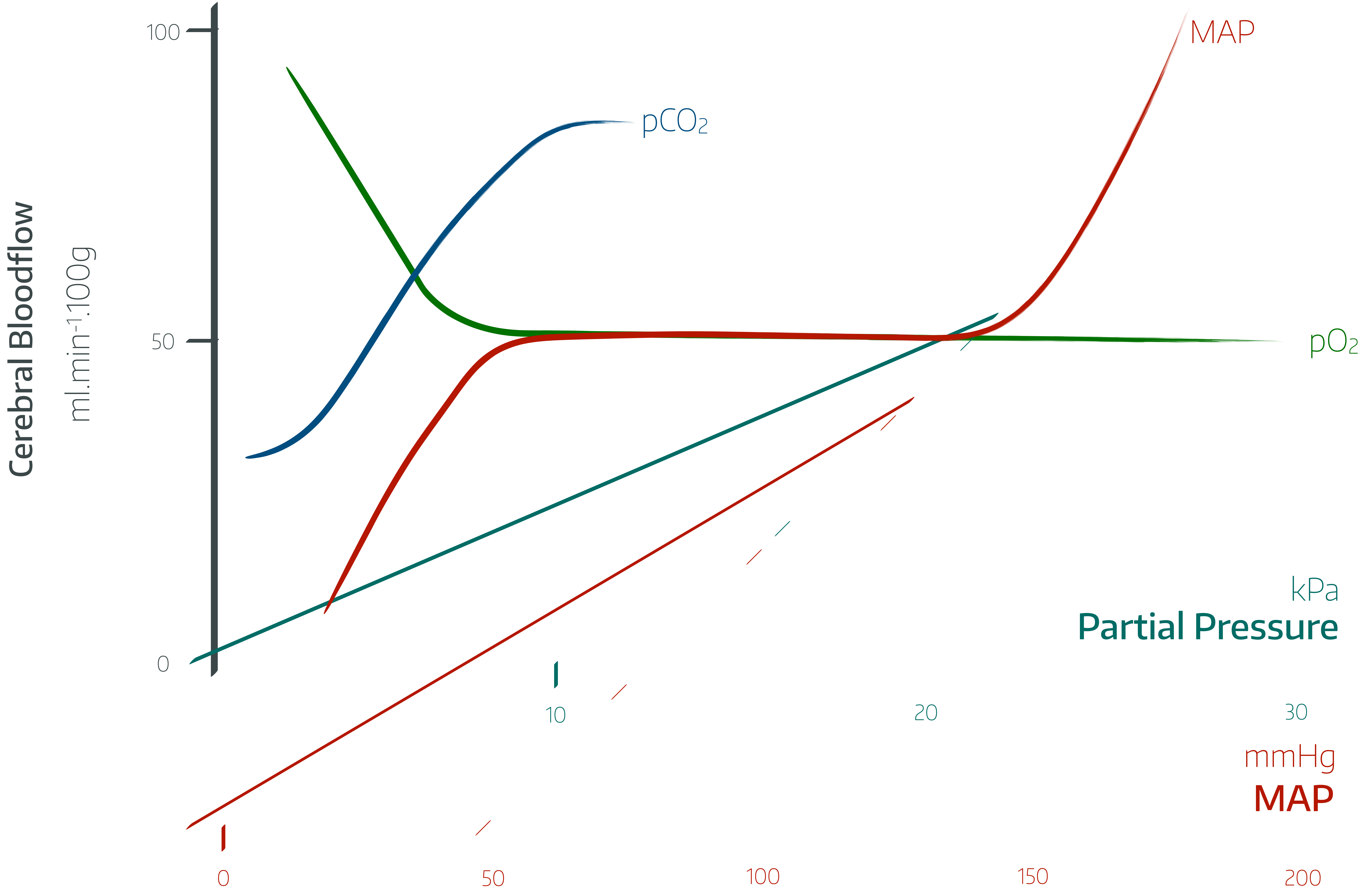
NEUROMUSCULAR JUNCTION



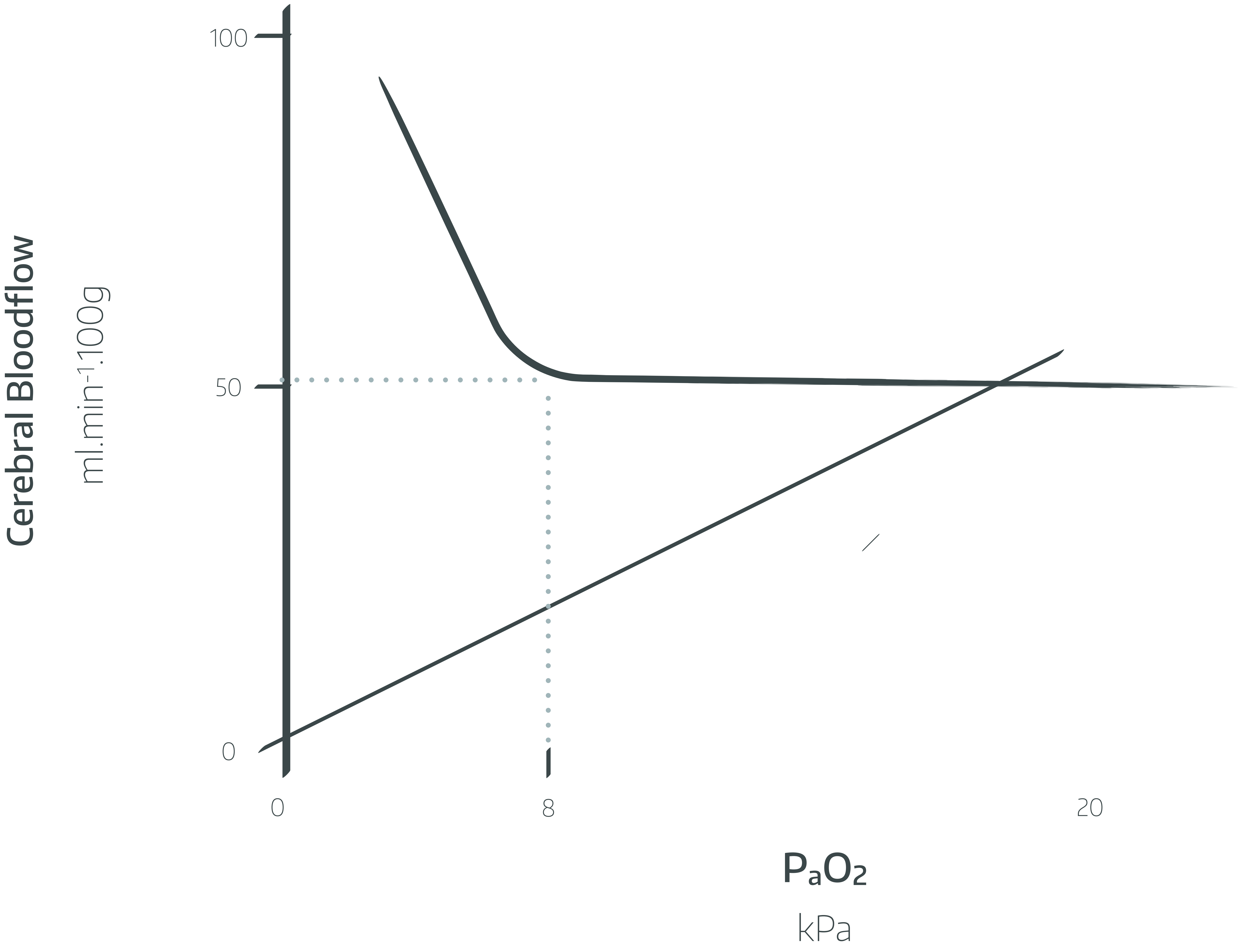
Cerebral Bloodflow



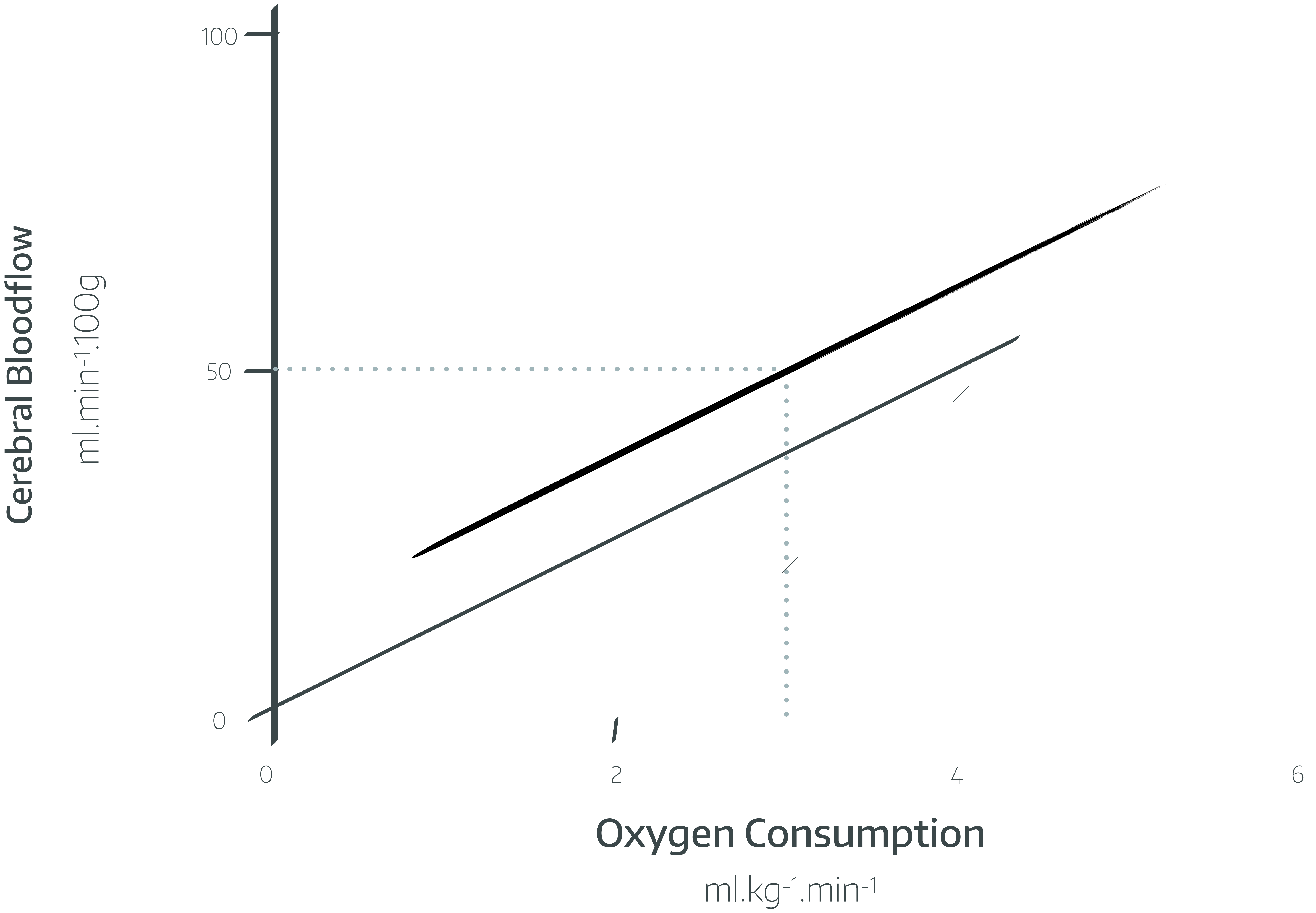
CEREBRAL BLOODFLOW



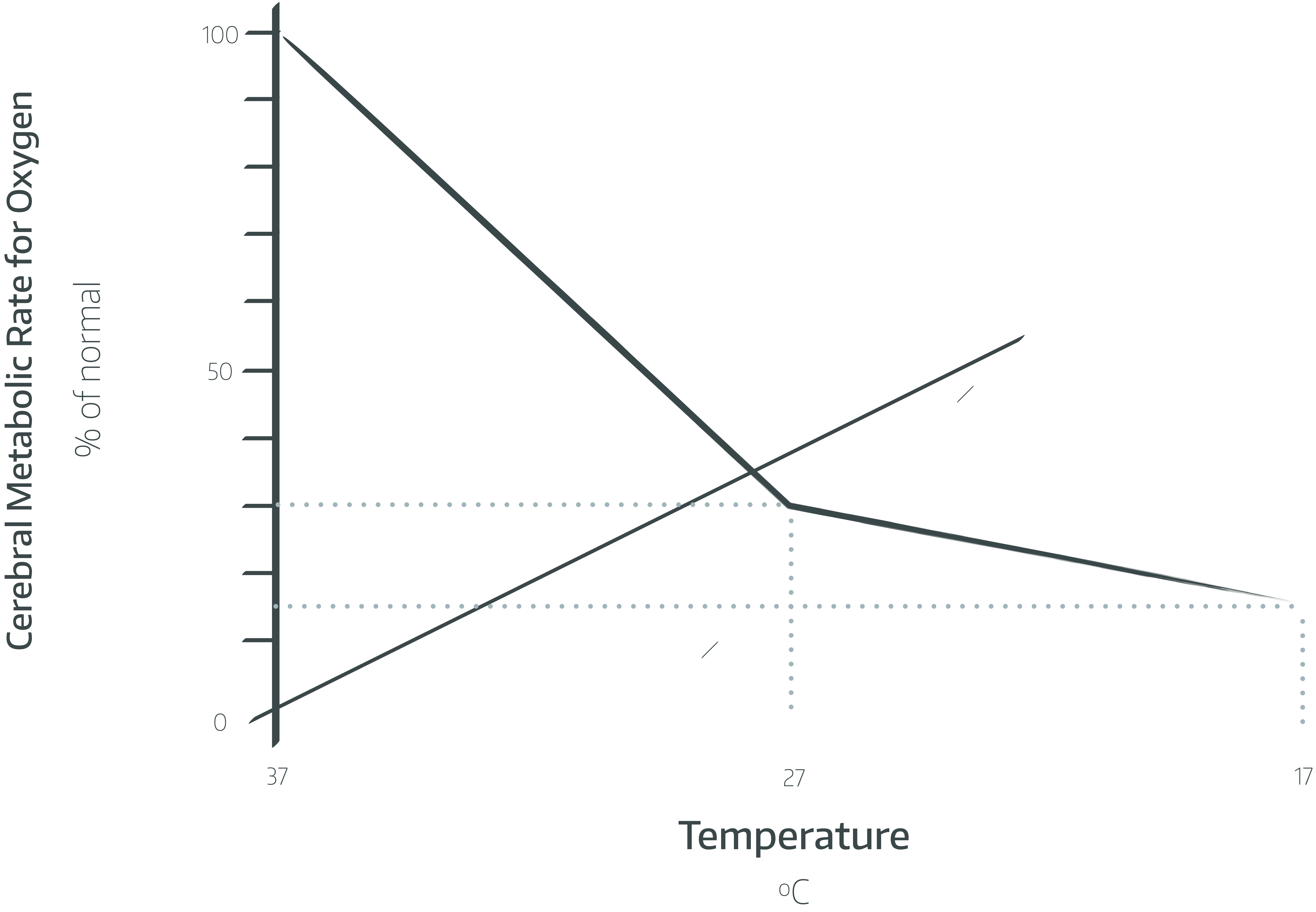
Cerebral Bloodflow



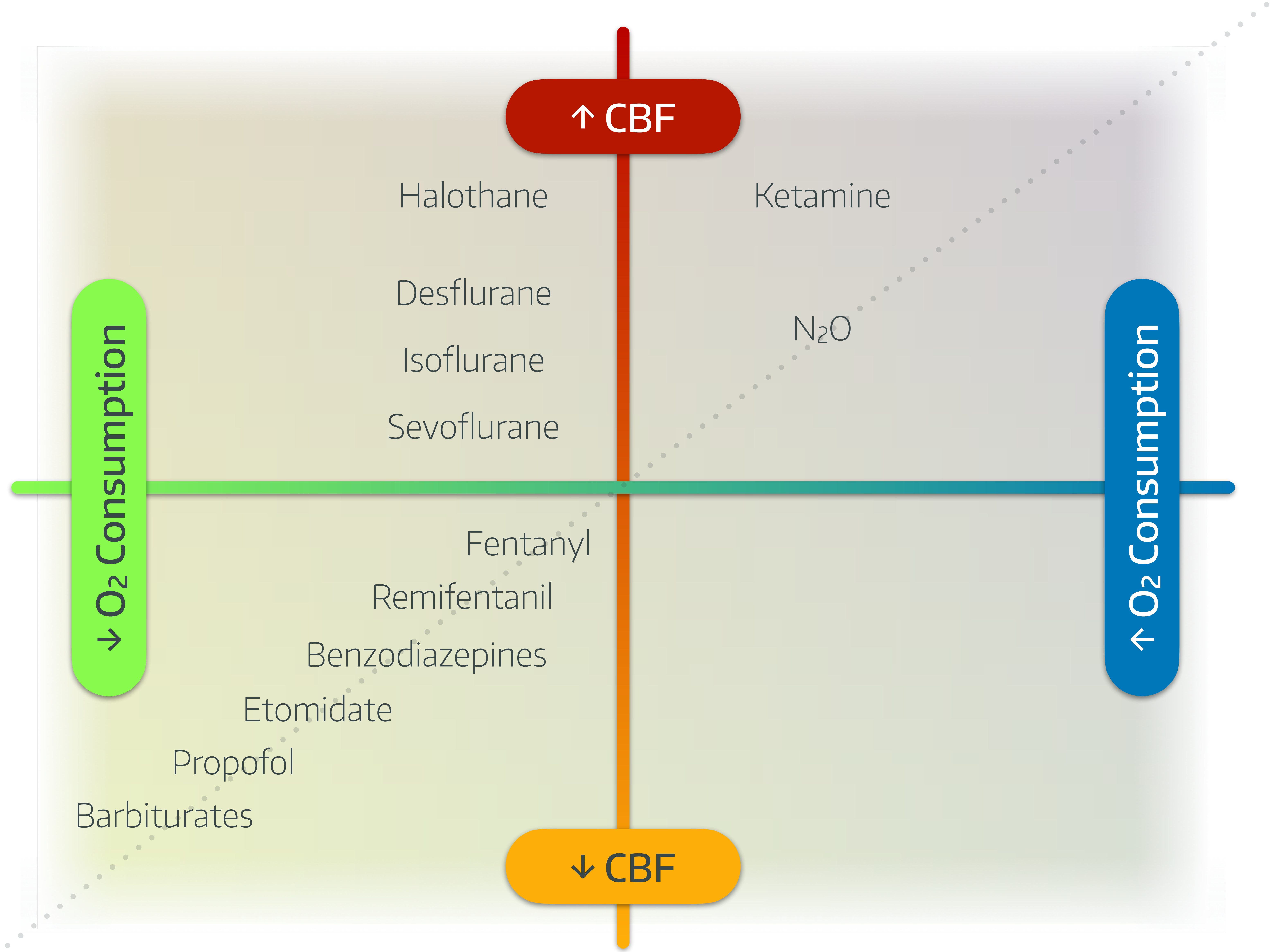
Cerebral Bloodflow



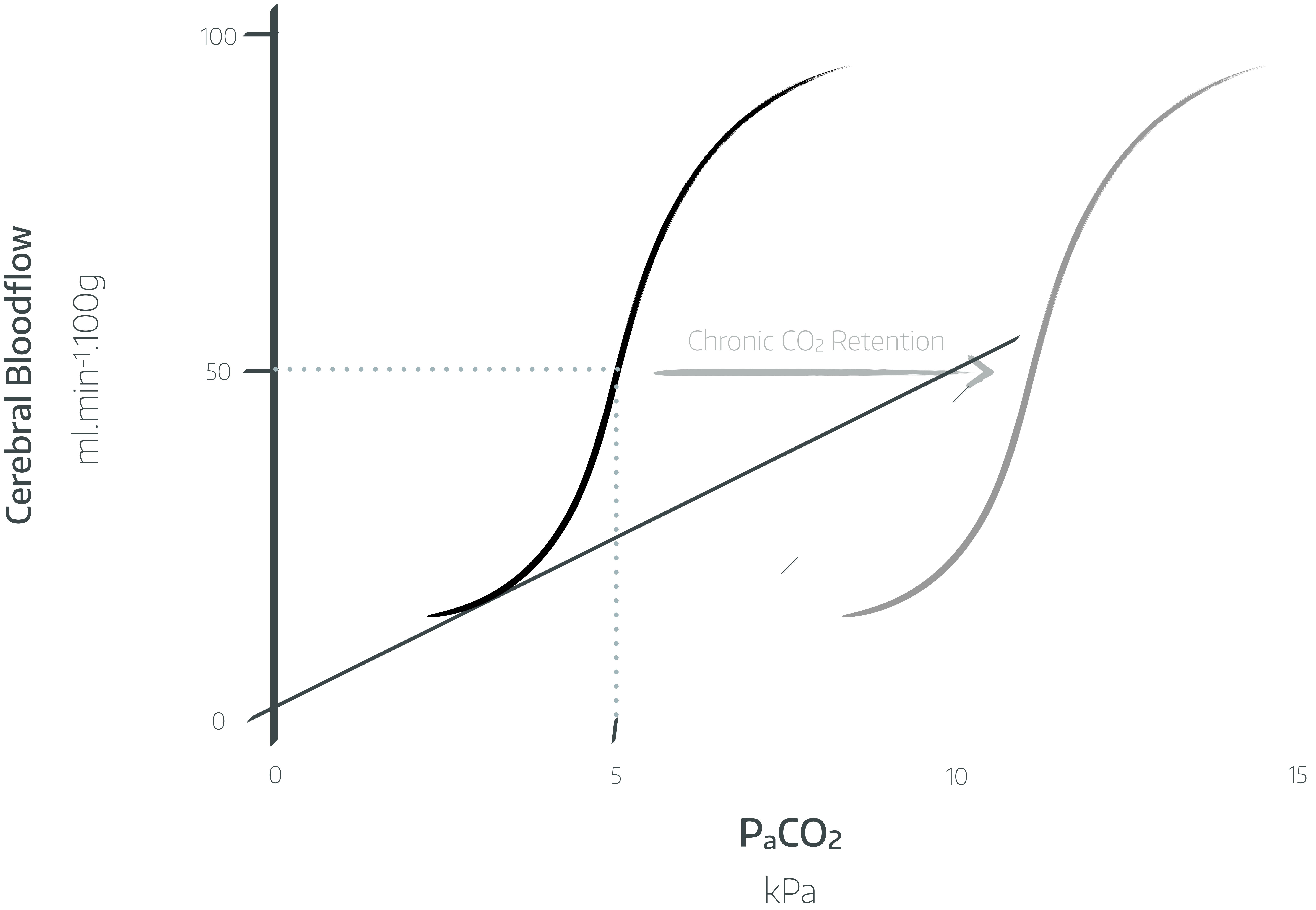
Cerebral Metabolic Rate



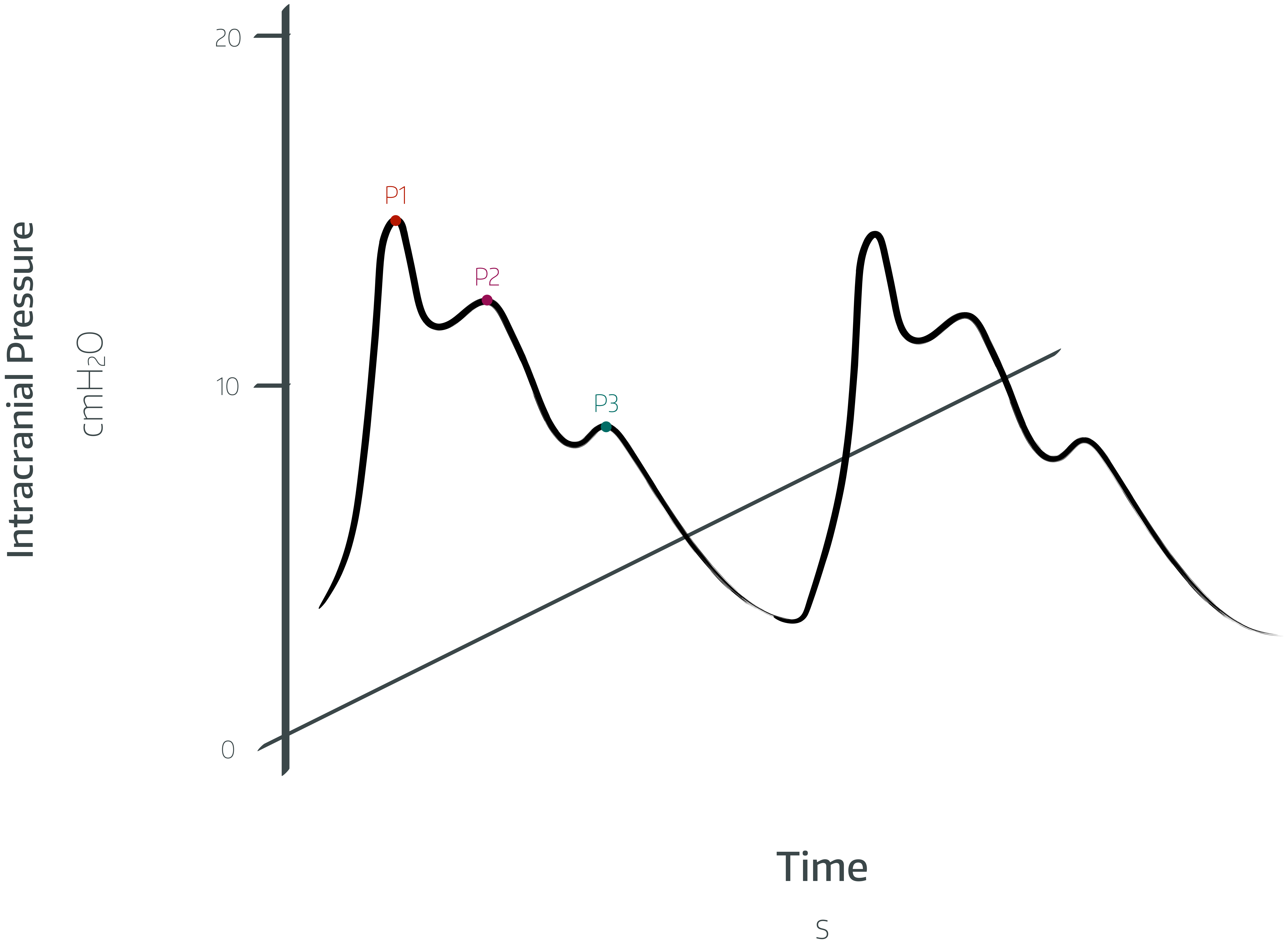
Cerebral Metabolic Rate



Cerebral Bloodflow



Intracranial Pressure



OXYGENATION

Alveolar Gas Equation

$$P_AO_2 = FiO_2\left(P_{ATM} - P_{H2O}\right) - \left(\frac{PaCO_2}{RQ}\right)$$

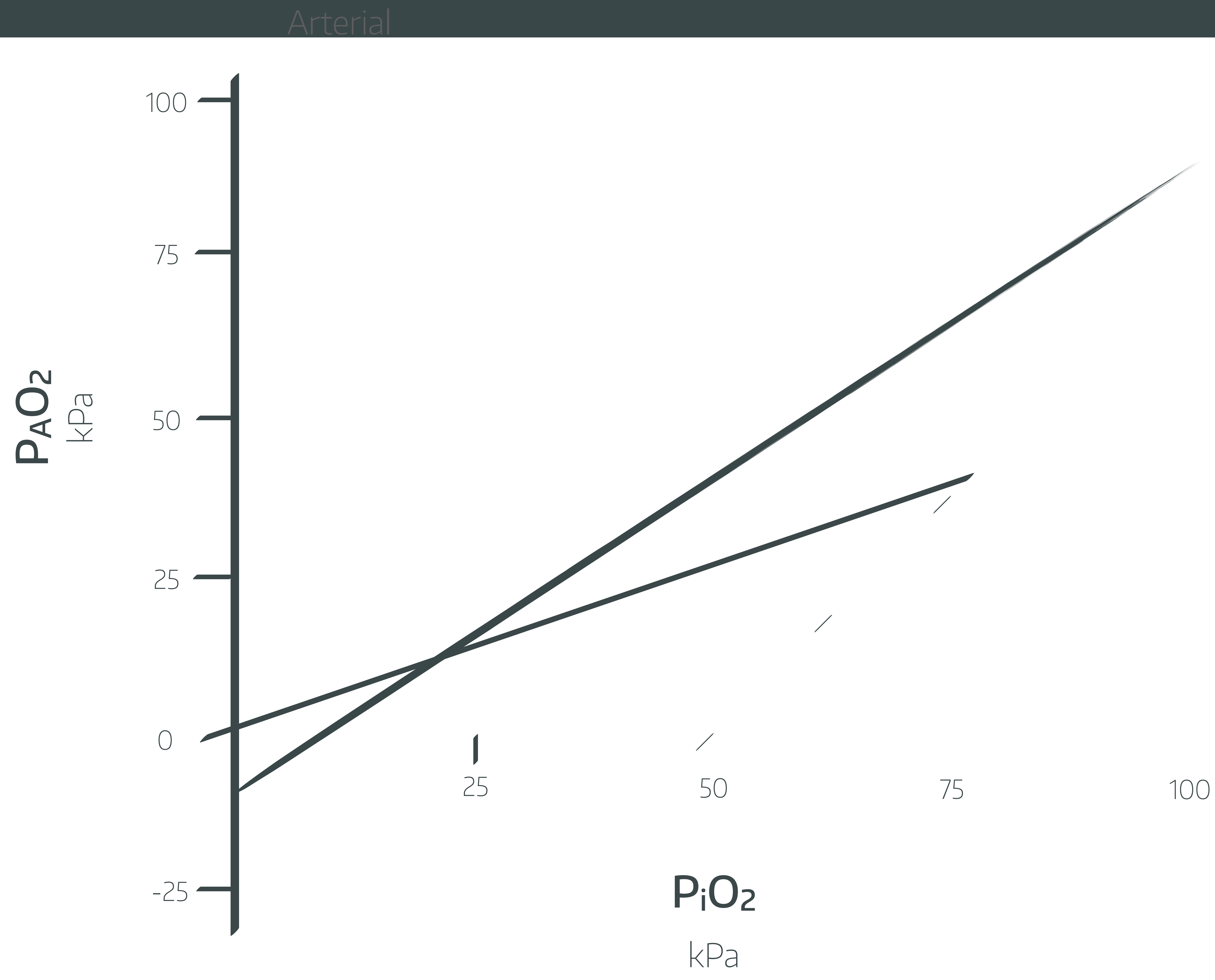
O₂ In: $FiO_2\left(P_{ATM} - P_{H2O}\right)$

O₂ Out: $\left(\frac{PaCO_2}{RQ}\right)$

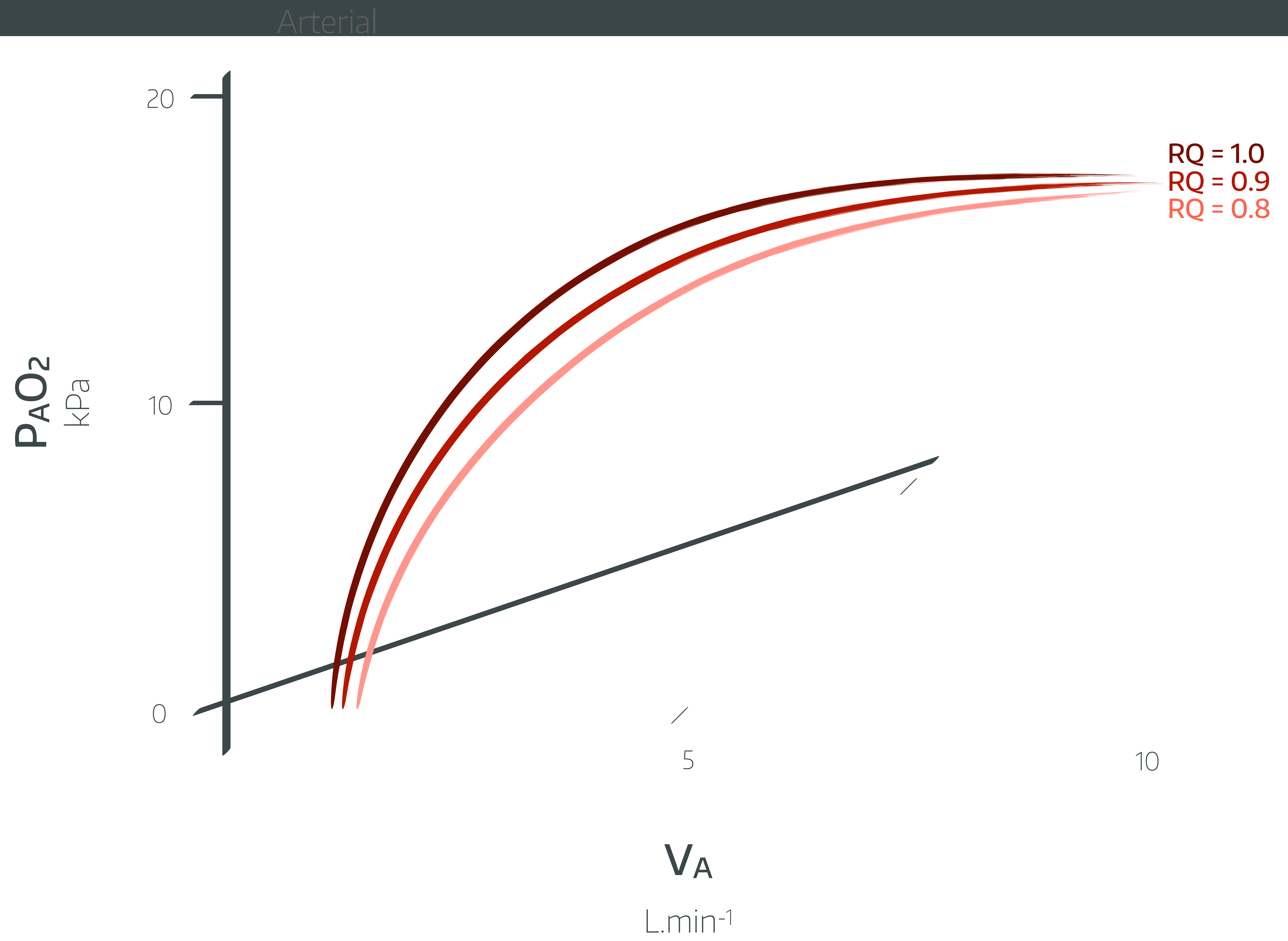
- P_AO_2: Partial pressure of Alveolar O_2
- FiO_2: Fraction of Inspired O_2
- P_{ATM}: Atmospheric Pressure
- P_{H2O}: Saturated Vapour Pressure of Water
- $PaCO_2$: Partial pressure of Arterial CO_2
- RQ: Respiratory Quotient

Alveolar Gas

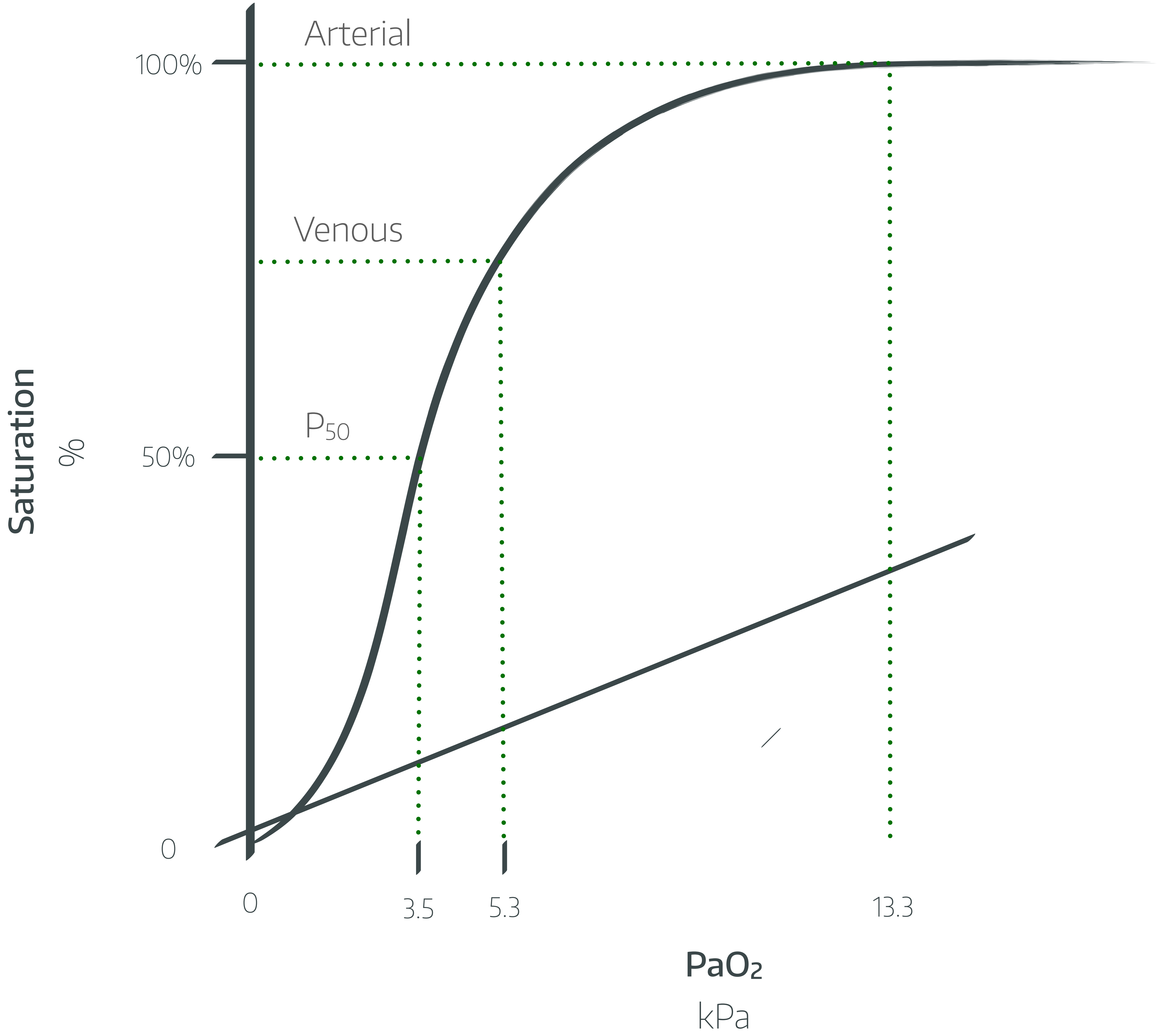
Oxygenation



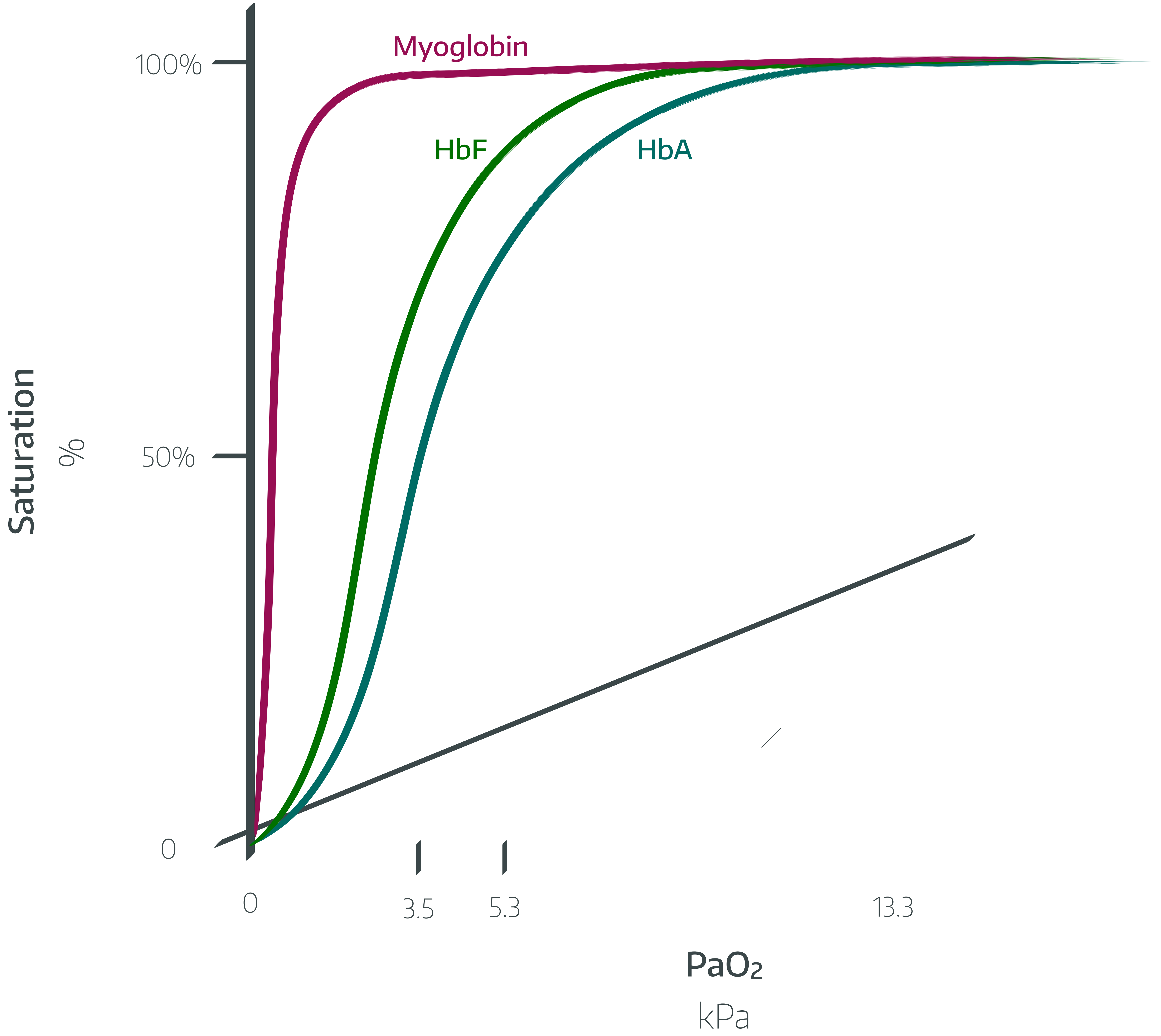
ALVEOLAR GAS



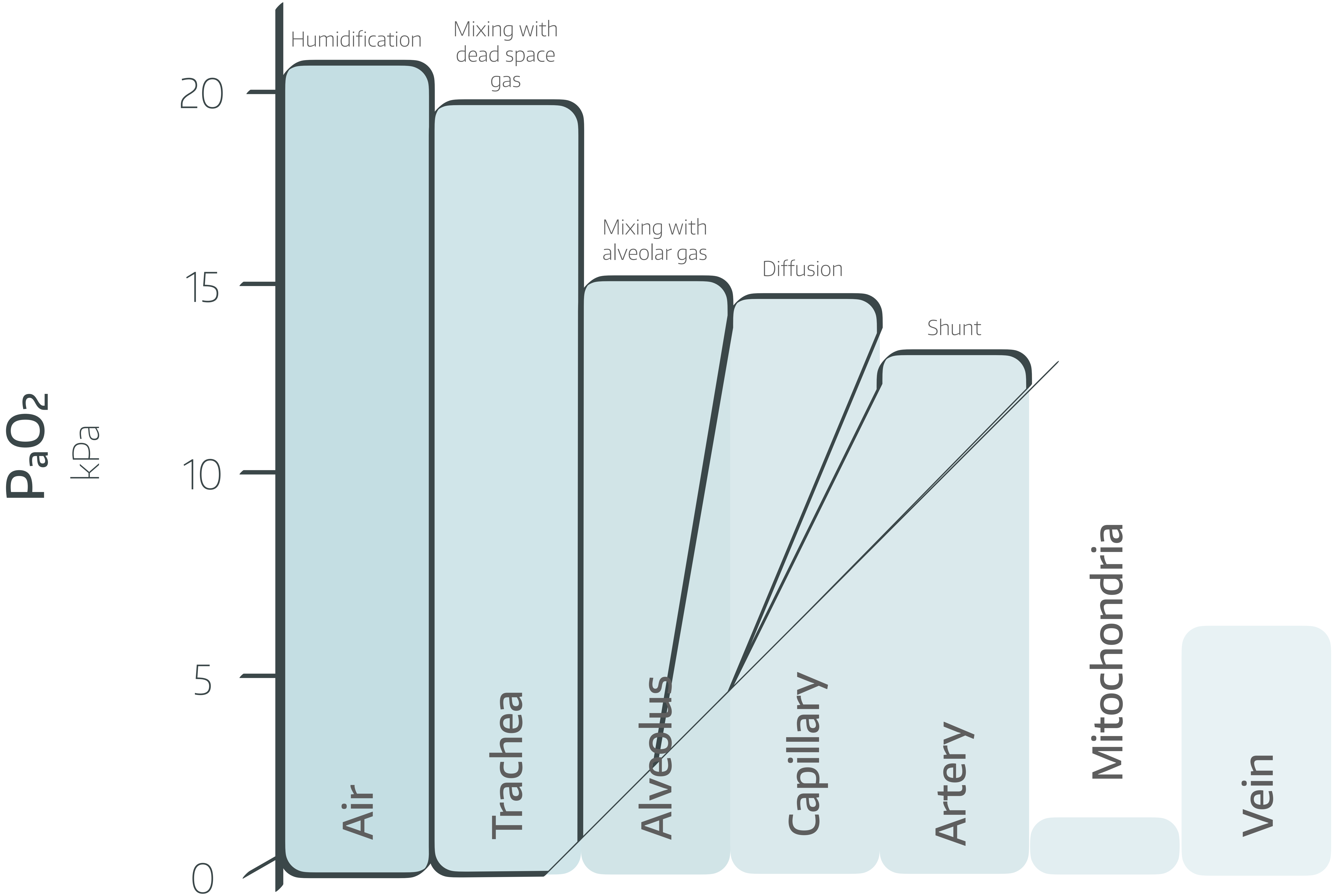
Oxygen Transport



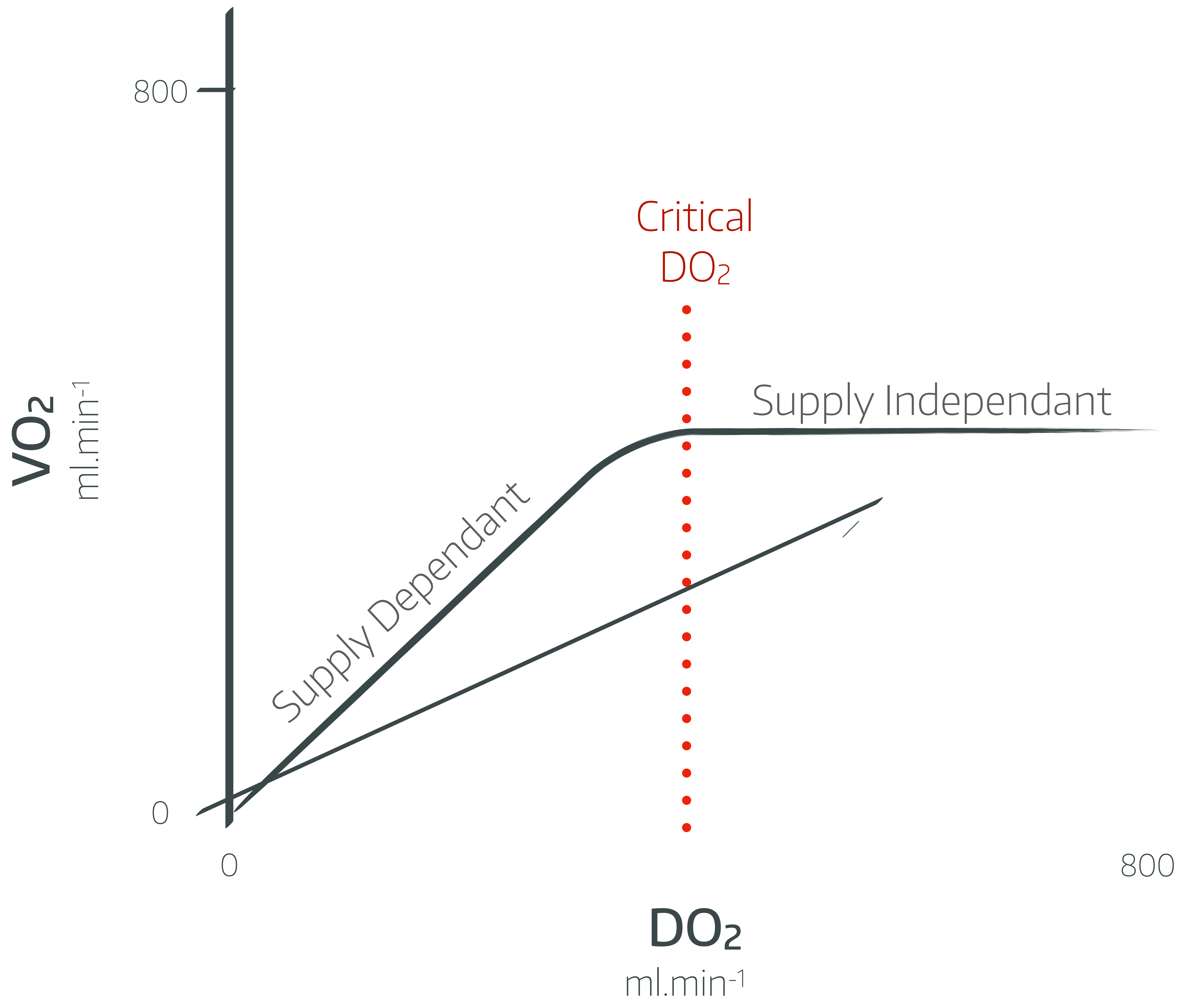
Oxygen Transport



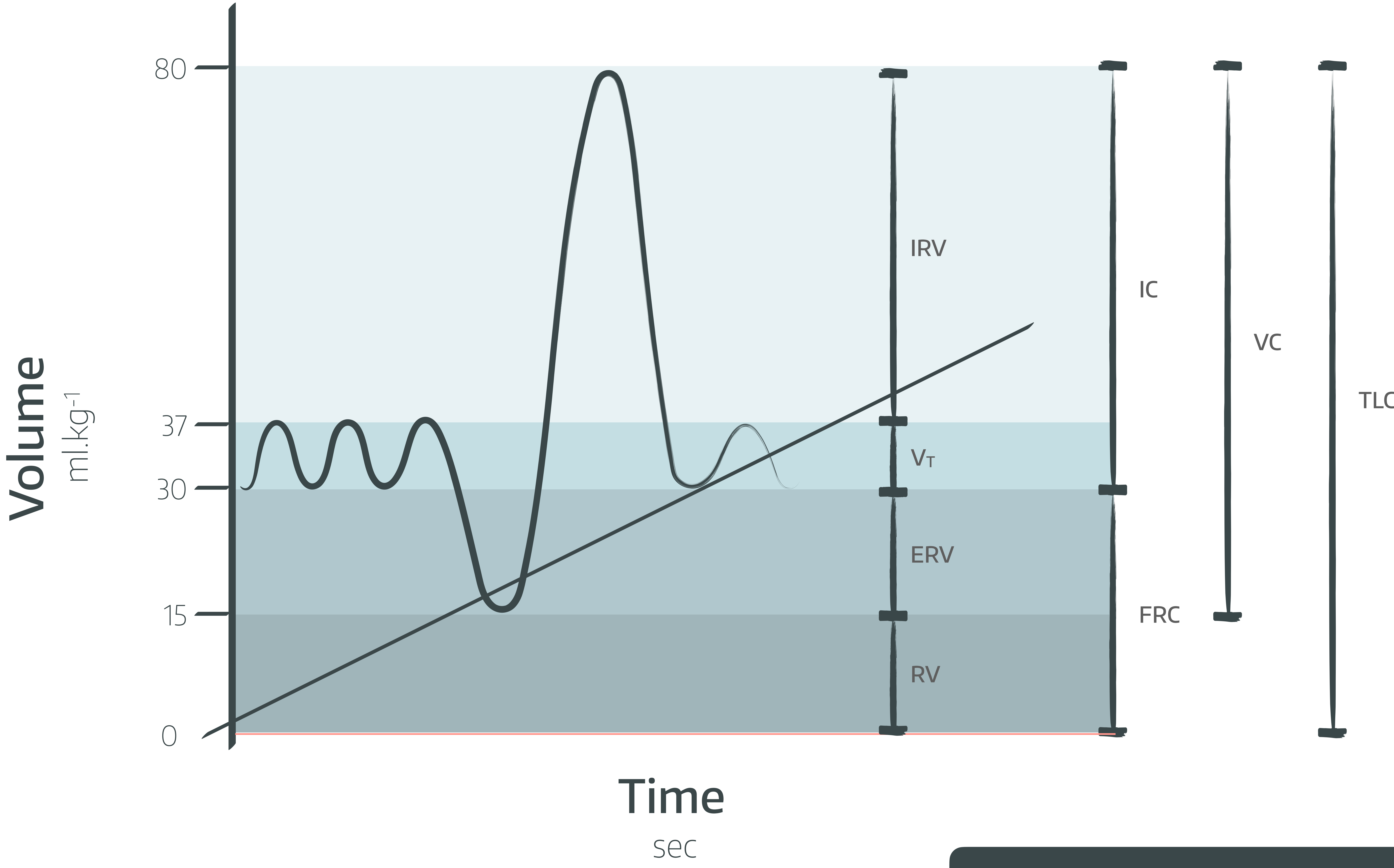
Oxygen Transport



Oxygen Transport

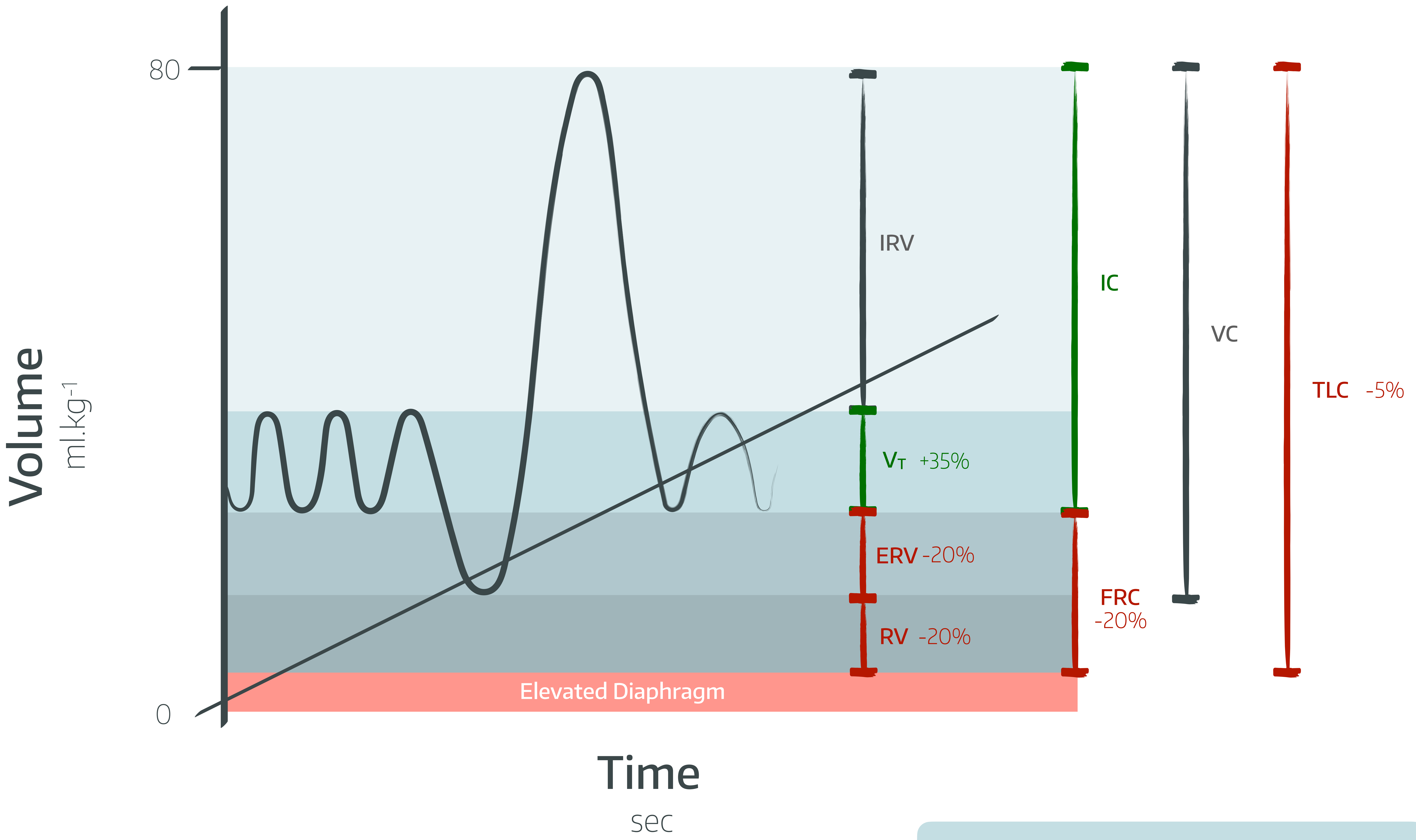


Respiratory Function



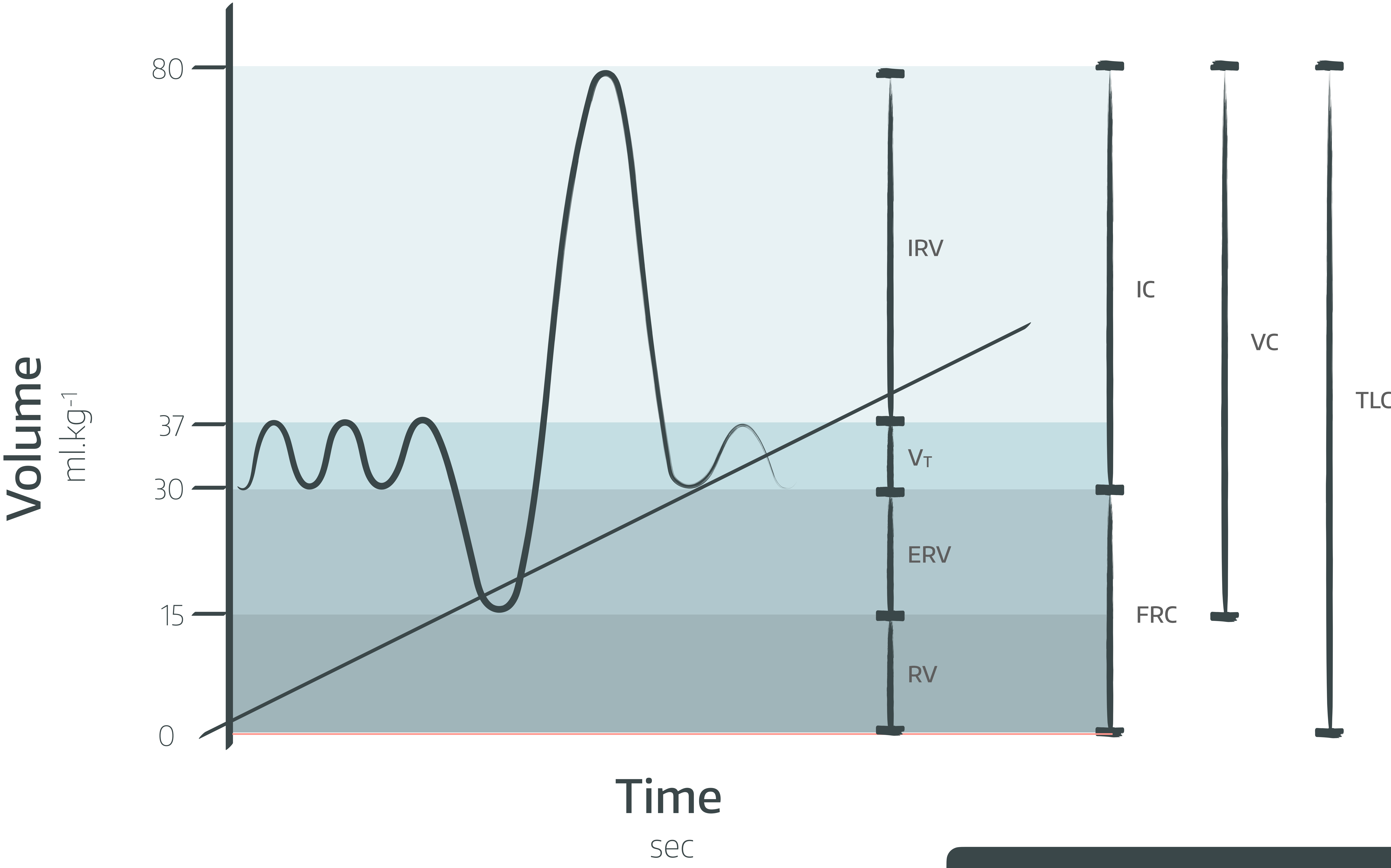
Not Pregnant

RESPIRATORY FUNCTION



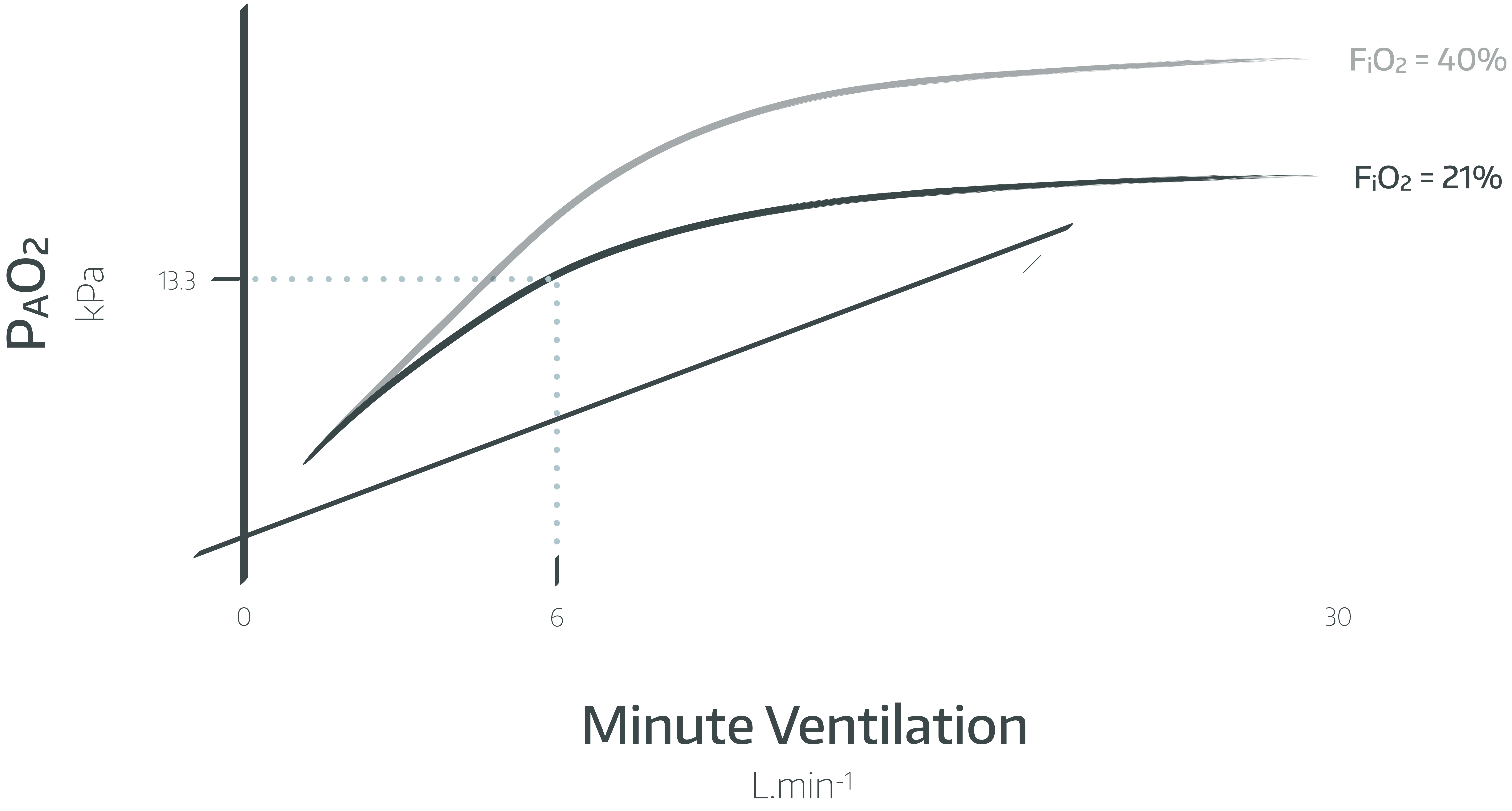
Pregnant

Respiratory Function

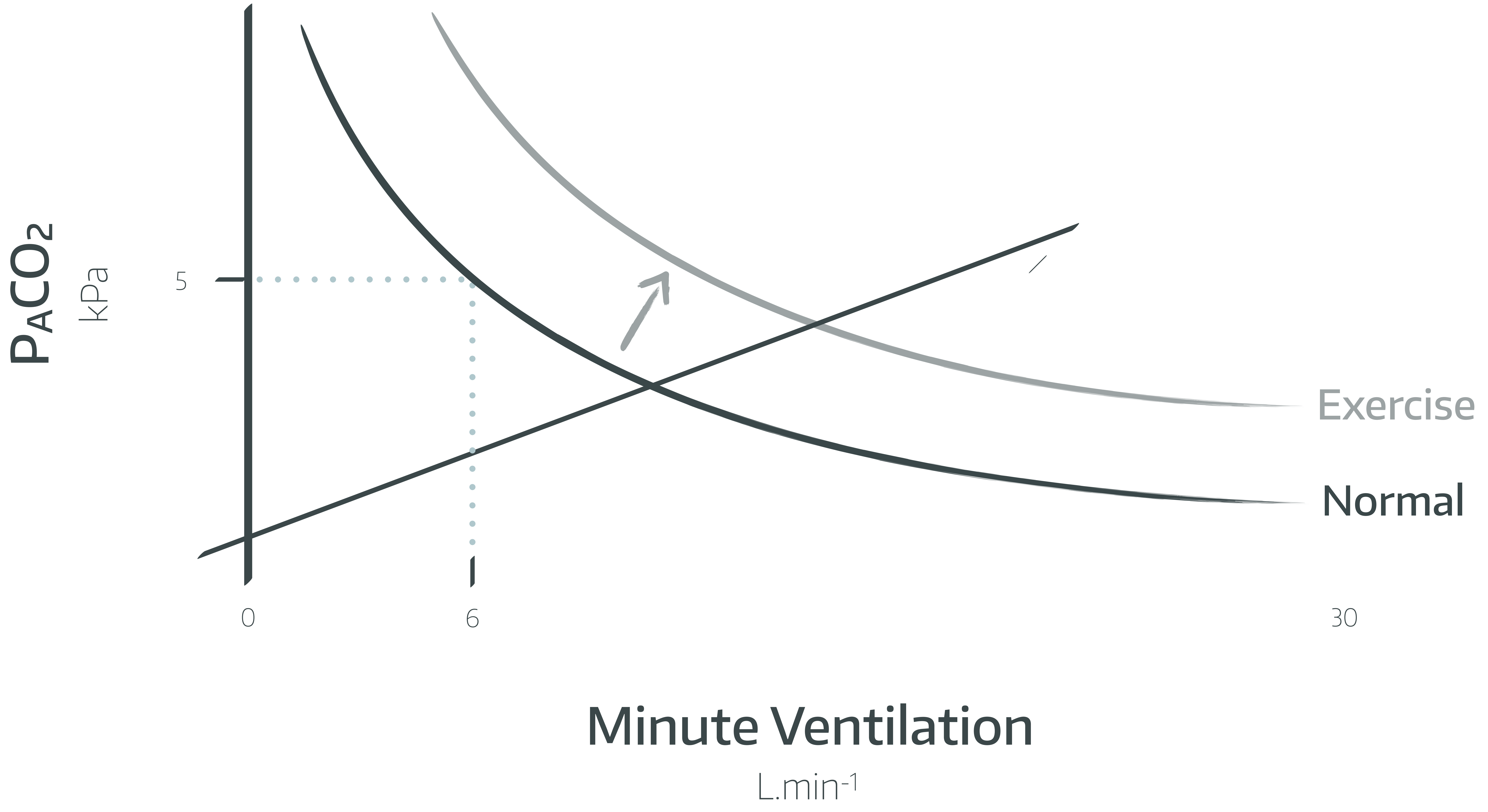


Not Pregnant

Effect of Minute Ventilation on Oxygenation

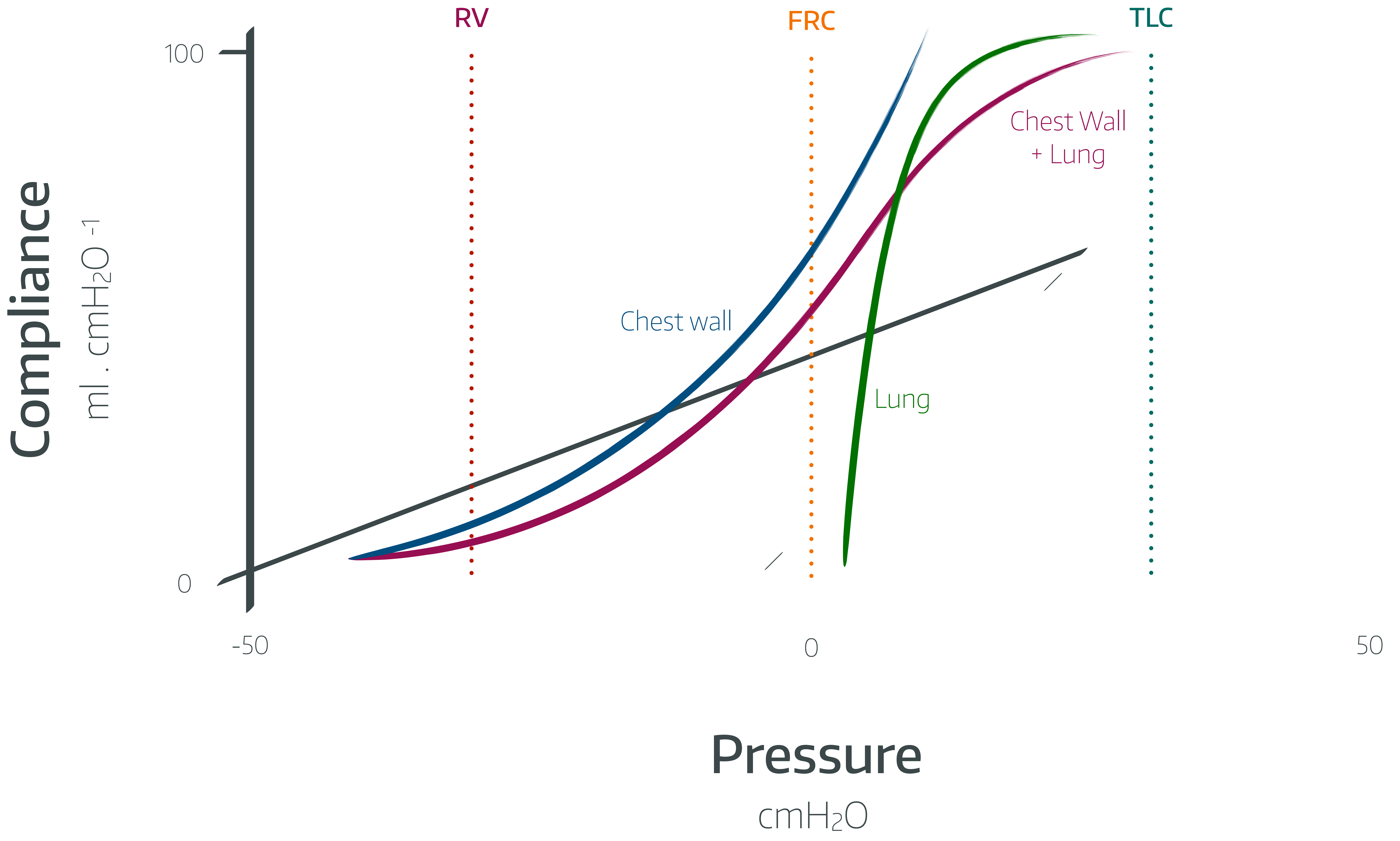


Effect of Minute Ventilation on CO_2



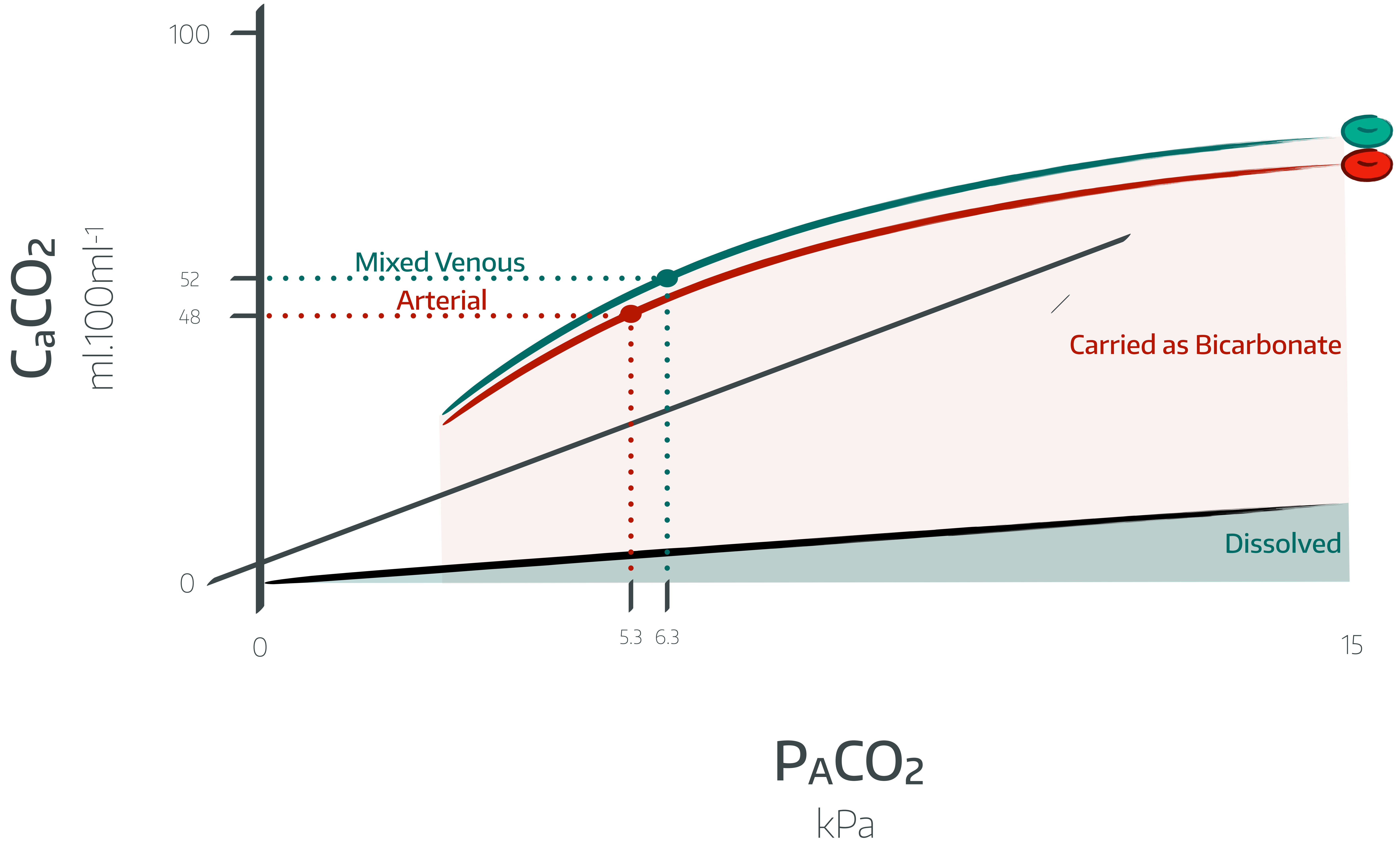
Respiratory Function

Lung Compliance

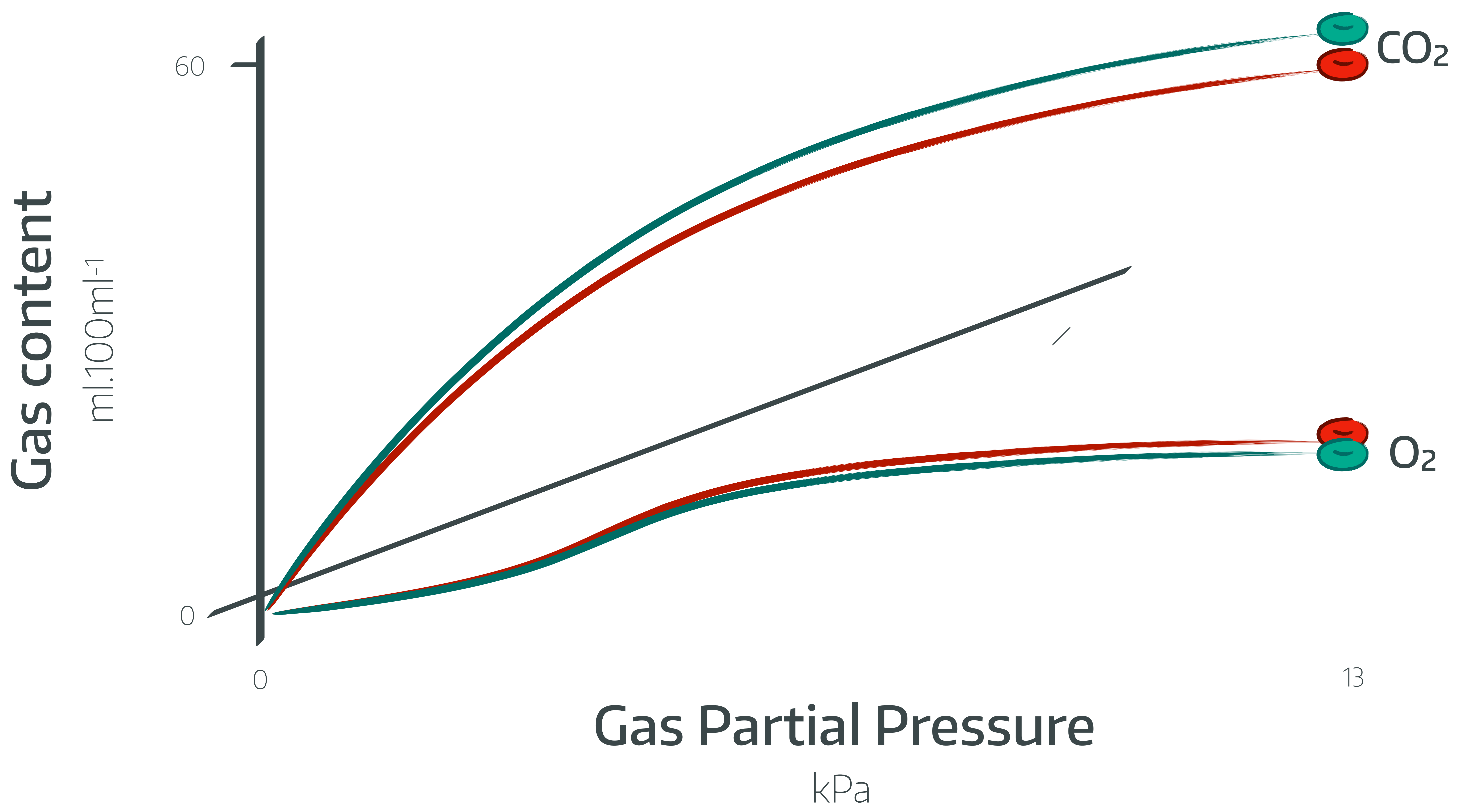


Respiratory Function

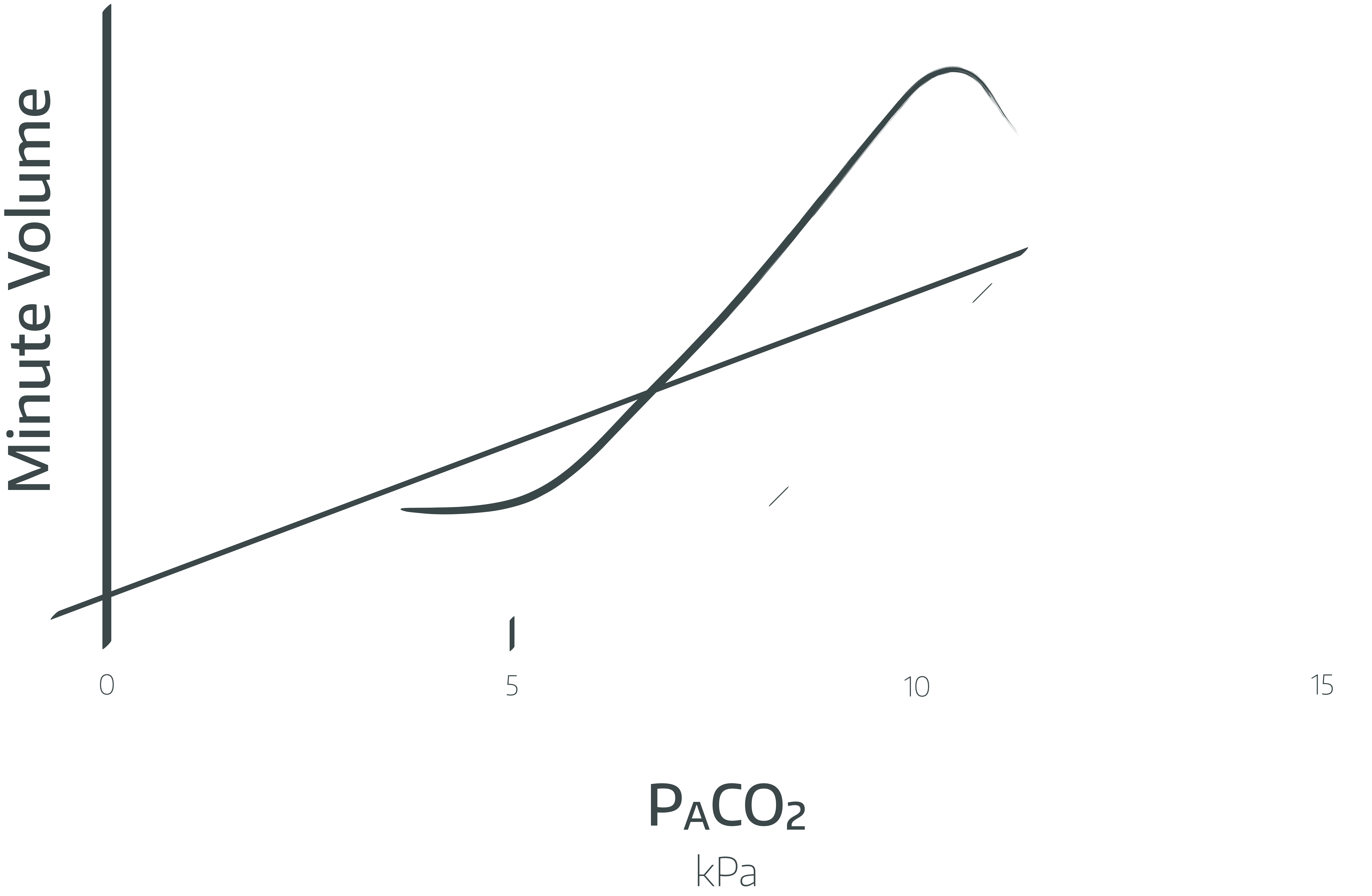
Transport of CO_2



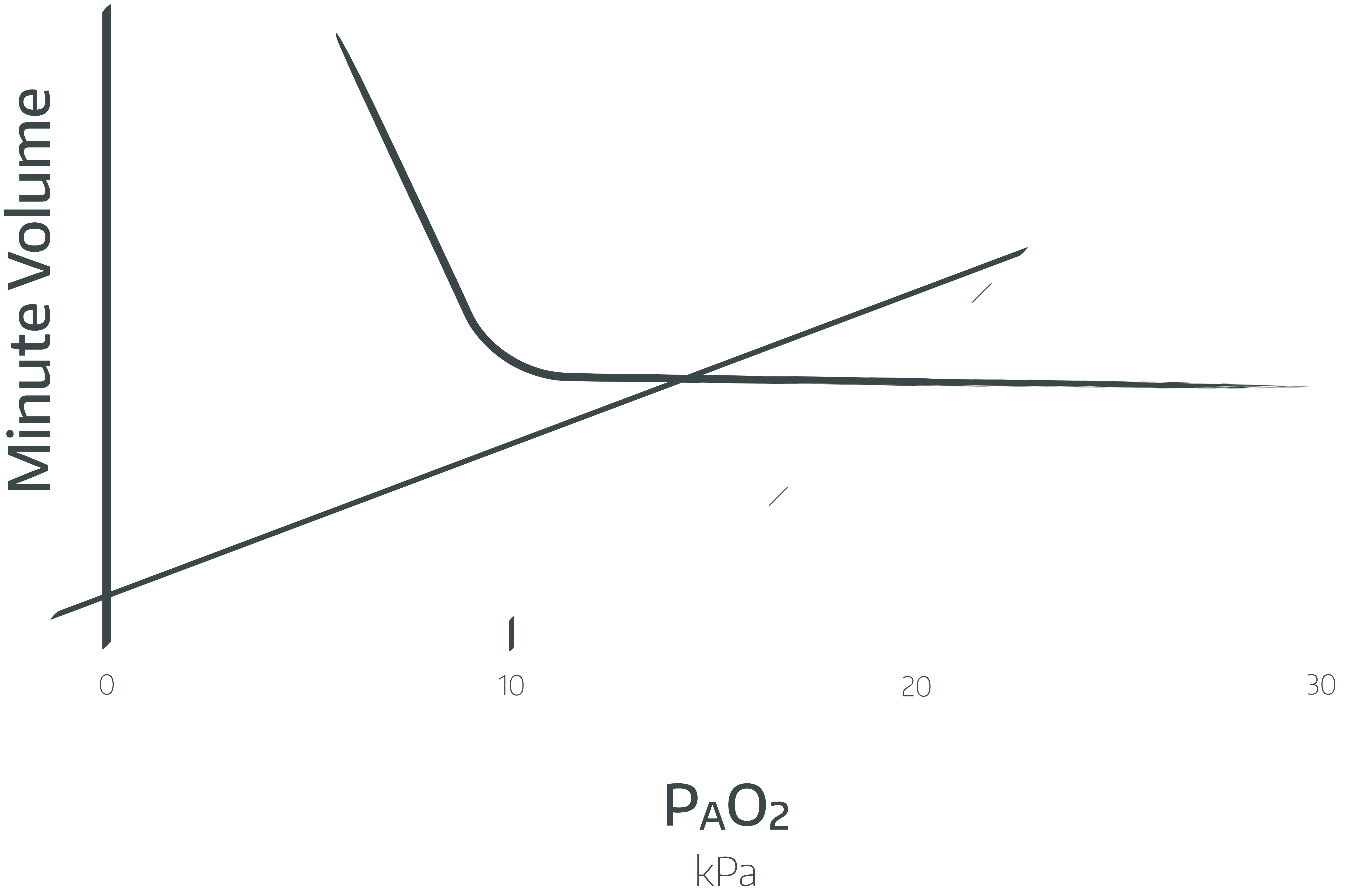
Transport of GASES



VENTILATORY RESPONSE TO CARBON DIOXIDE

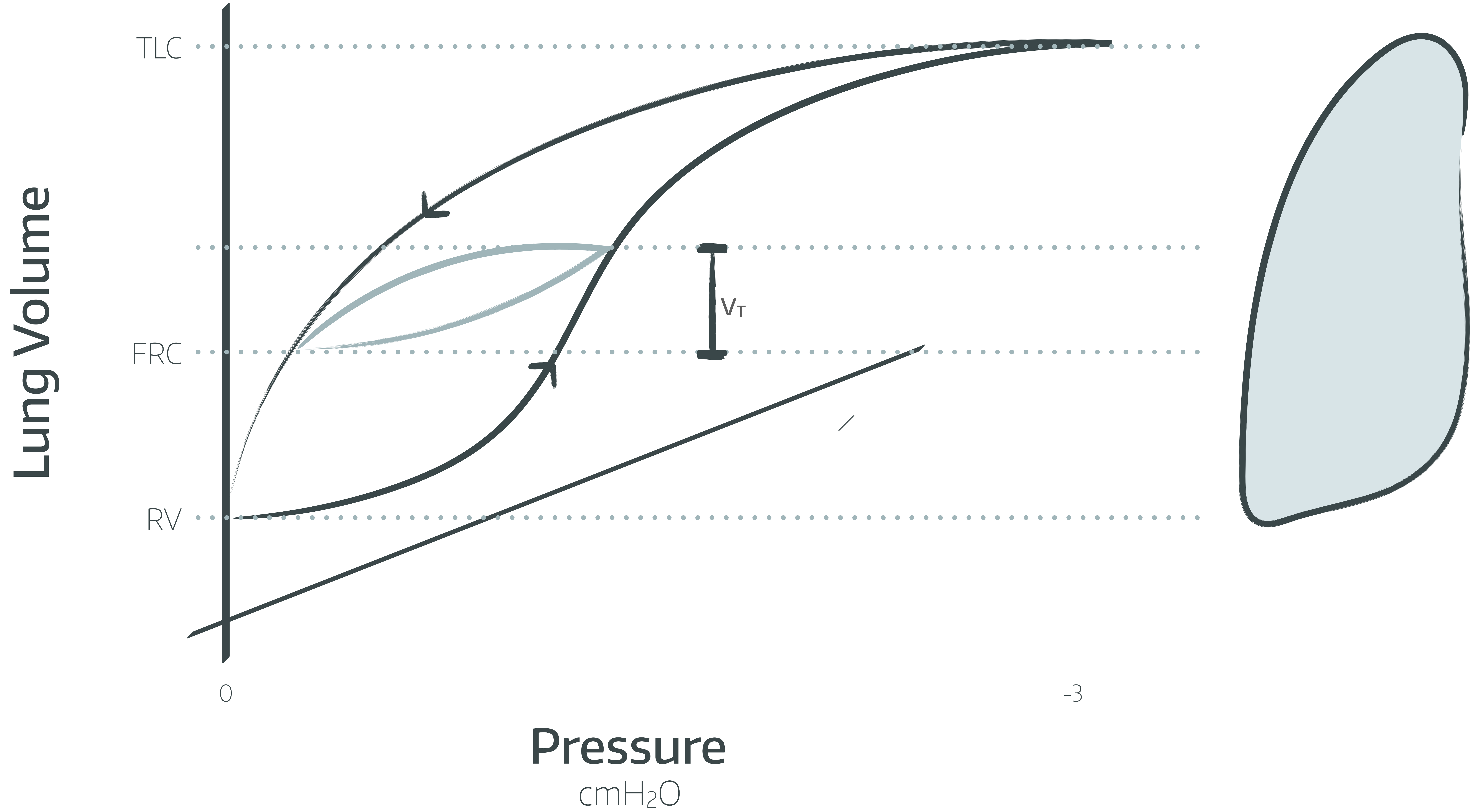


Ventilatory Response to Oxygen

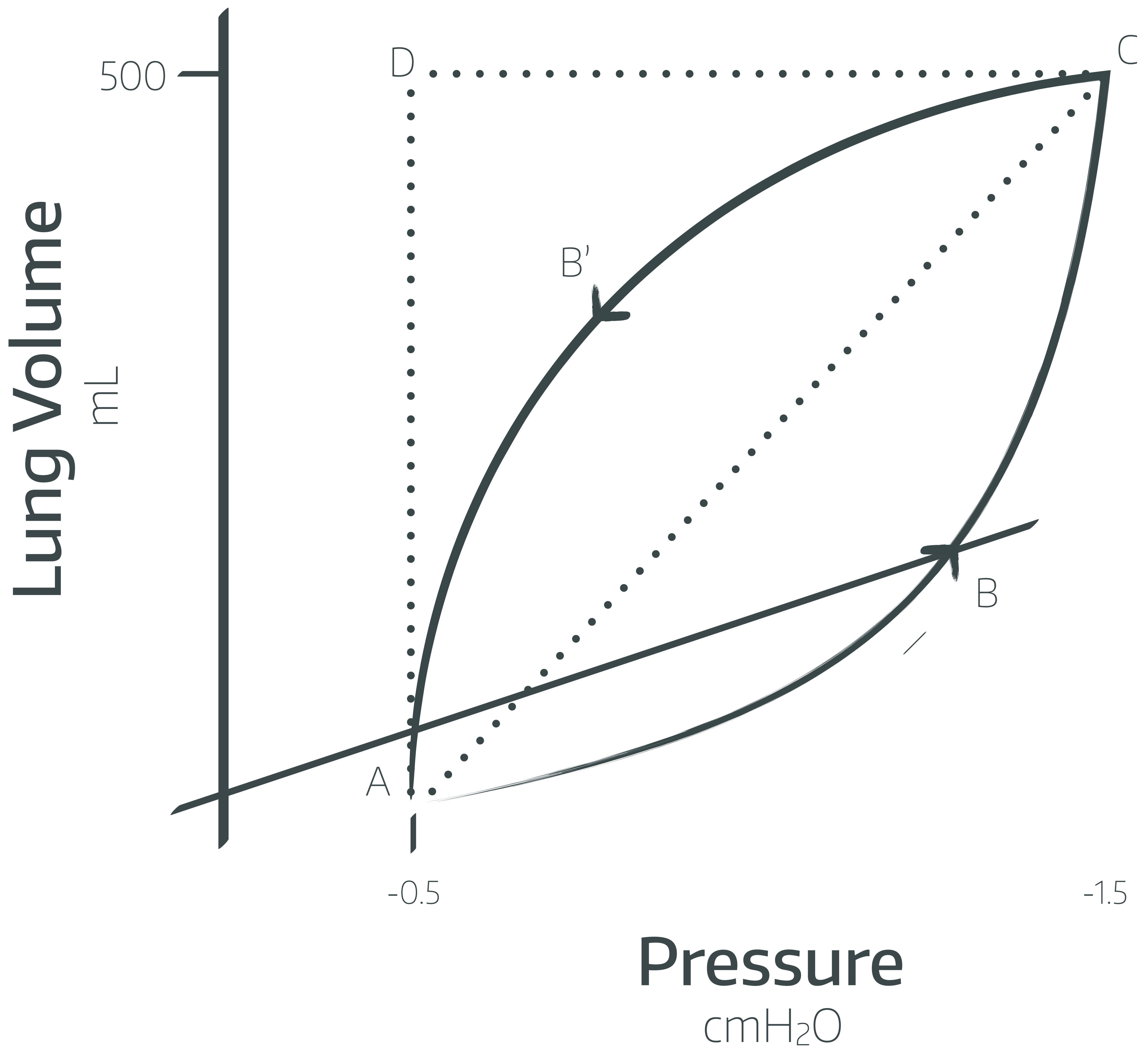


Respiratory Function

Pressure-Volume Curve

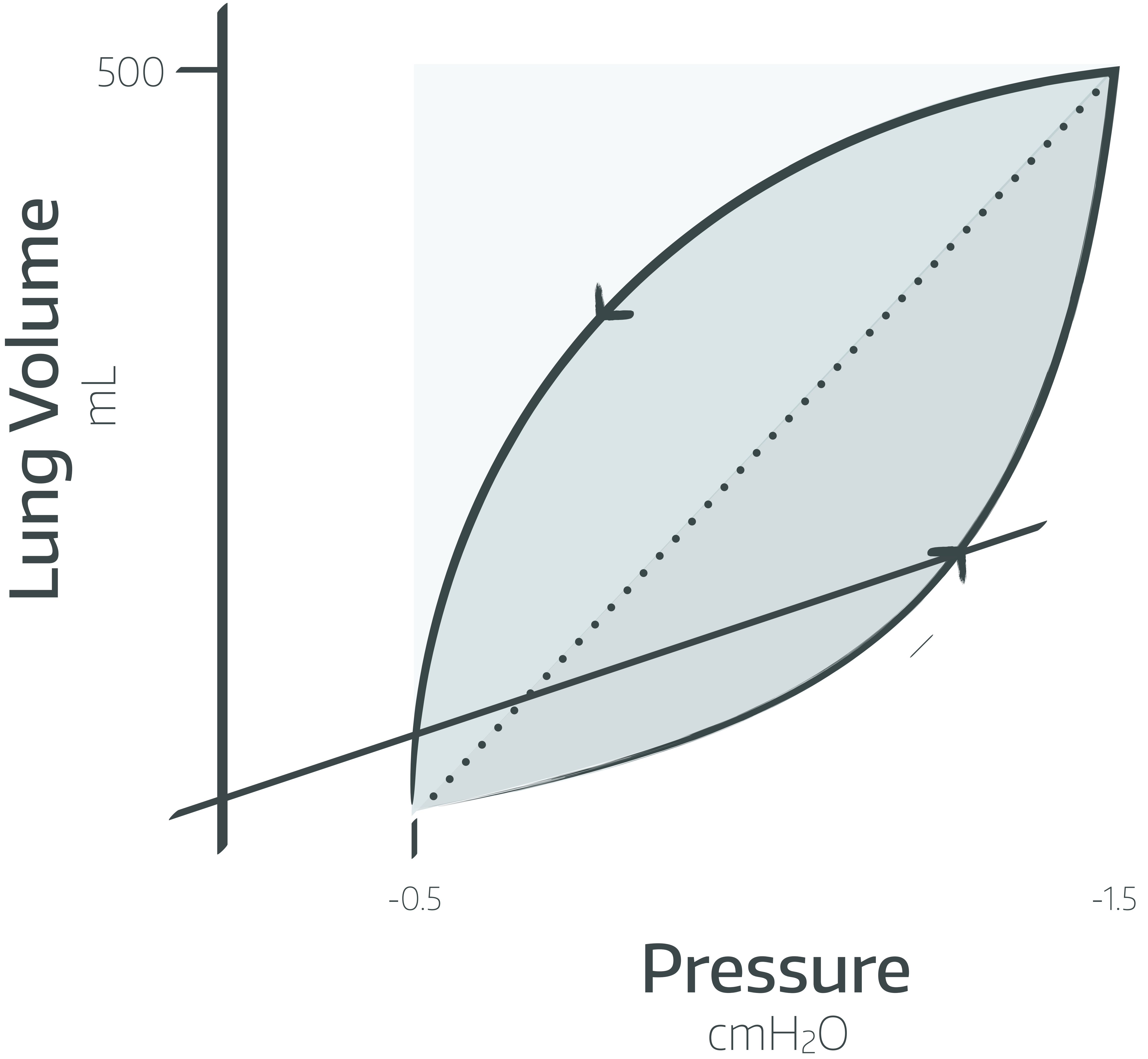


PRESSURE-VOLUME CURVE



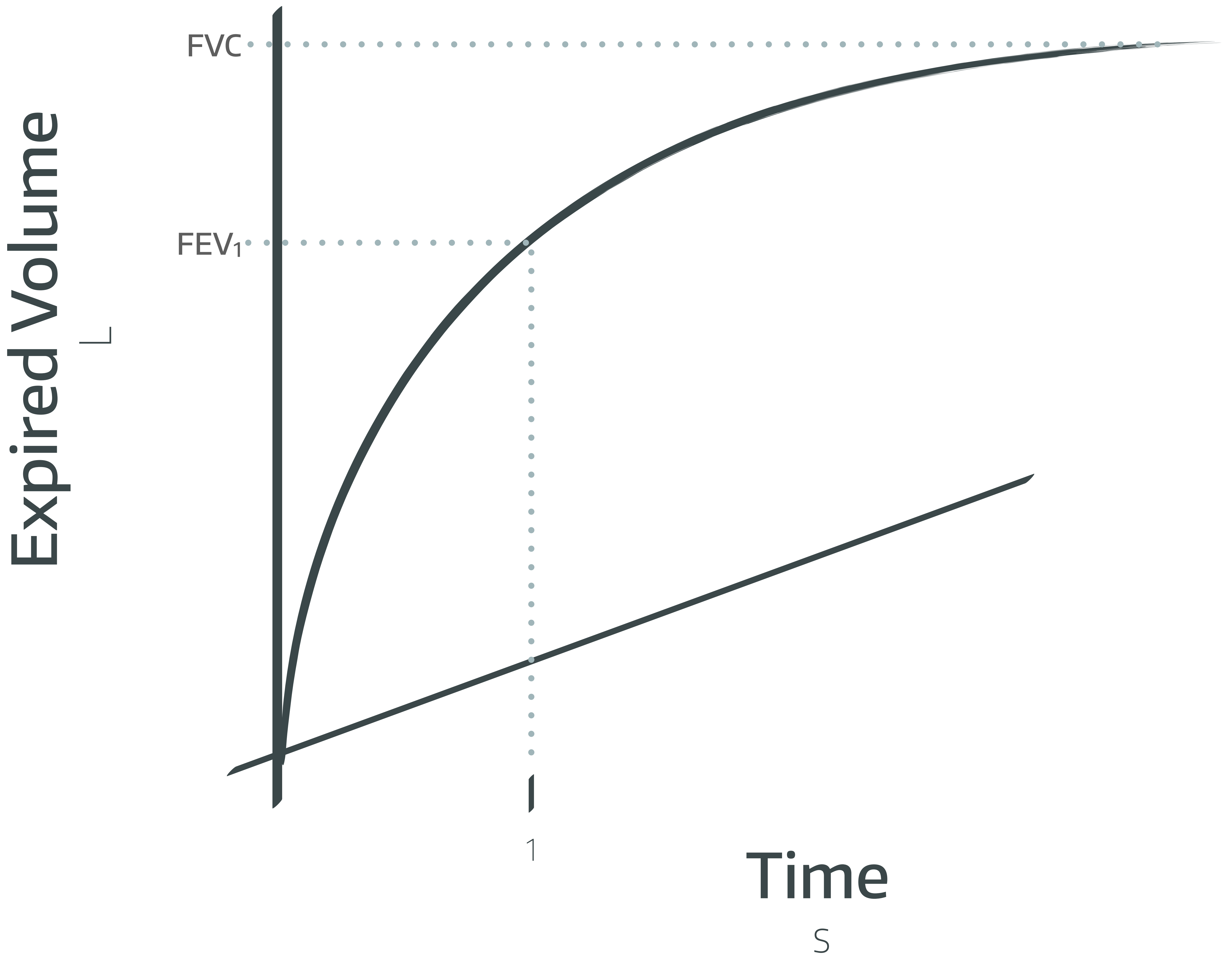
Pressure-Volume Curve

Respiratory Function

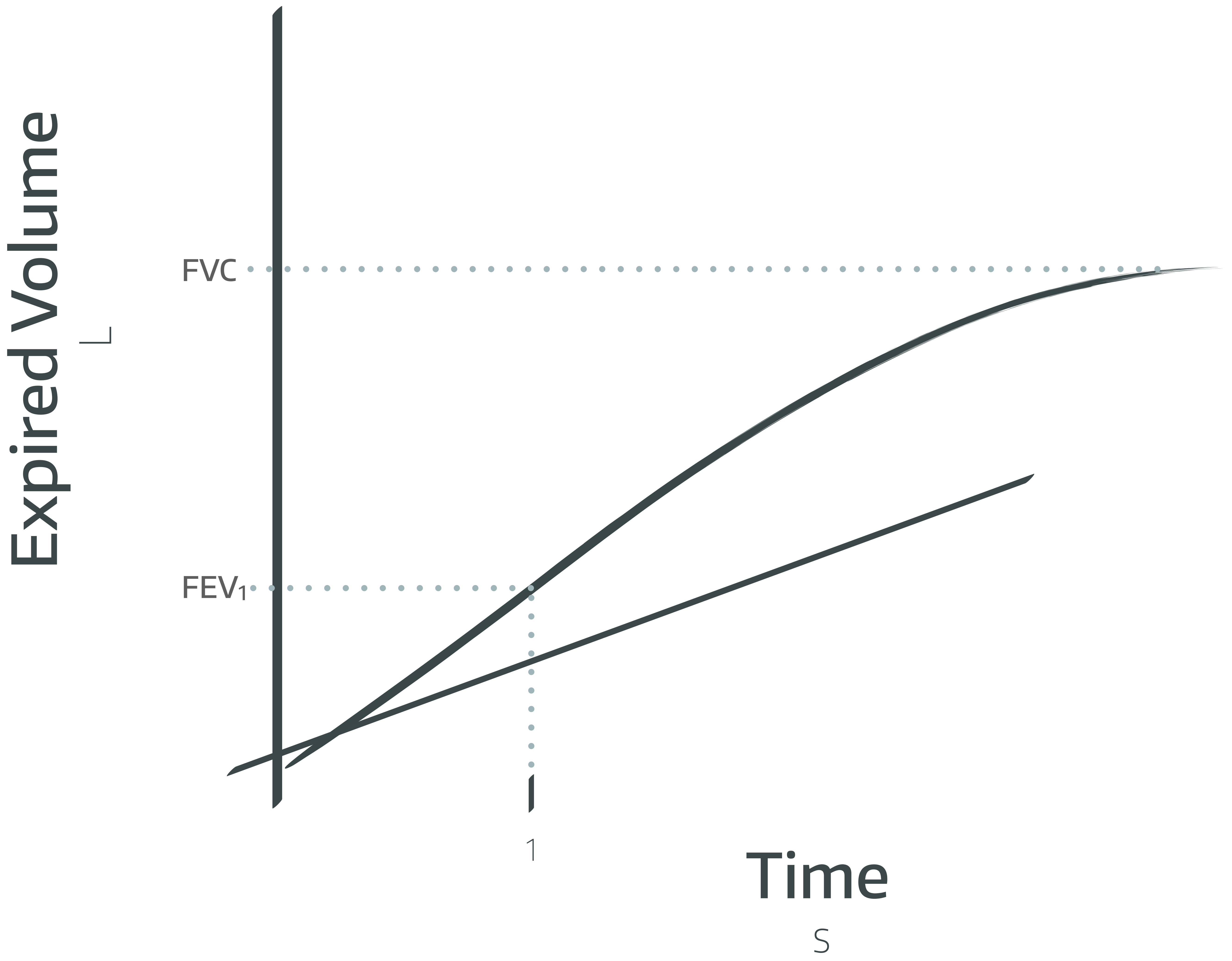


Respiratory Function

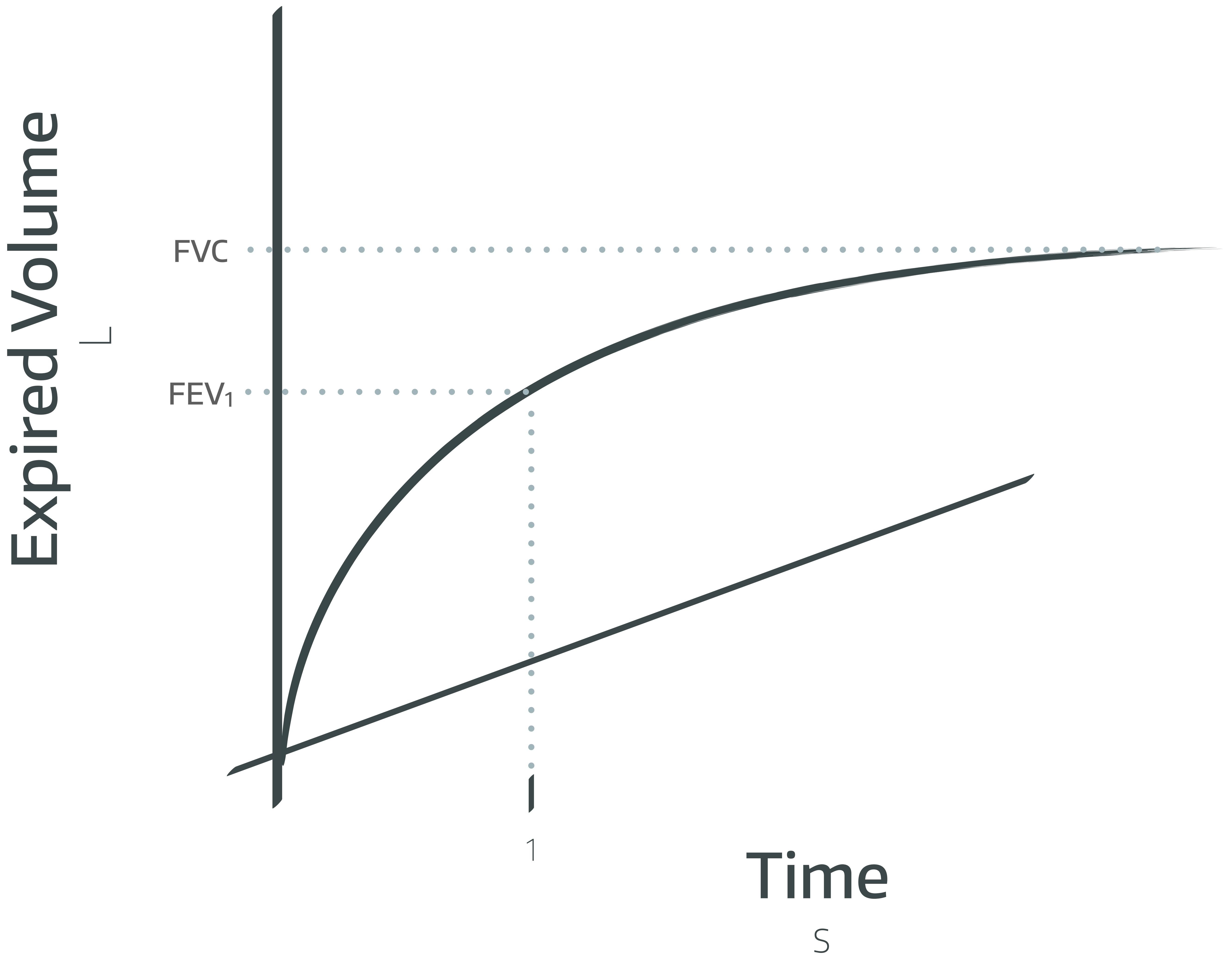
Vitalograph: Normal



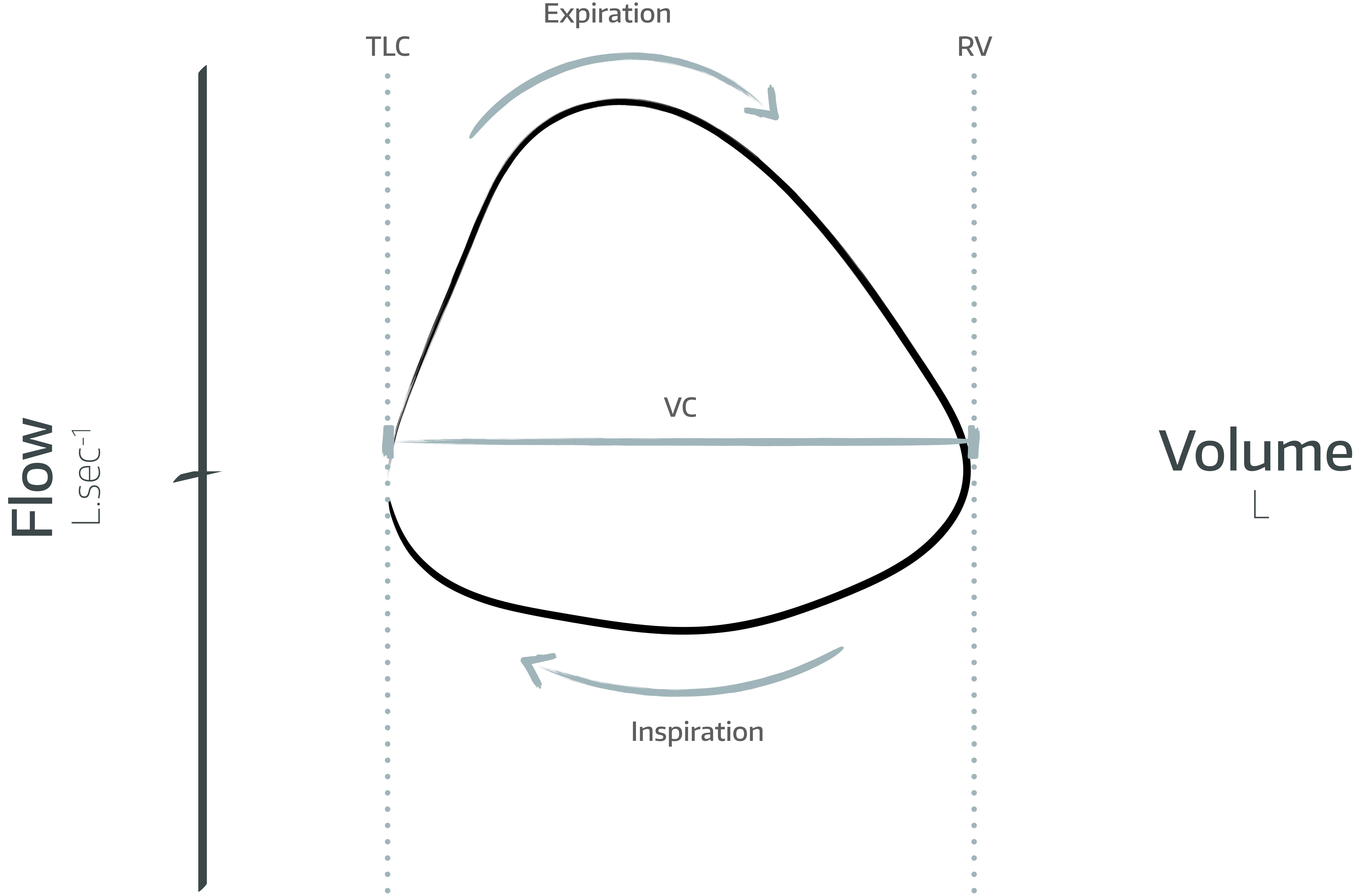
VITALOGRAPH: Obstructive



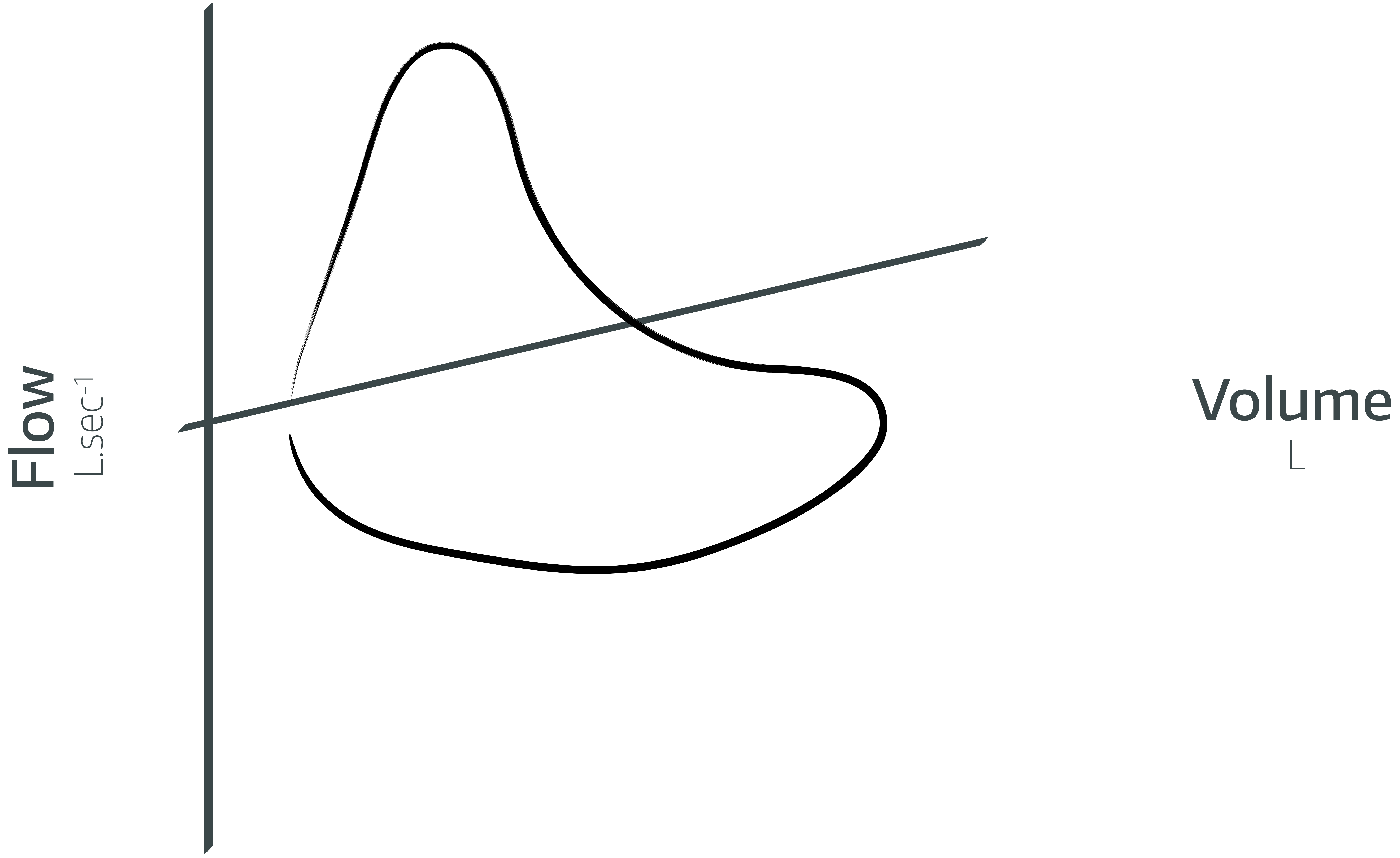
VITALOGRAPH: Restrictive



Flow-Volume Loops: Normal

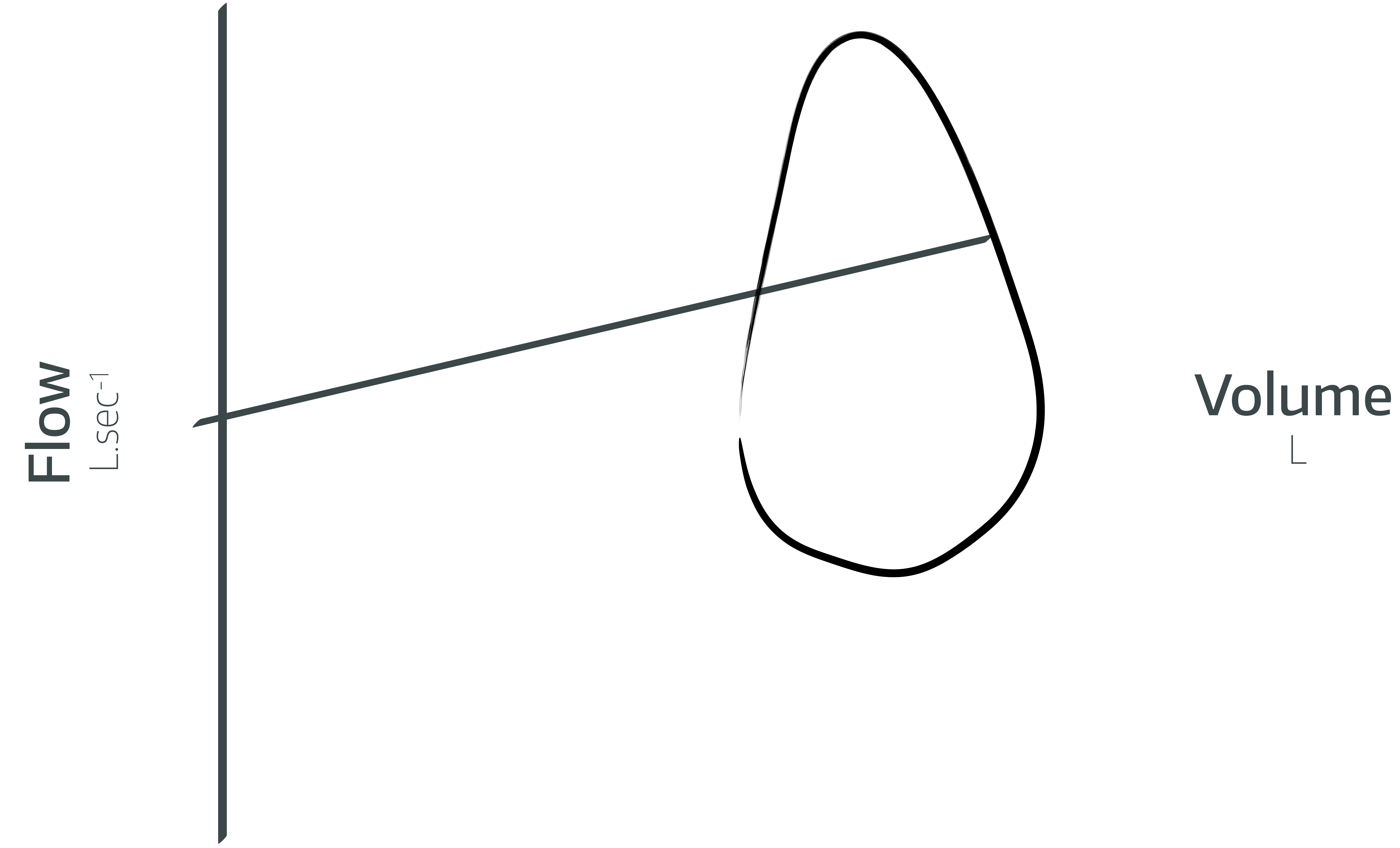


Flow-Volume Loops: Obstructive

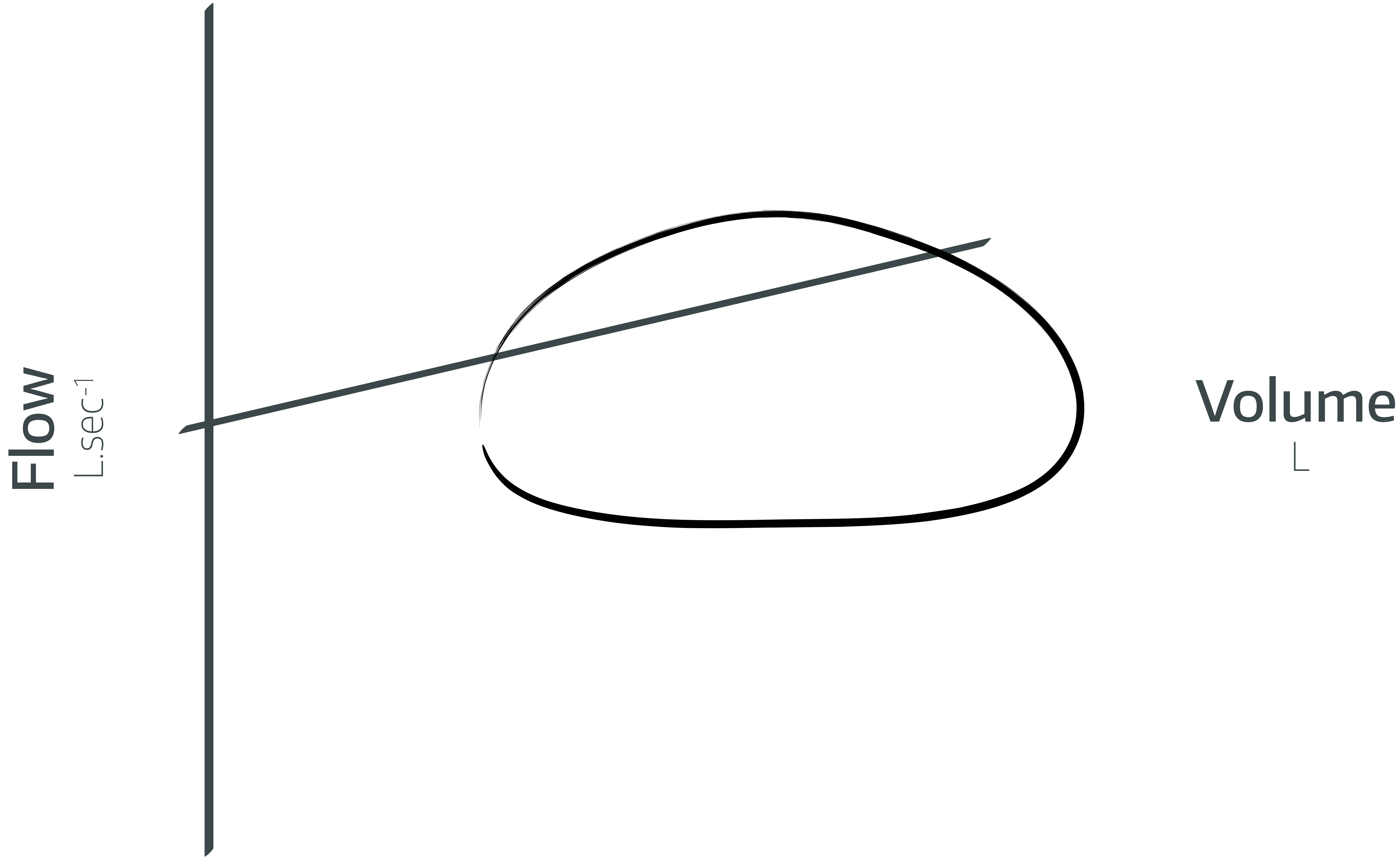


Respiratory Function

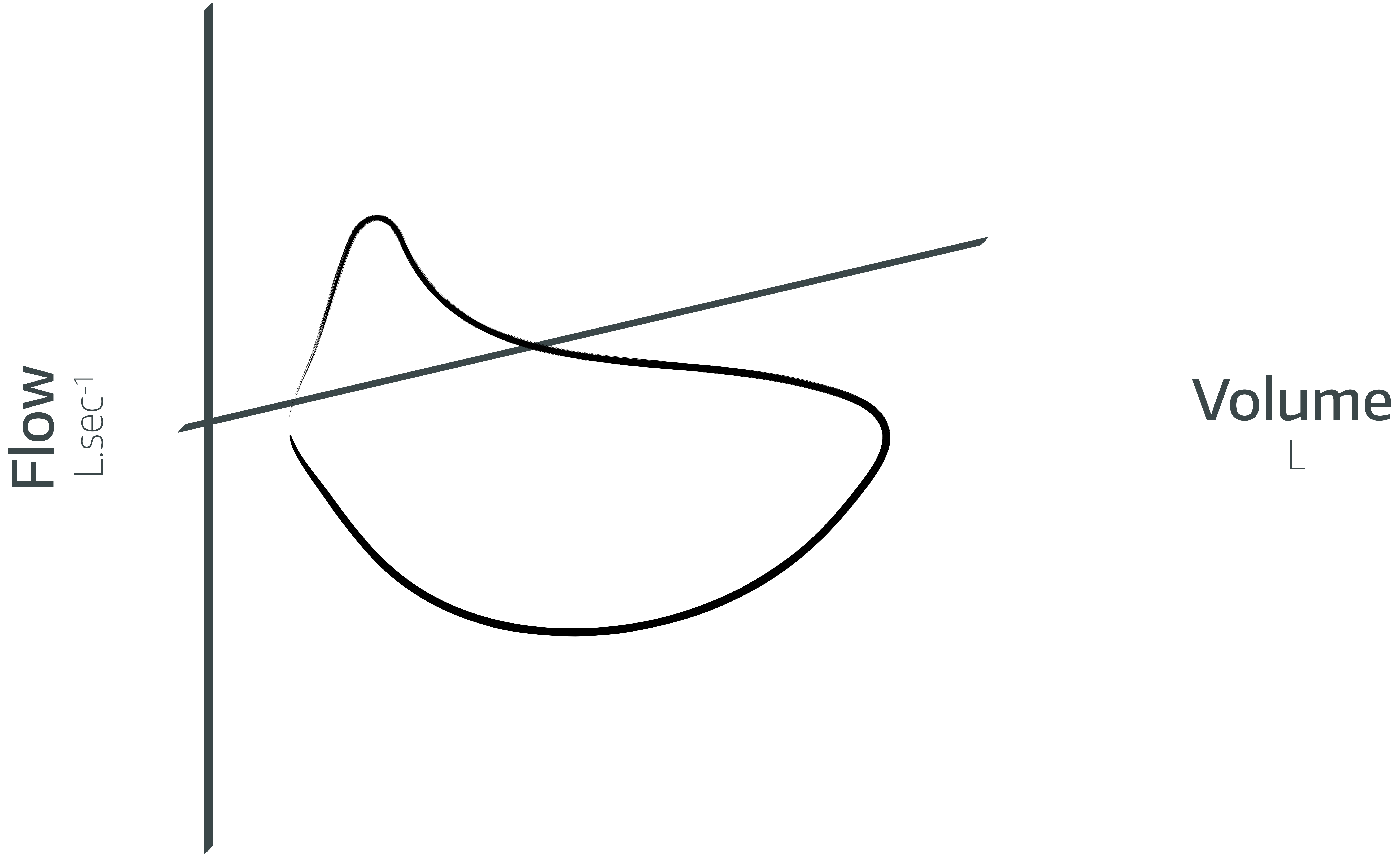
Flow-Volume Loops: Restrictive



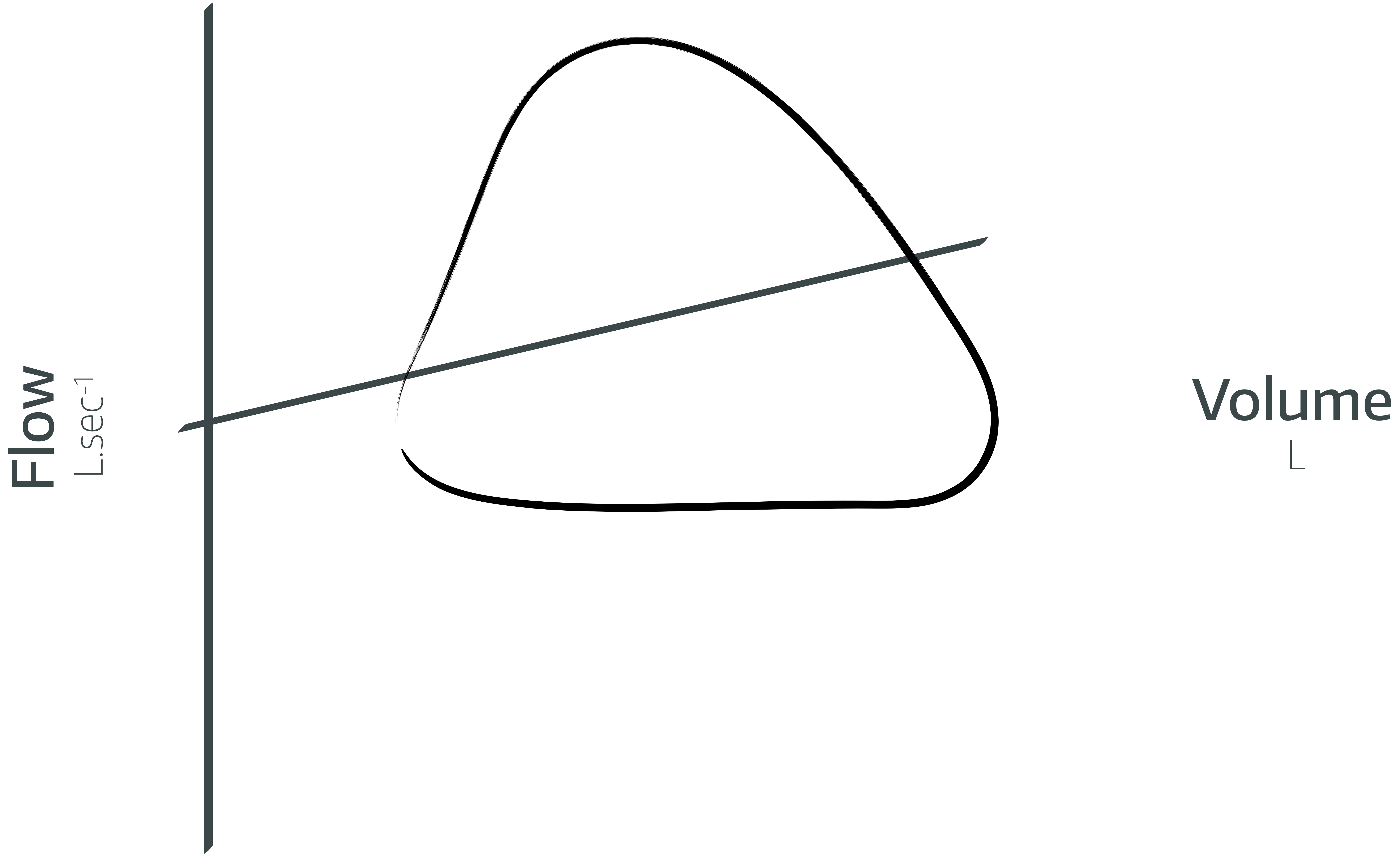
Flow-Volume Loops: Fixed Airway Obstruction



FLOW-VOLUME LOOPS: Variable Intrathoracic Airway Obstruction



FLOW-VOLUME LOOPS: Variable Extrathoracic Airway Obstruction



The Bohr Equation (Physiological Dead Space)

Dead Space

Fraction of Alveolar CO_2

Fraction of Expired CO_2

$$\frac{V_D}{V_T} = \frac{F_ACO_2 - F_ECO_2}{F_ACO_2}$$

Tidal Volume

Fraction of Alveolar CO_2

THE BOHR EQUATION (PHYSIOLOGICAL DEAD SPACE)

Tidal Volume = Dead space + Alveolar Volume

i.e. $V_T = V_D + V_A$

$\therefore \quad V_A = V_T - V_D \quad (1)$

Expired CO_2 can only come from alveolar volume (not dead space)

$\therefore \quad V_T \times F_ECO_2 = V_A \times F_ACO_2 \quad (2)$

Substitute Equation 1 into Equation 2

$$V_T \times F_ECO_2 = (V_T - V_D) \times F_ACO_2$$

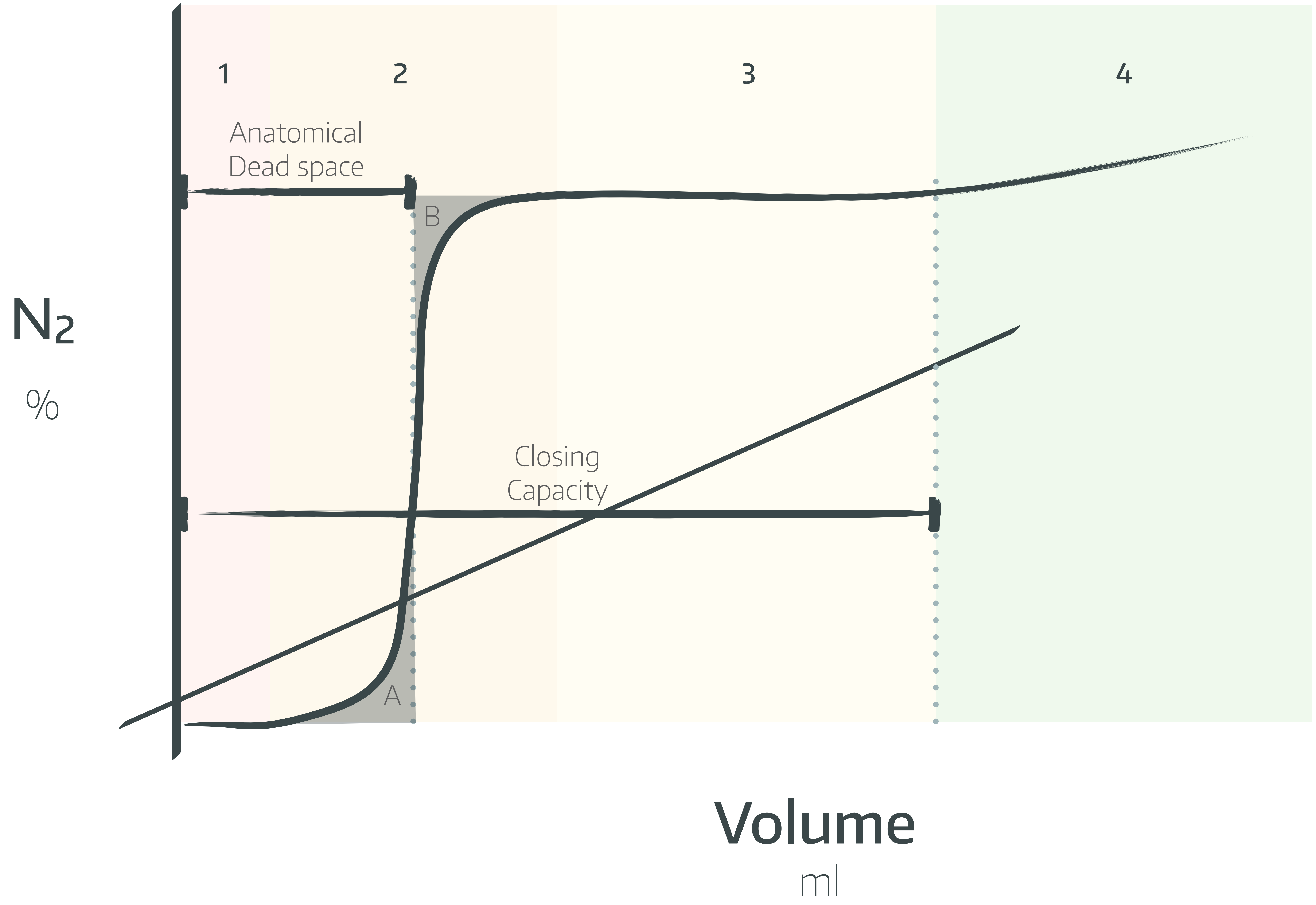
$$V_T \times F_ECO_2 = (V_T \times F_ACO_2) - (V_D \times F_ACO_2)$$

$$V_D \times F_ACO_2 = (V_T \times F_ACO_2) - (V_T \times F_ECO_2) = V_T\,(F_ACO_2 - F_ECO_2)$$

$$\frac{V_D}{V_T} = \frac{F_ACO_2 - F_ECO_2}{F_ACO_2}$$

Respiratory Function

Fowler's Method (Anatomical Dead Space)



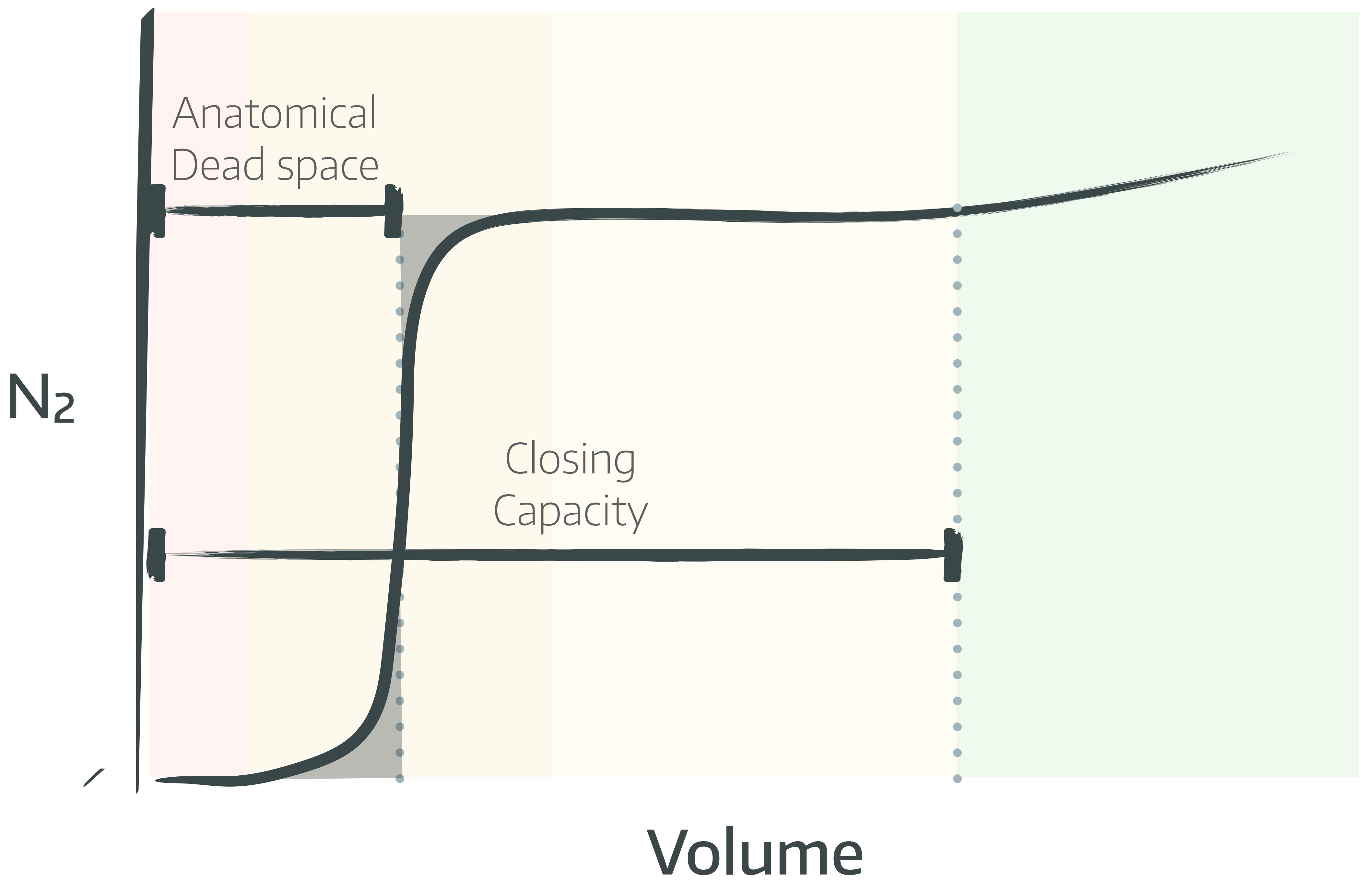
FOWLER'S METHOD (ANATOMICAL DEAD SPACE)

Steps

1. 100% O_2 Vital Capacity Breath
2. Exhale to Residual volume to measure N_2 content & volume
3. Plot [N_2] against Volume

Measured & Derived Parameters

Closing Volume
Closing Capacity
Closing Volume : Vital Capacity Ratio
Closing Capacity : Total Lung Capacity Ratio



Pure Dead Space. 100% O_2 as there is no gas exchange here

Pure Alveolar Gas. Plateau phase.

Mixture of O_2 & N_2 from alveolar units

Closing Capacity corresponds to sudden N_2 increase

Pulmonary Vascular Resistance

Pulmonary Vascular Resistance

Mean Pulmonary Artery Pressure

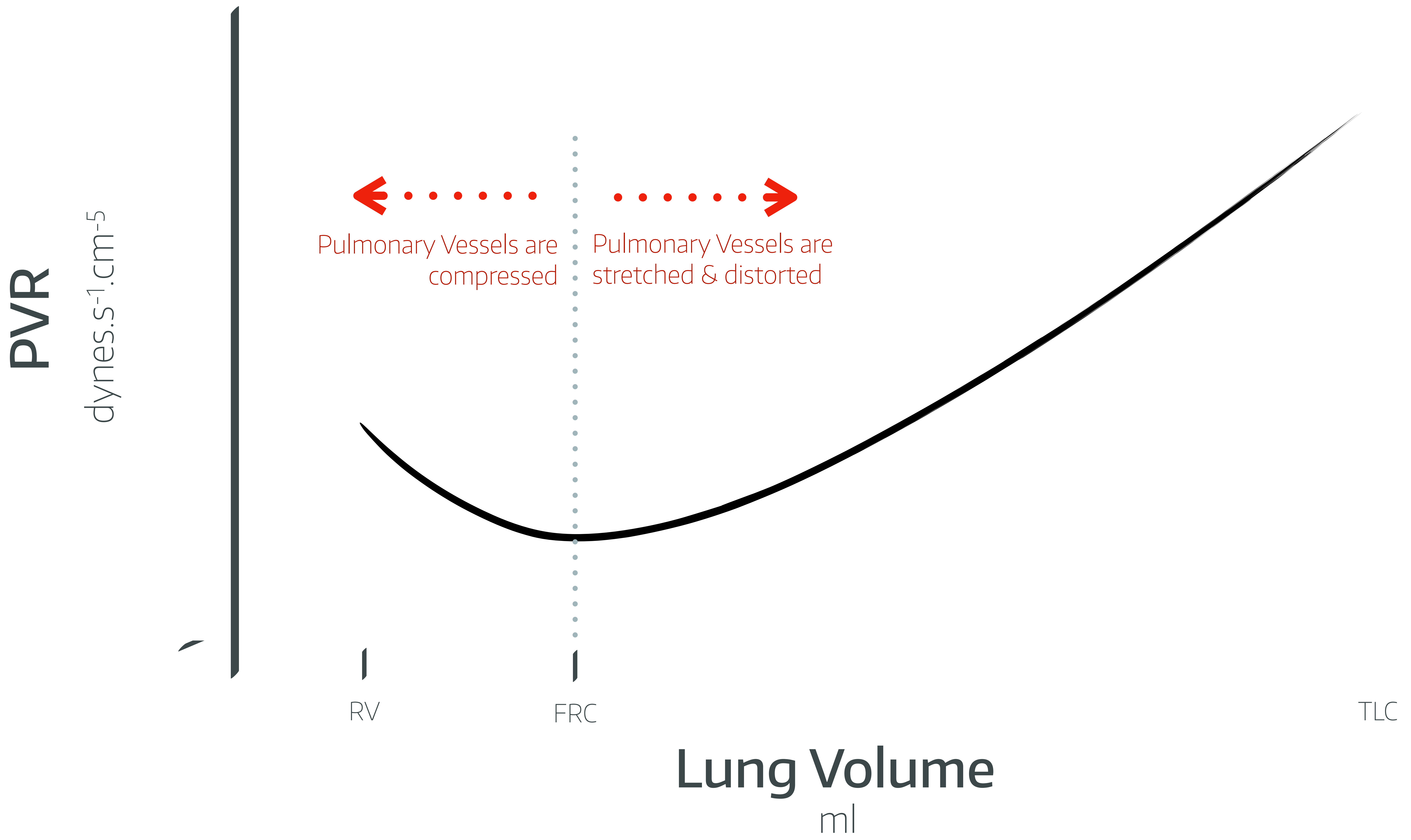
Left Atrial Pressure

$$PVR = \frac{MPAP - LAP}{CO} \times 80$$

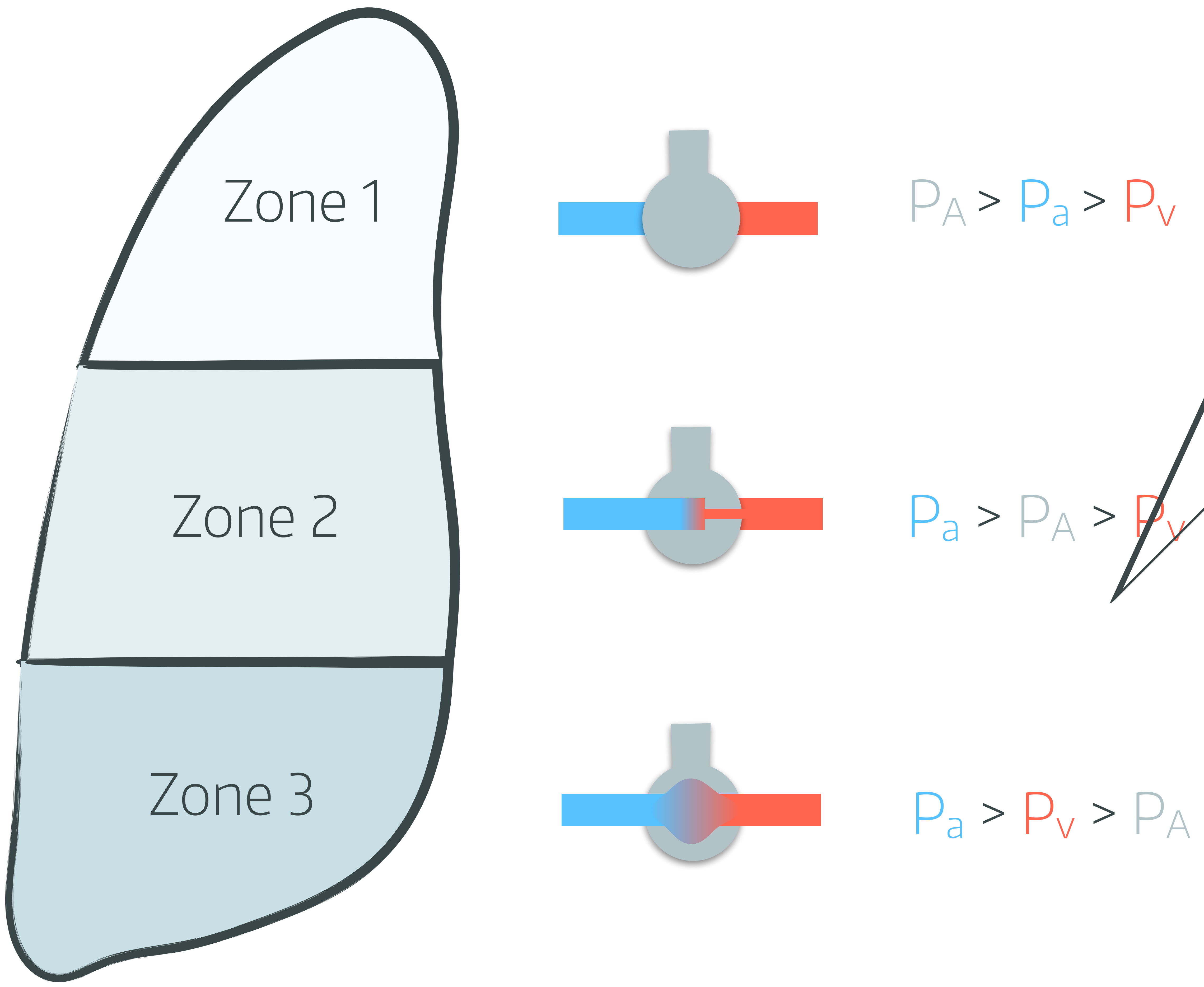
Cardiac Output

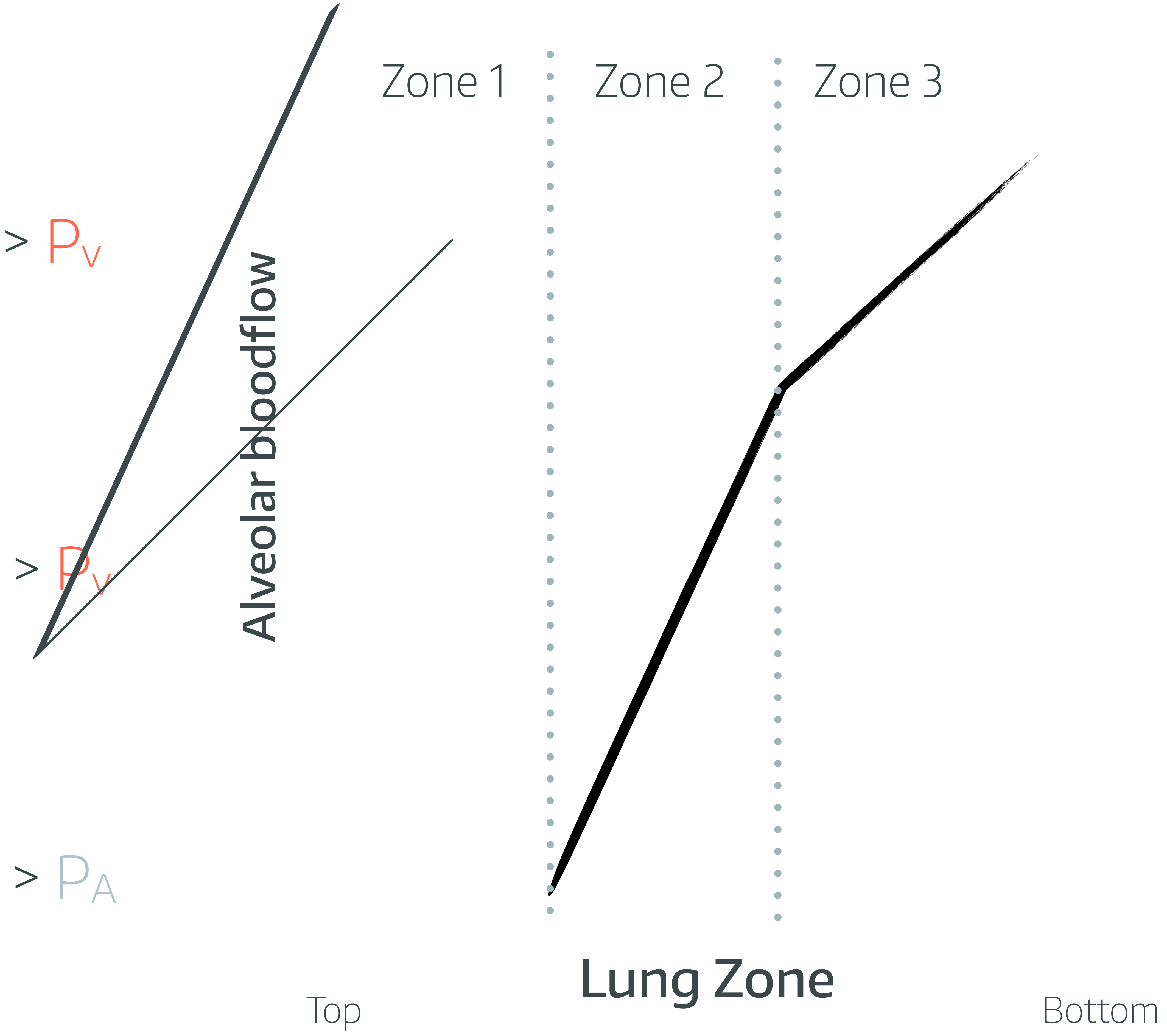
Unit Conversion Coefficient

PULMONARY VASCULAR RESISTANCE

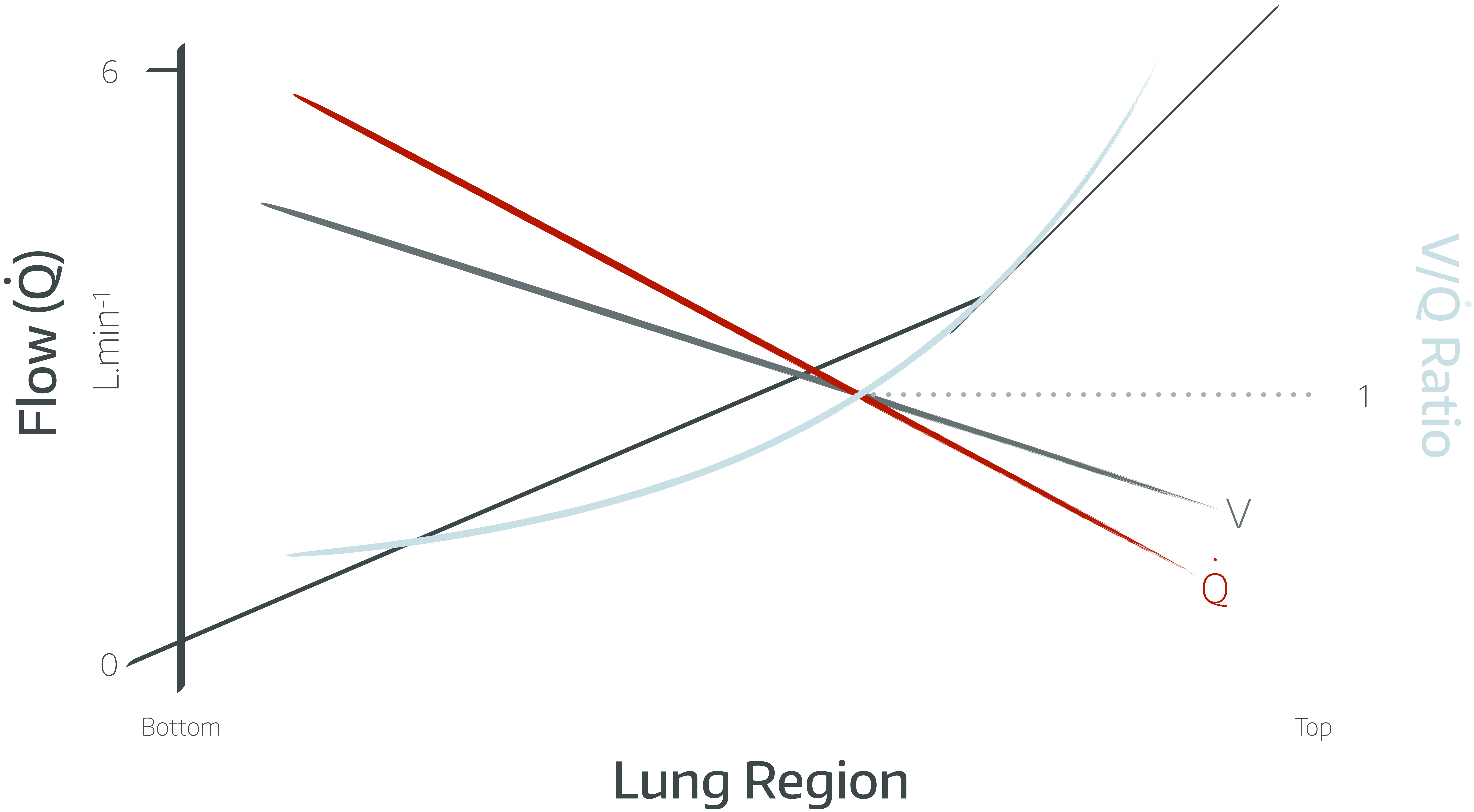


WEST ZONES

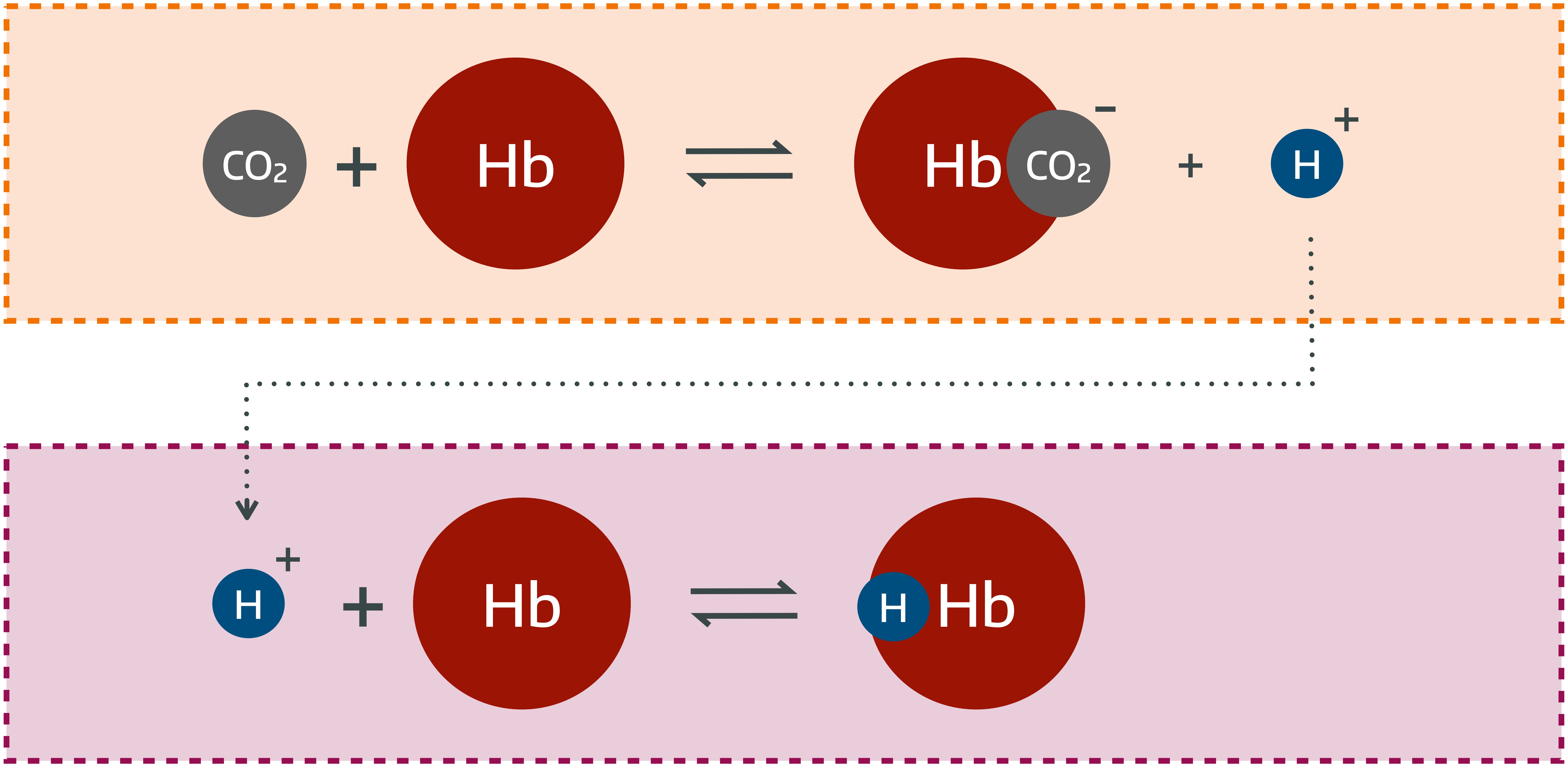

Zone 1
Zone 2
Zone 3
$P_A > P_a > P_v$
$P_a > P_A > P_v$
$P_a > P_v > P_A$


Zone 1
Zone 2
Zone 3
Alveolar bloodflow
Lung Zone
Top
Bottom

Ventilation-Perfusion Matching

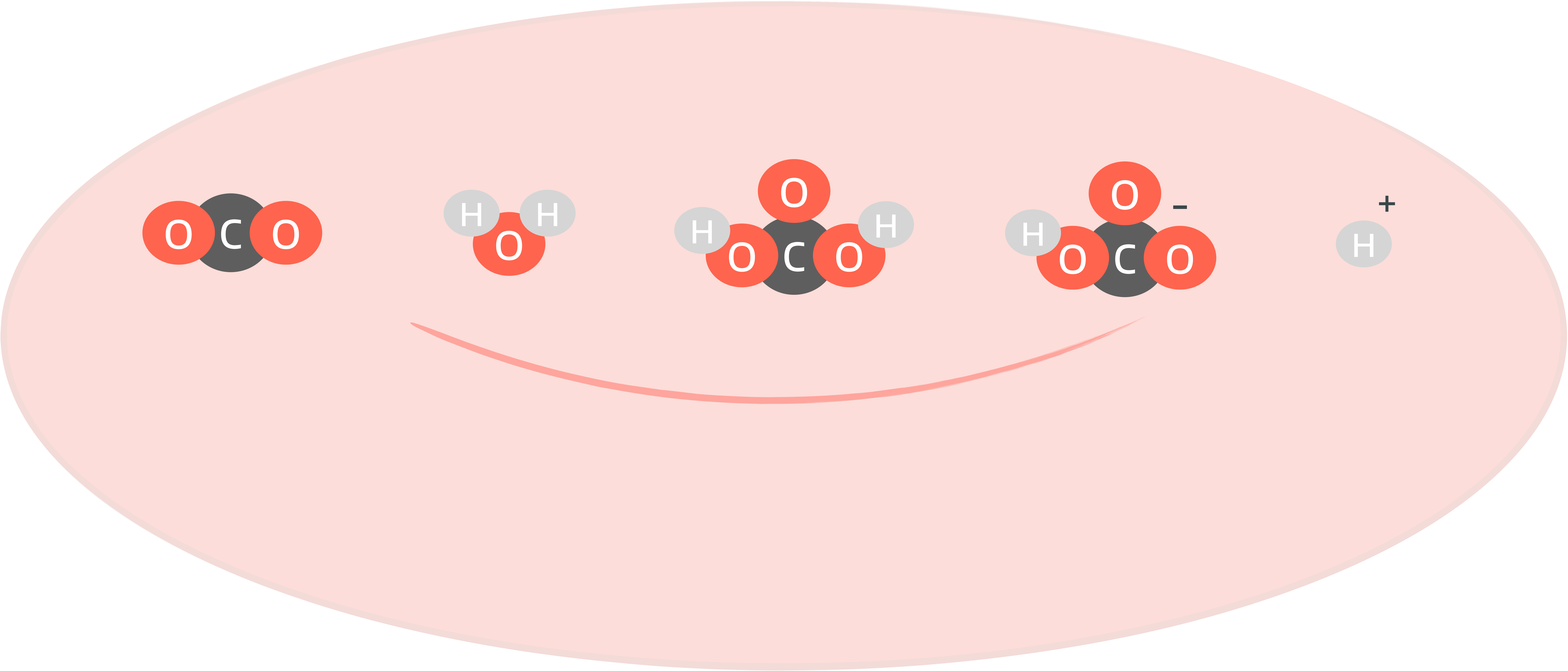


CARBON DIOXIDE CARRIAGE



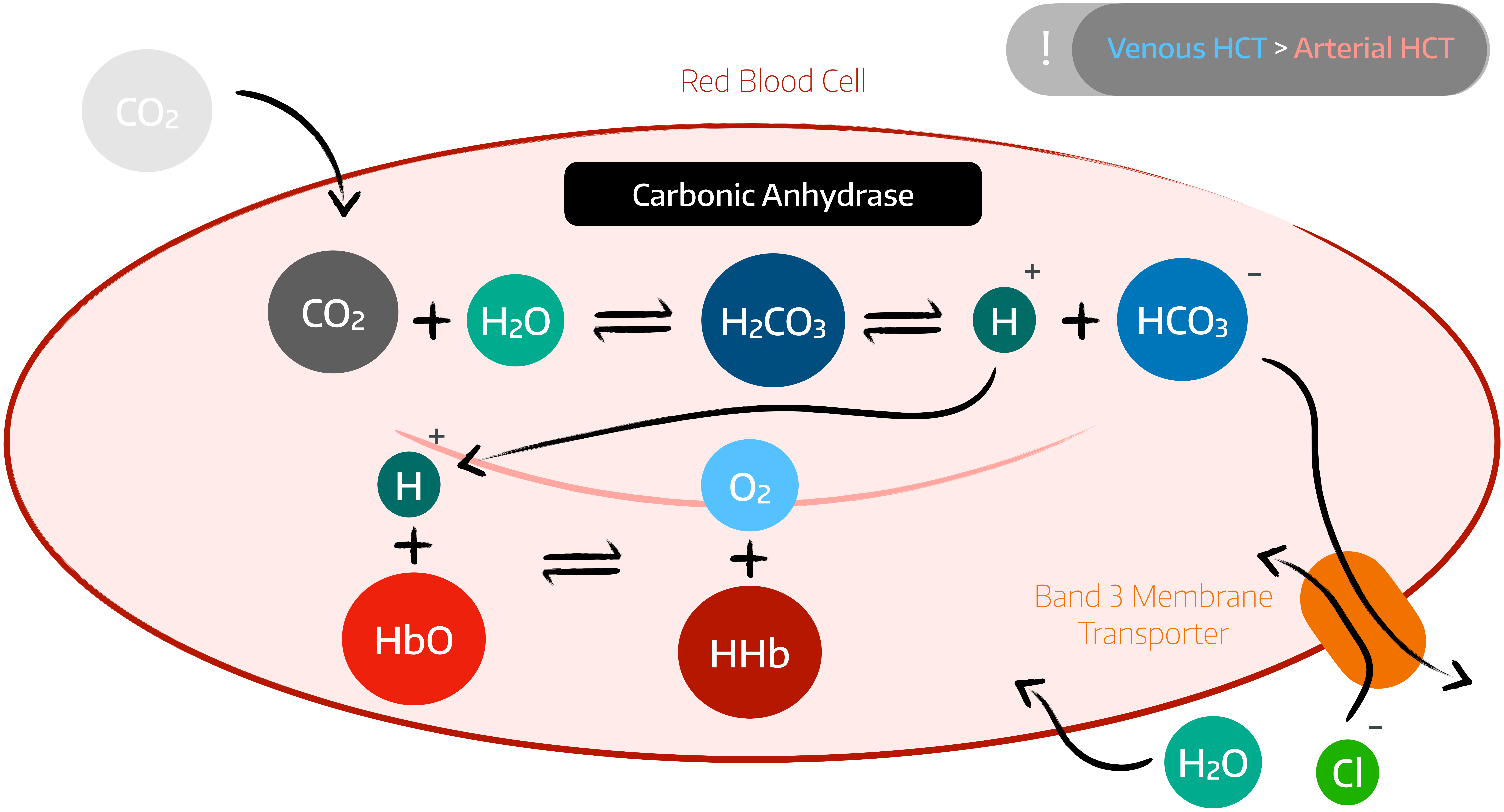
METABOLISM

The Chloride Shift



METABOLISM

THE CHLORIDE SHIFT

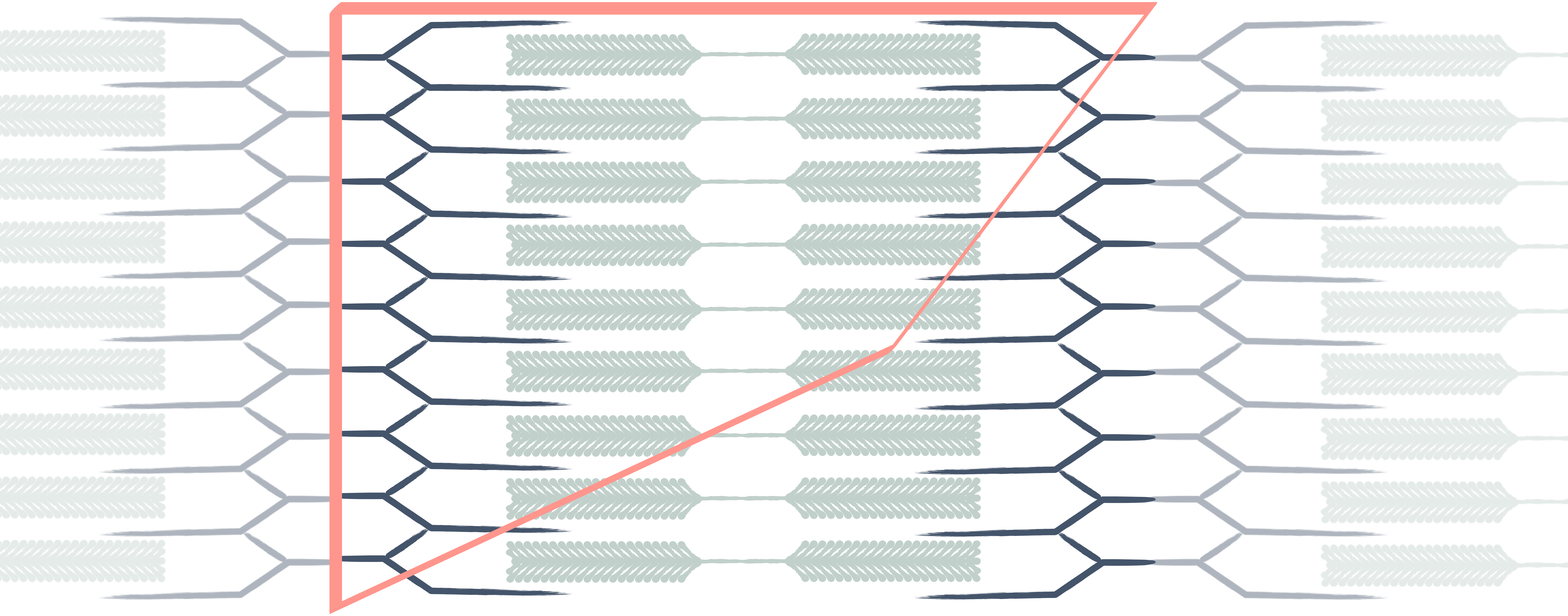


CARBON DIOXIDE & HAEMOGLOBIN

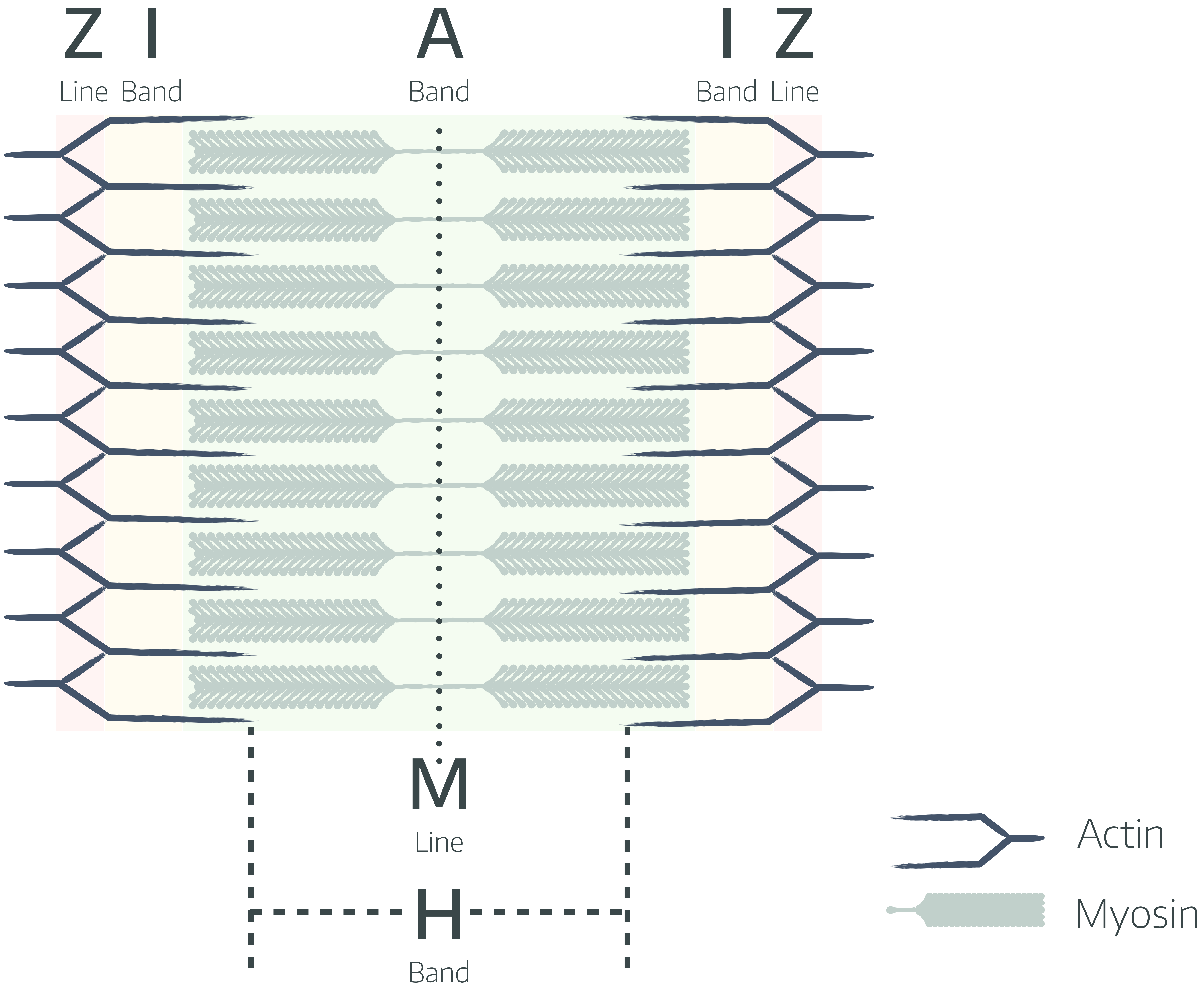
$$CO_2 + Hb \rightleftharpoons HbCO_2^- + H^+$$

$$Hb + H^+ \rightleftharpoons HHb$$

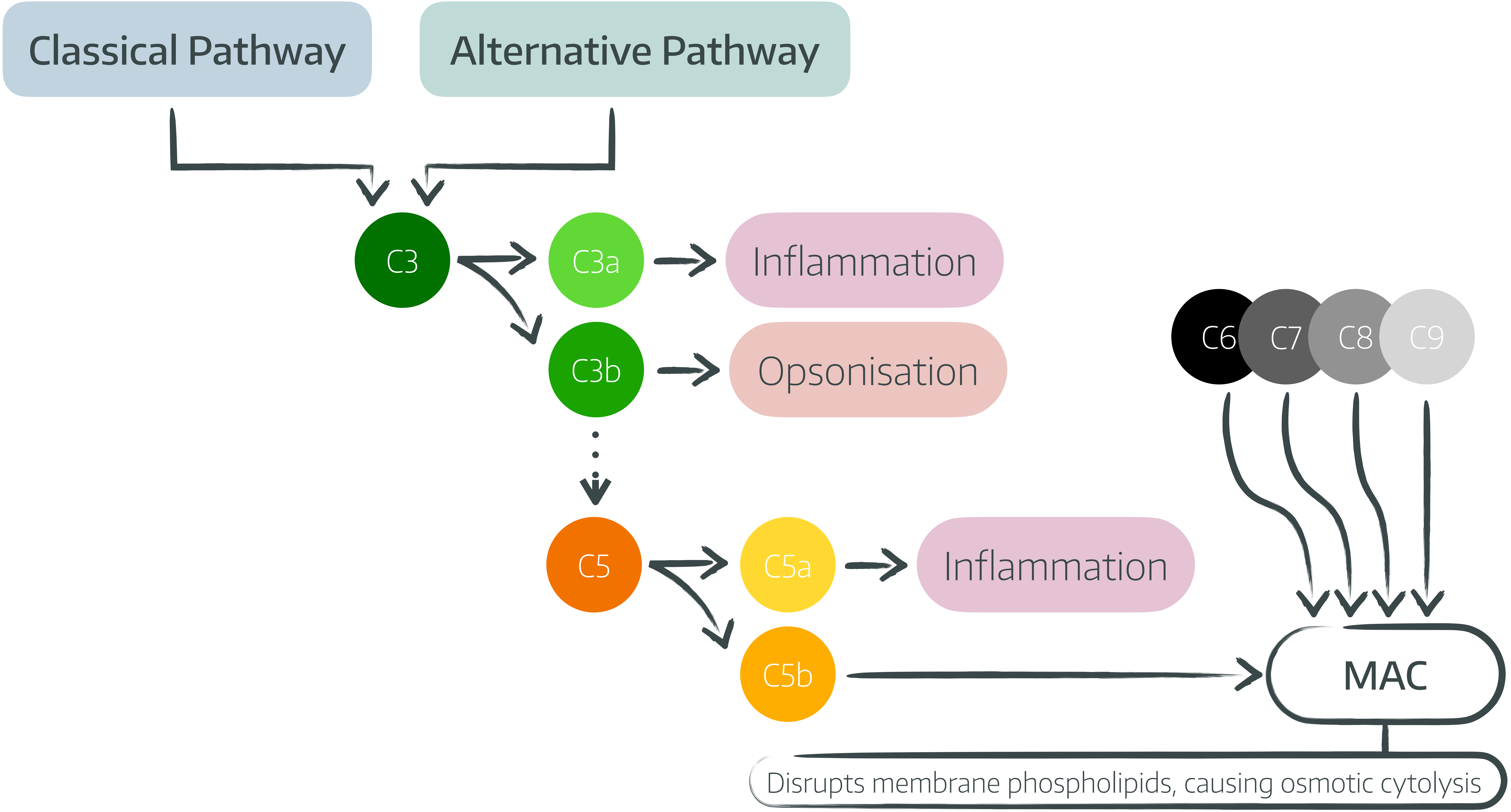
The Sarcomere

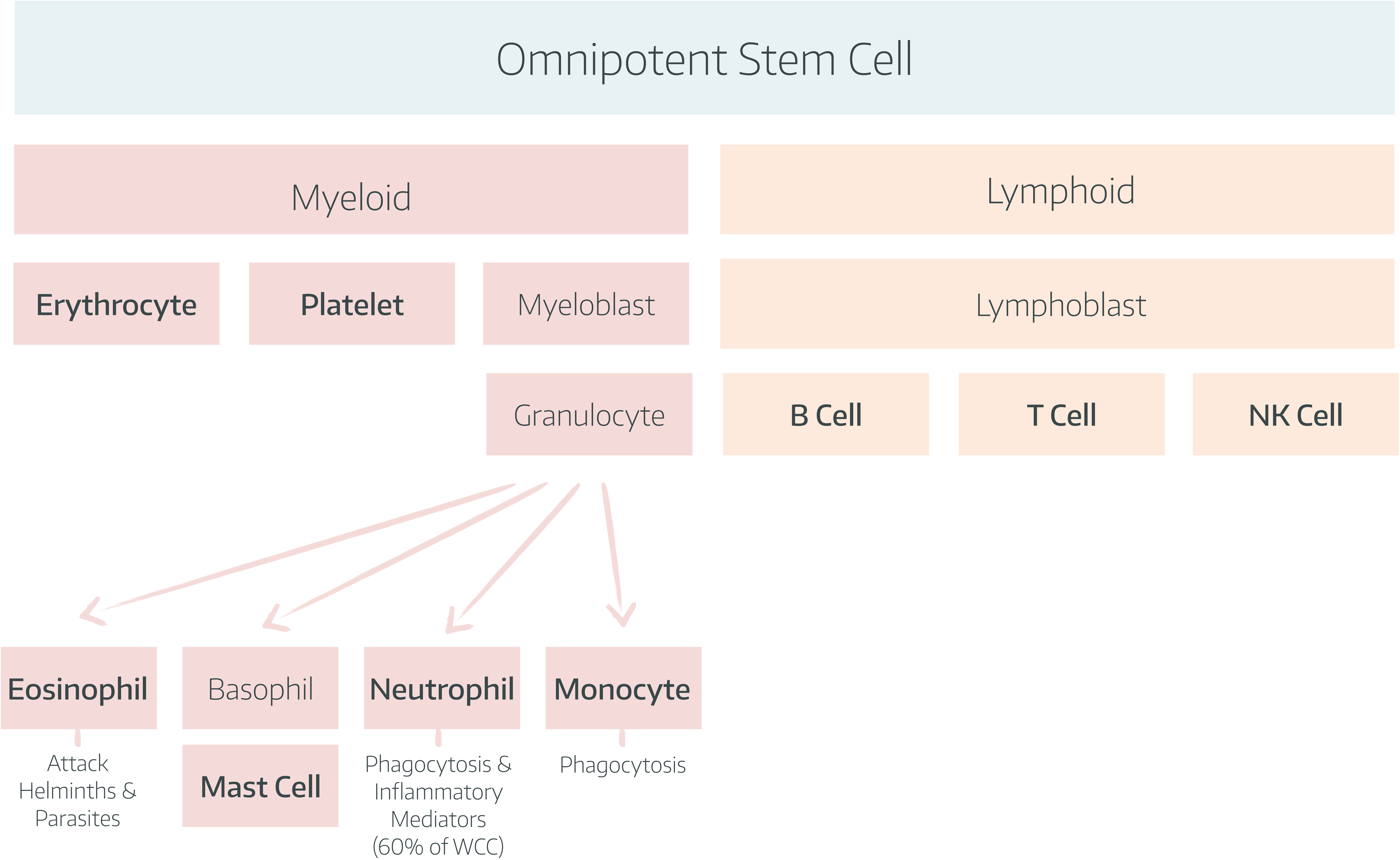


Muscle Function



Complement

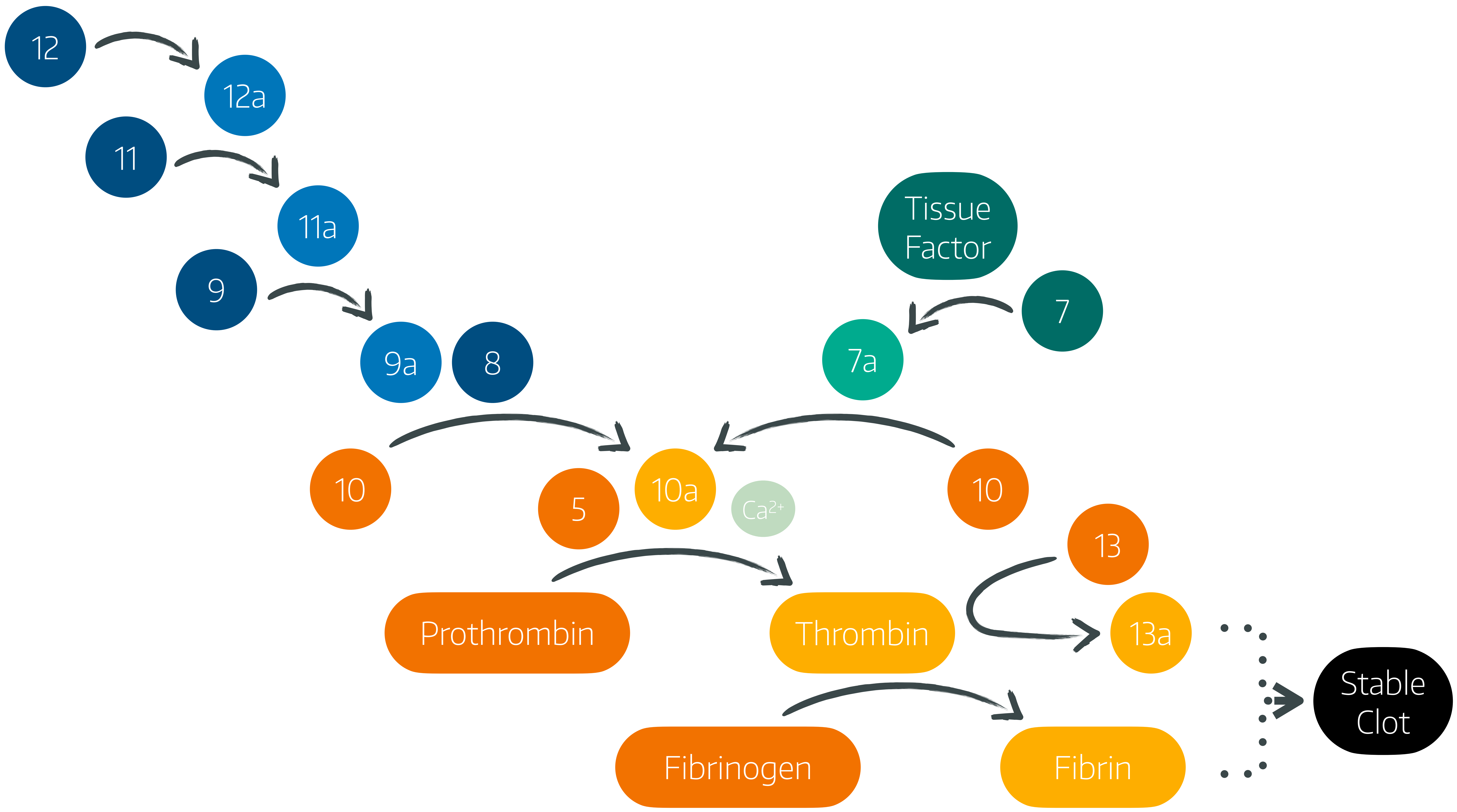

Classical Pathway
Alternative Pathway
C3
C3a
Inflammation
C3b
Opsonisation
C5
C5a
Inflammation
C5b
C6
C7
C8
C9
MAC
Disrupts membrane phospholipids, causing osmotic cytolysis


Omnipotent Stem Cell
Myeloid
Lymphoid
Erythrocyte
Platelet
Myeloblast
Lymphoblast
Granulocyte
B Cell
T Cell
NK Cell
Eosinophil
Basophil
Neutrophil
Monocyte
Attack Helminths & Parasites
Mast Cell
Phagocytosis & Inflammatory Mediators (60% of WCC)
Phagocytosis

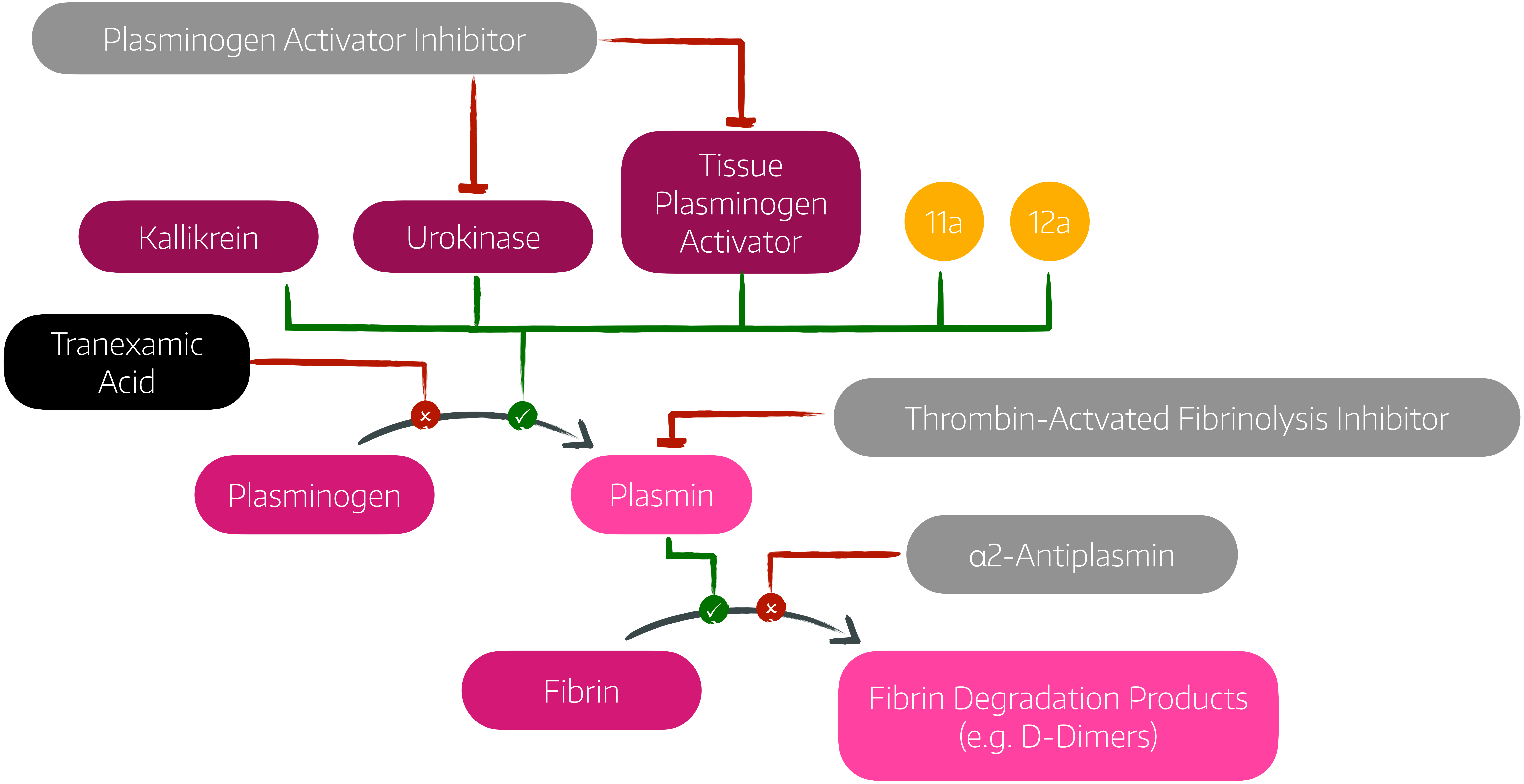
HAEMATOLOGY

Intrinsic Pathway APTT

Extrinsic Pathway PT

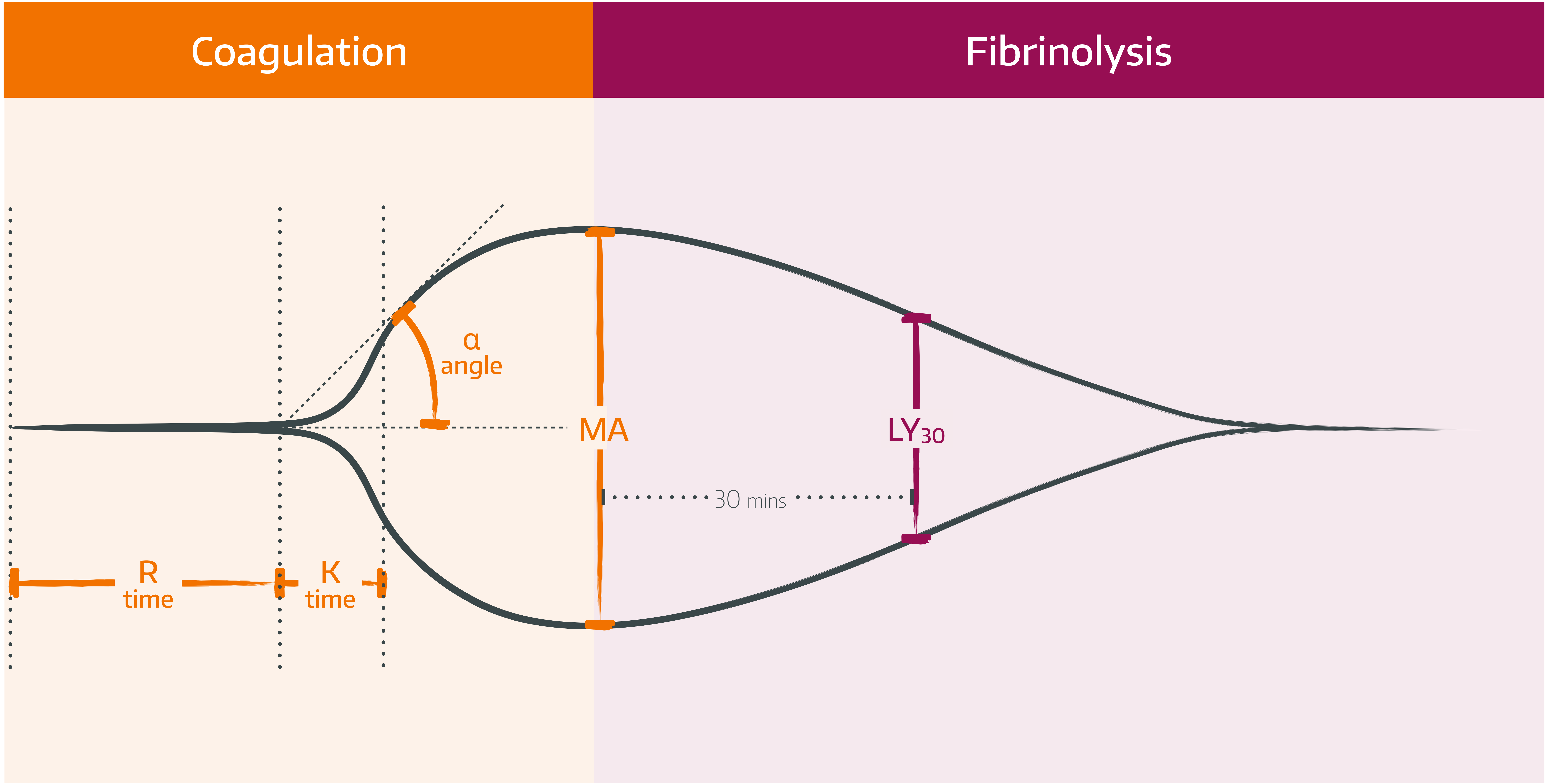


FIBRINOLYSIS

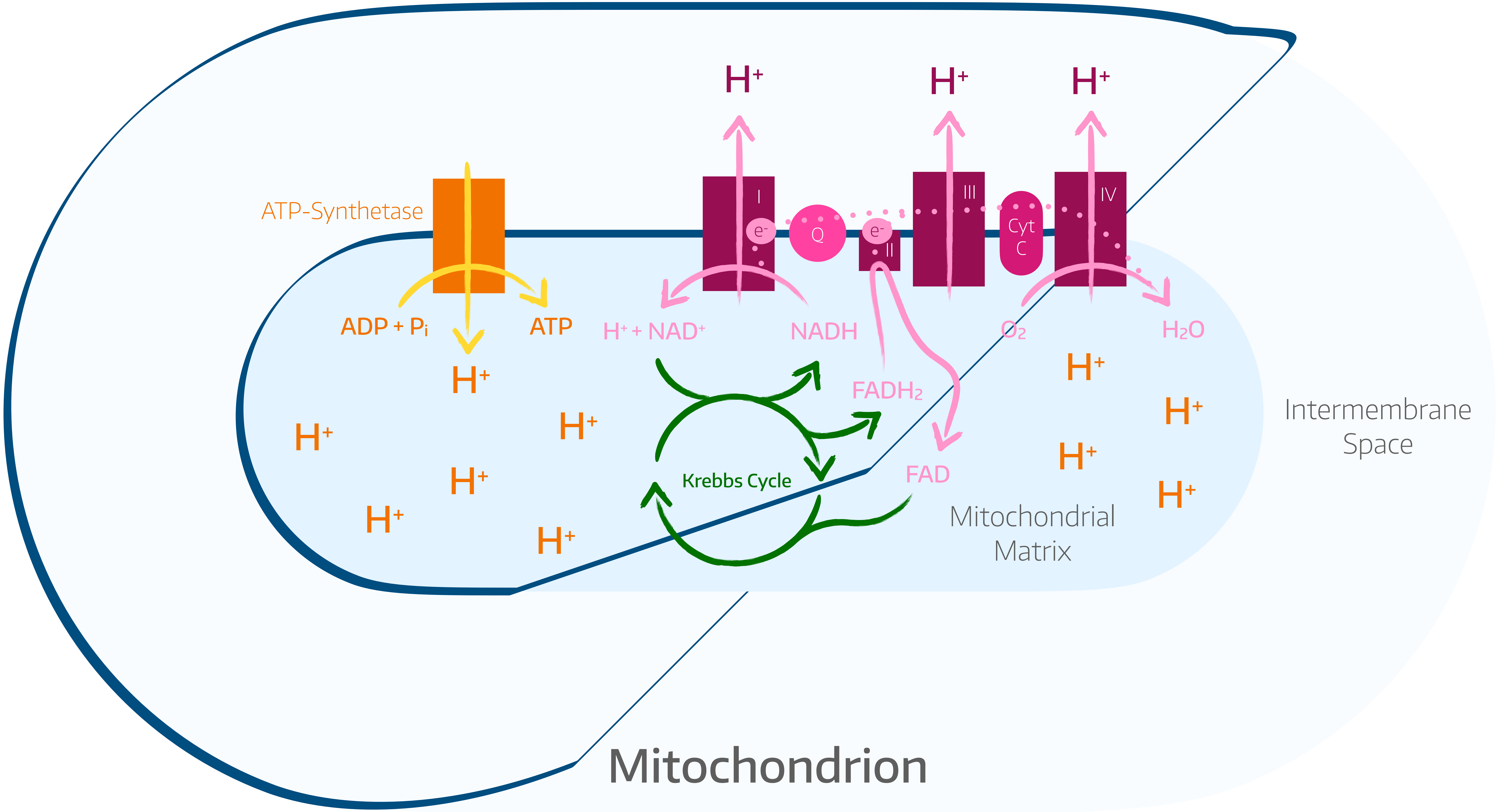


HAEMATOLOGY

THROMBOELASTOMETRY

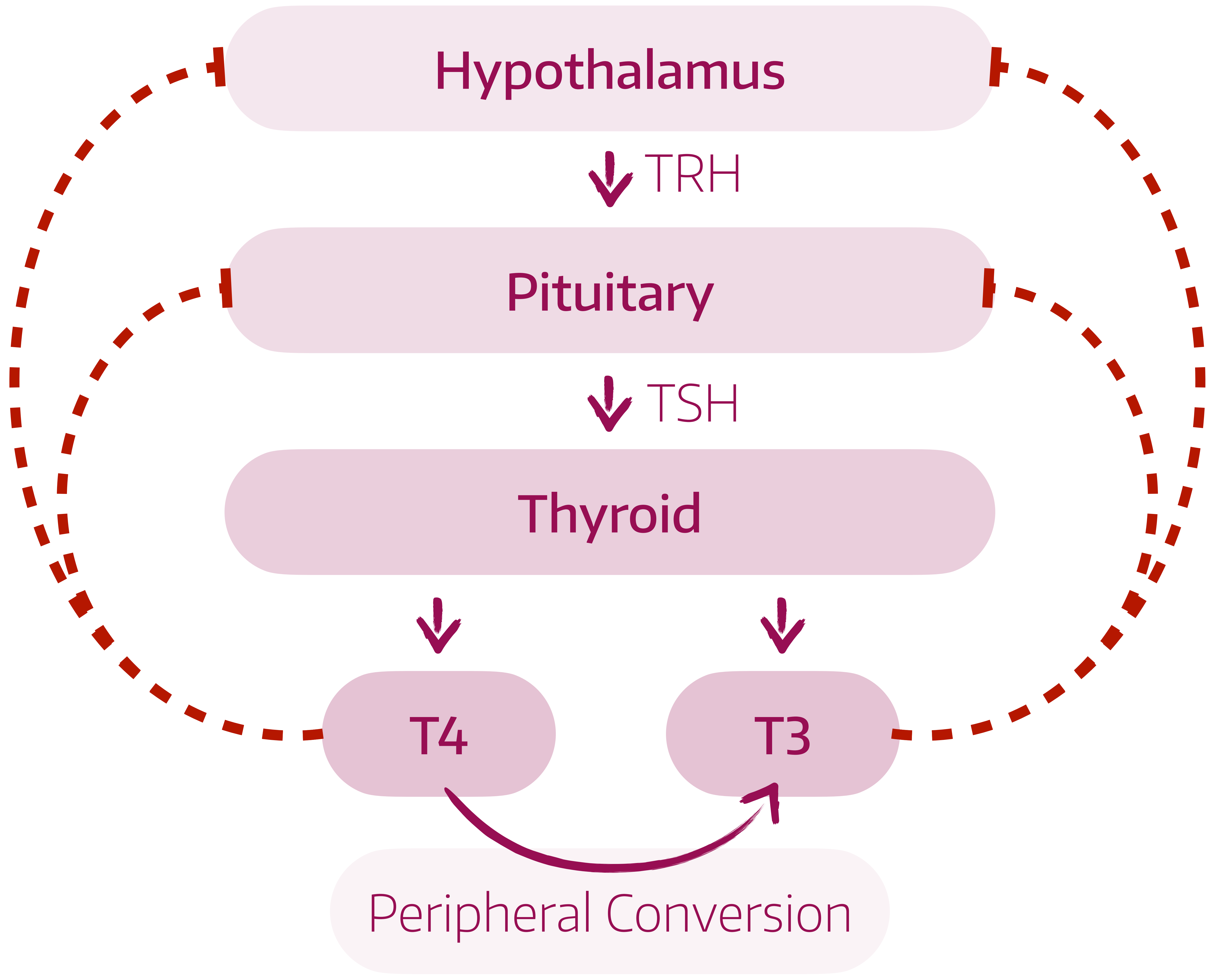


Cellular Biology

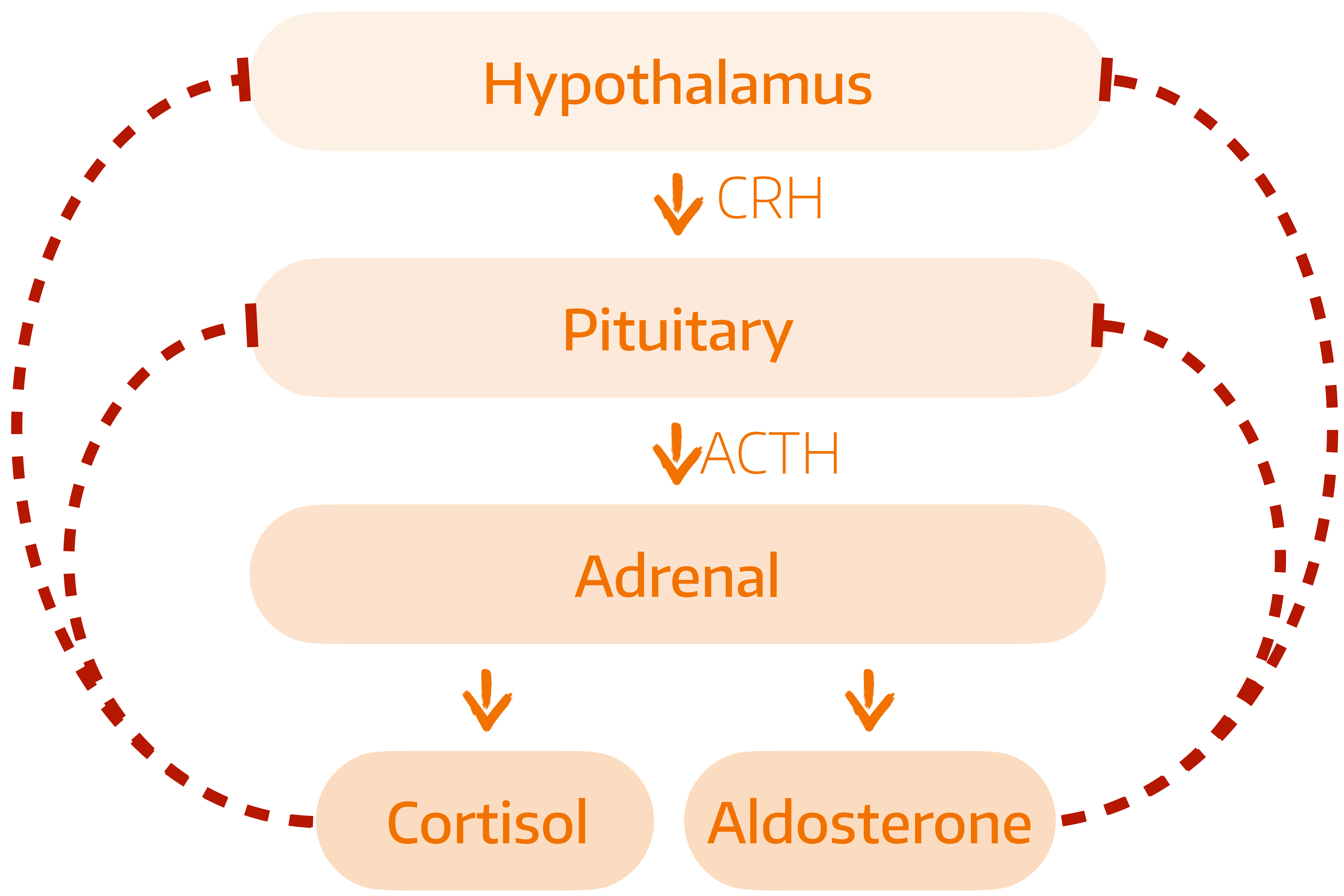


Mitochondrion

Thyroid Axis

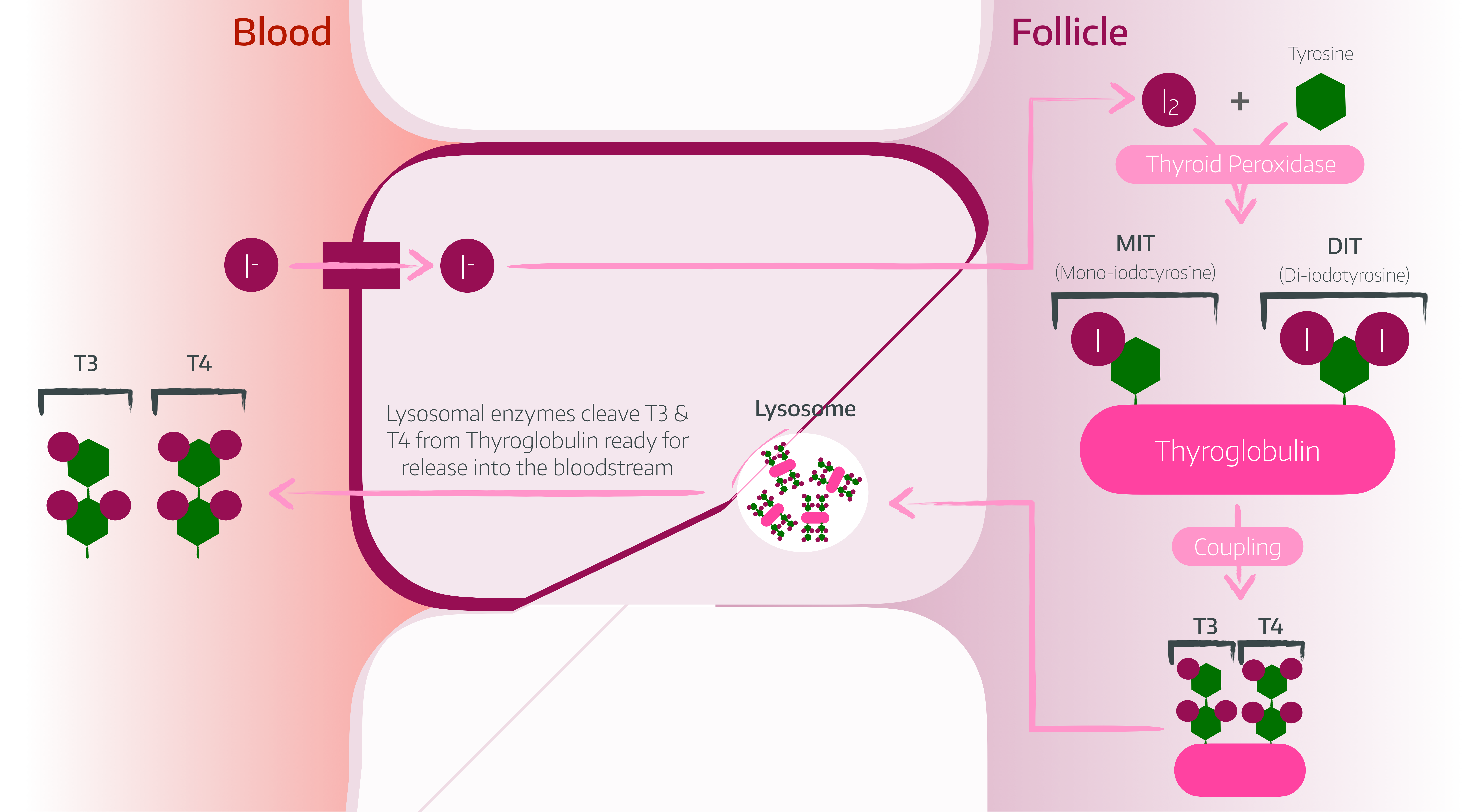


Adrenal Axis



Endocrinology

Thyroid Hormone Release



Endocrinology

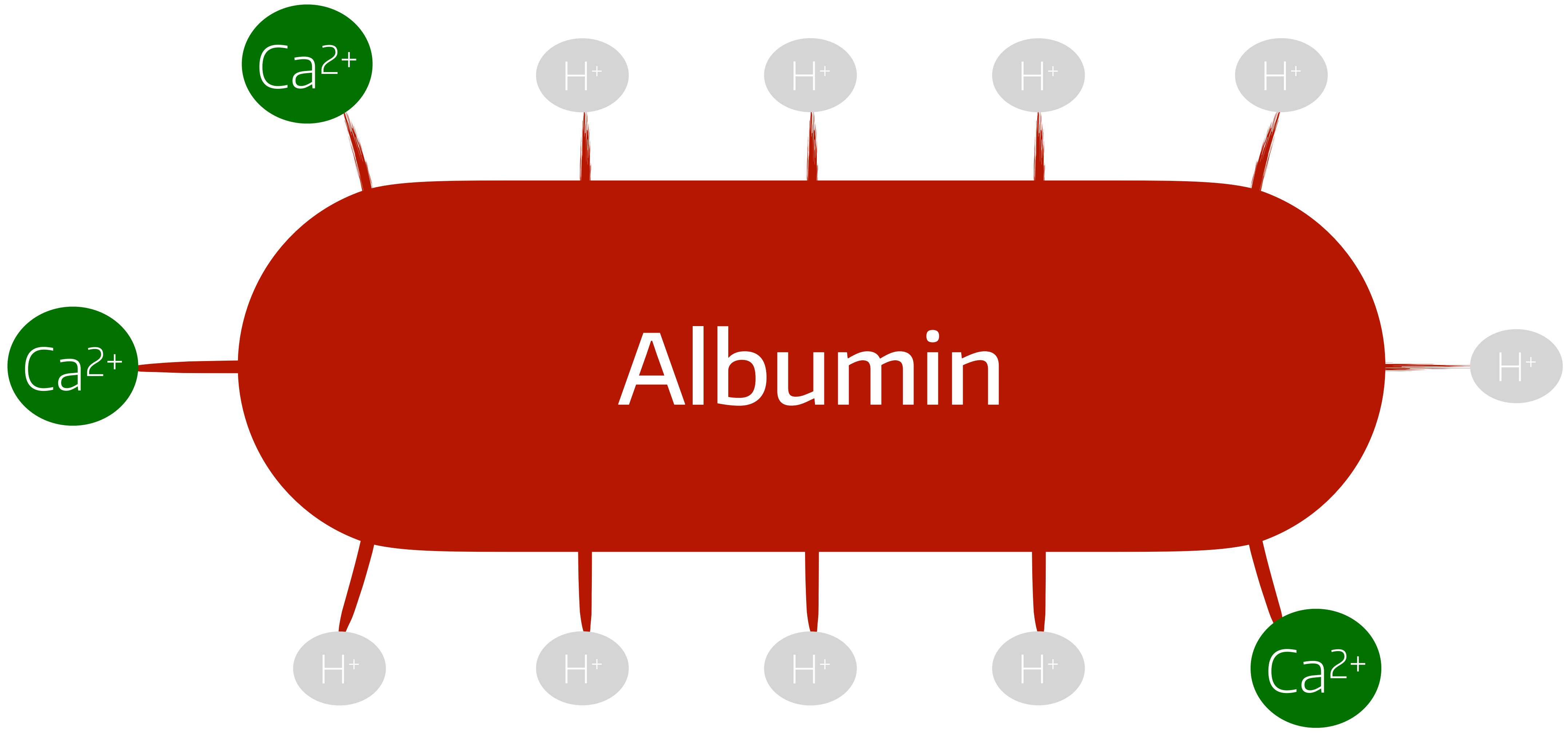
Calcium

Normal Plasma Ca^{2+}: 2.2 - 2.7 $mmol.L^{-1}$

Total Body Ca^{2+}: 1200g

- **Skeletal 98%**
  - As hydroxyapetite
  - (Calcium + Physophorus + Hydroxide)
- **Extracellular Fluid 1%**
  - **Ionised 50%**
    - "Free"
  - **Complexed 10%**
    - Ion Couplets with Citrate, Bicarbonate, etc.
  - **Protein-Bound 40%**
    - 90% to Albumin
    - 10% to Globulins
- **Tissues 1%**
  - (Especially Muscle)

CALCIUM



Albumin has 12 Binding Sites

Usually only 10-15% of them are used up by calcium

Why does hyperventilation cause tingly fingers

If pH rises...

1) Less H^+ can compete with Ca^{2+} for albumin binding-sites
2) Albumin undergoes a conformational change
3) HCO_3^- increases

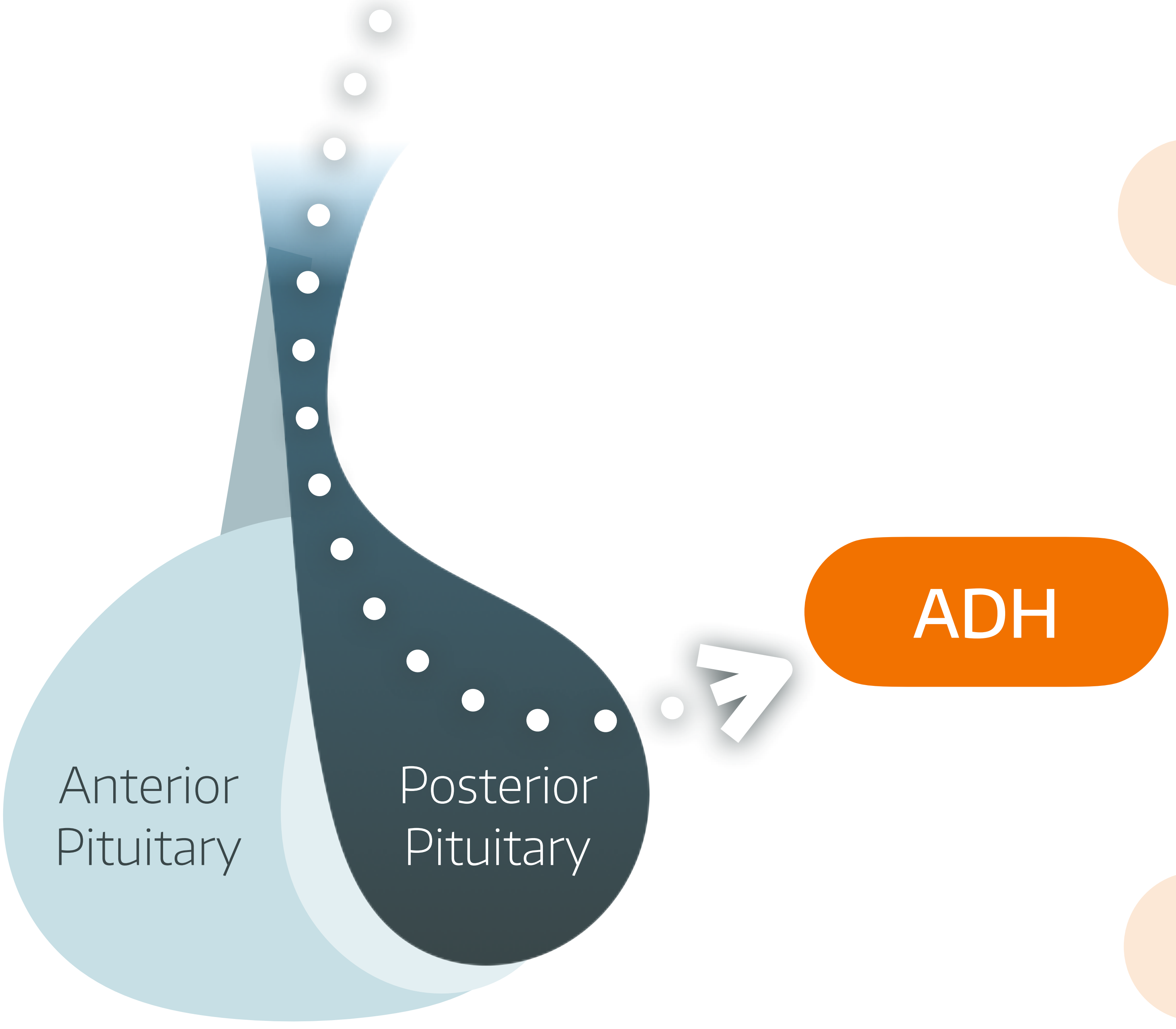
> Increased Calcium Binding reduces the Ionised Fraction

> Reduced Plasma Ca^{2+} leads to increased excitability of peripheral nerve axons

ADH VASOPRESSIN

Supraoptic Nucleus of Hypothalamus

- Angiotensin II
- Sympathetic Nervous System
- ↑ Osmolality
- Hypovolaemia
- Hypotension



Receptors:

ADH V$_1$R — **Vascular Smooth Muscle**

Vasoconstriction

ADH V$_2$R — **Collecting Duct** (Basolateral Membrane)

Renal Fluid Absorption (via aquaporins)

Control of Hormone Release

Peptides	Steroids	Amino Acid Derivatives
Examples Insulin Glucagon ACTH Gastrin	**Examples** Cortisol Aldosterone Testosterone Oestrogen	**Examples** Thyroid Hormones Catecholamines Serotonin Melatonin
Key Points Prohormones Vesicles Cell Membrane Release Fast Onset	**Key Points** Cholesterol Not stored Carrier Proteins Intracellular Receptors Gene Expression Slow & Long-Acting	**Key Points** T3 & T4 are protein-bound and have nuclear receptors Adrenaline is polar Adrenaline is fast-acting & has membrane receptor

HYPONATRAEMIA

LOW URINARY SODIUM

Dehydrated

Replace salt & water

THINK ABOUT

Vomiting / Diarrhoea
Pancreatitis
Exercise
Haemorrhage

Fluid Overloaded

Fluid-restrict (+/- diuretic*)

THINK ABOUT

Oliguric / Osm > 100
Cardiac Failure
Nephrotic Syndrome
Liver Cirrhosis

Polyuric / Osm < 100
(Excessive water intake)

HIGH URINARY SODIUM

Dehydrated

Replace salt & water

THINK ABOUT

Renal issues
Diuretics
Cerebral salt-wasting

Fluid Overloaded

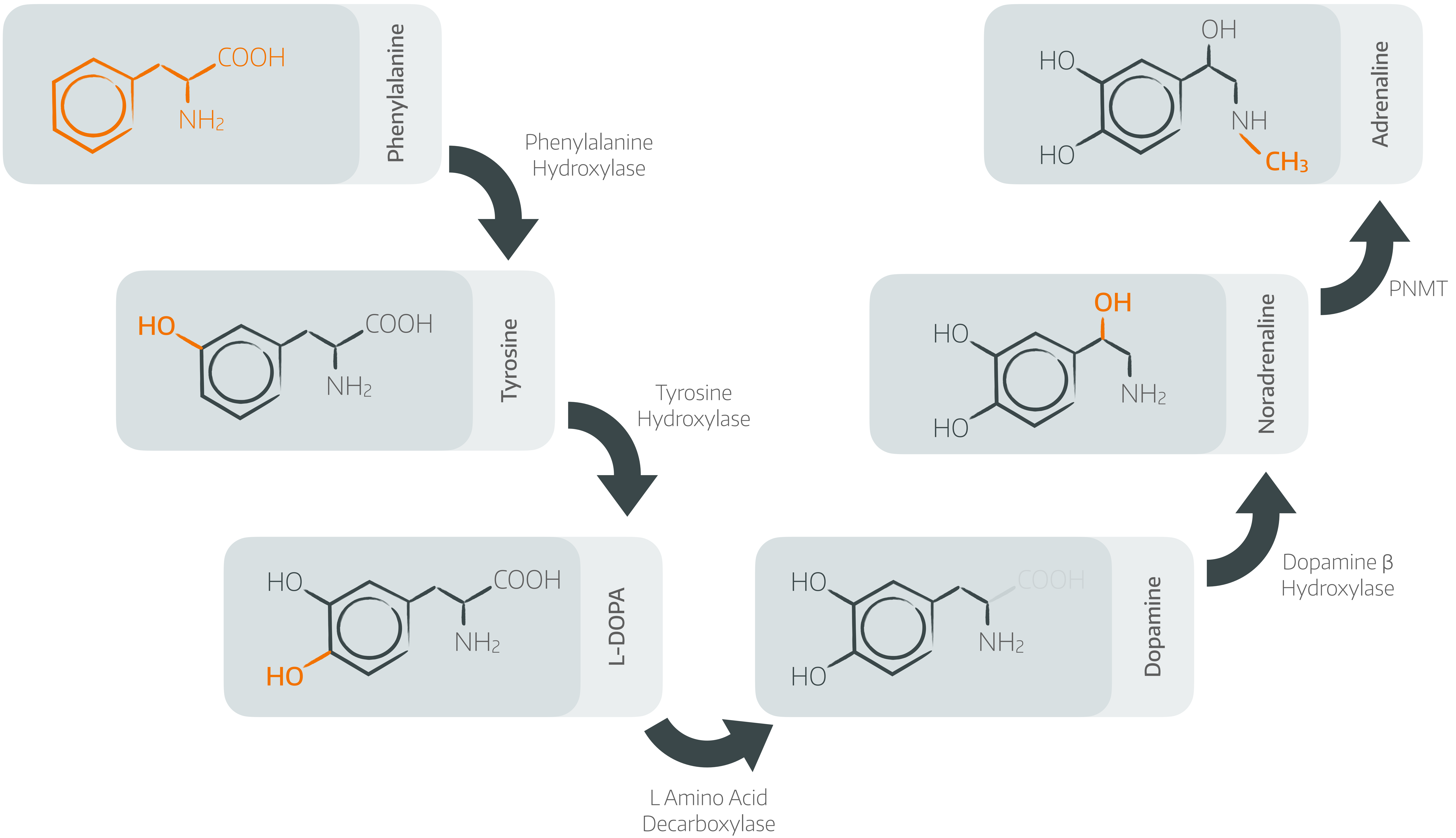
Fluid-restrict & talk to Endocrine

THINK ABOUT

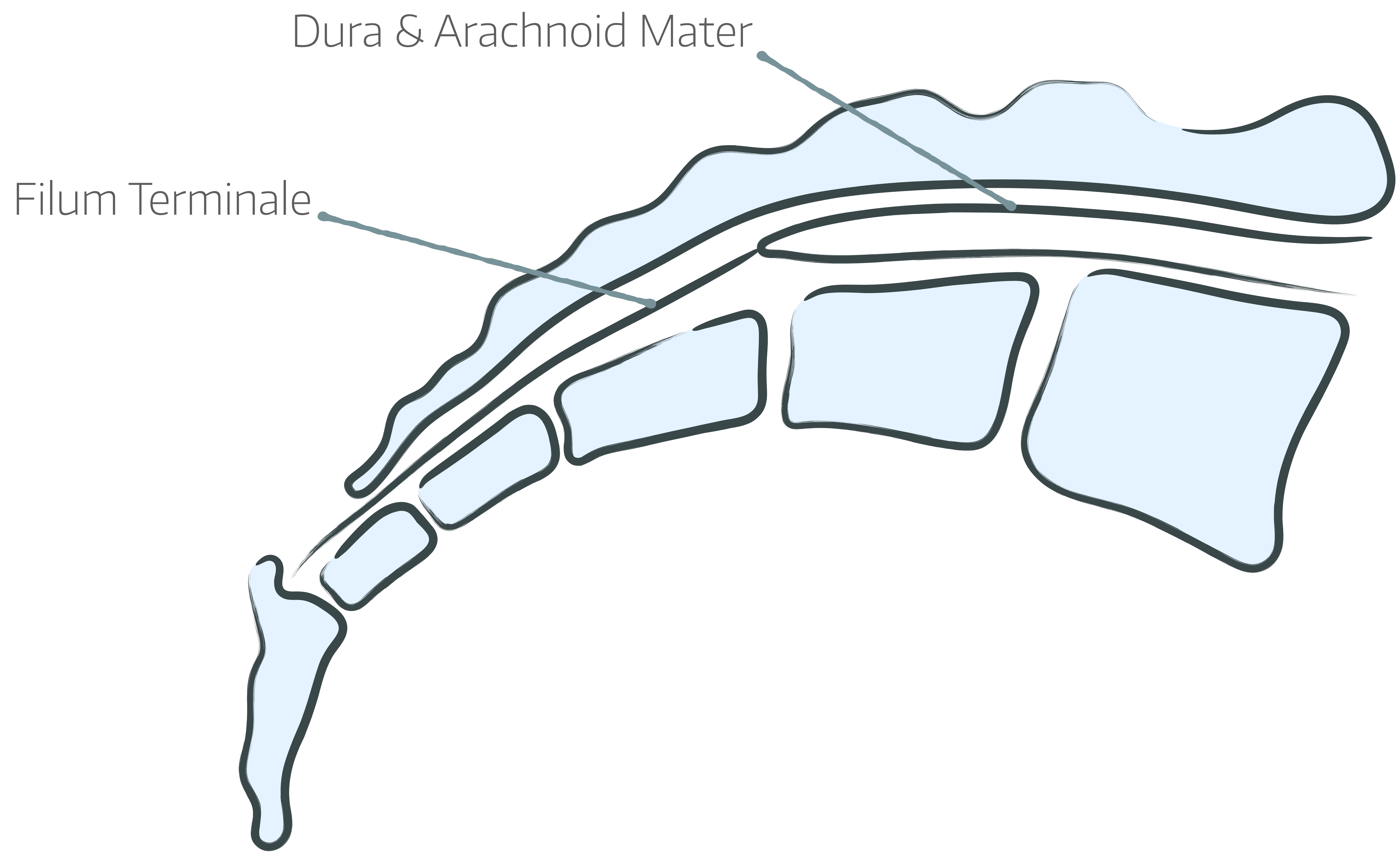
SIADH
Hypothyroidism
Glucocorticoid Deficiency

Endocrinology

Adrenaline Synthesis

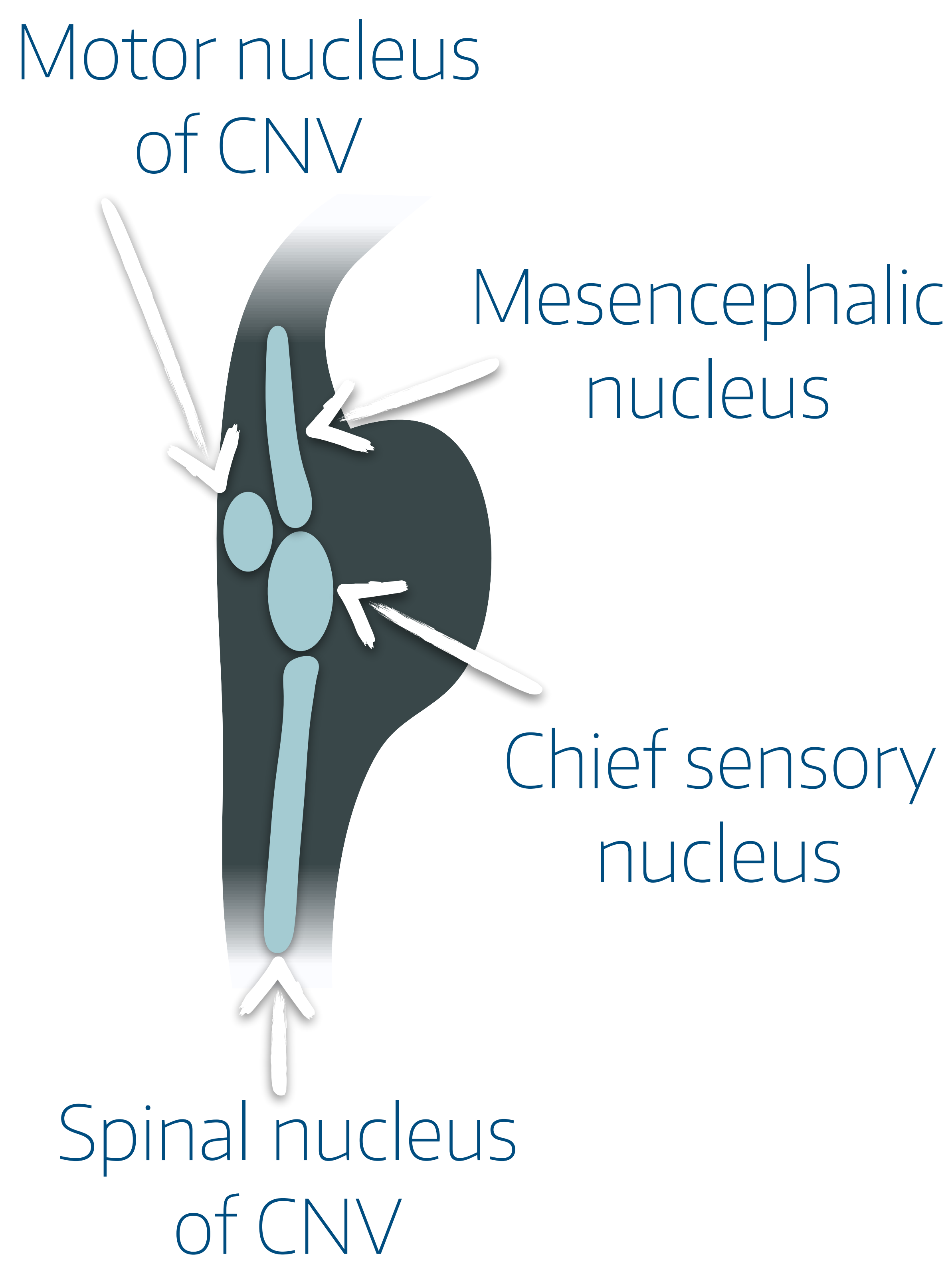


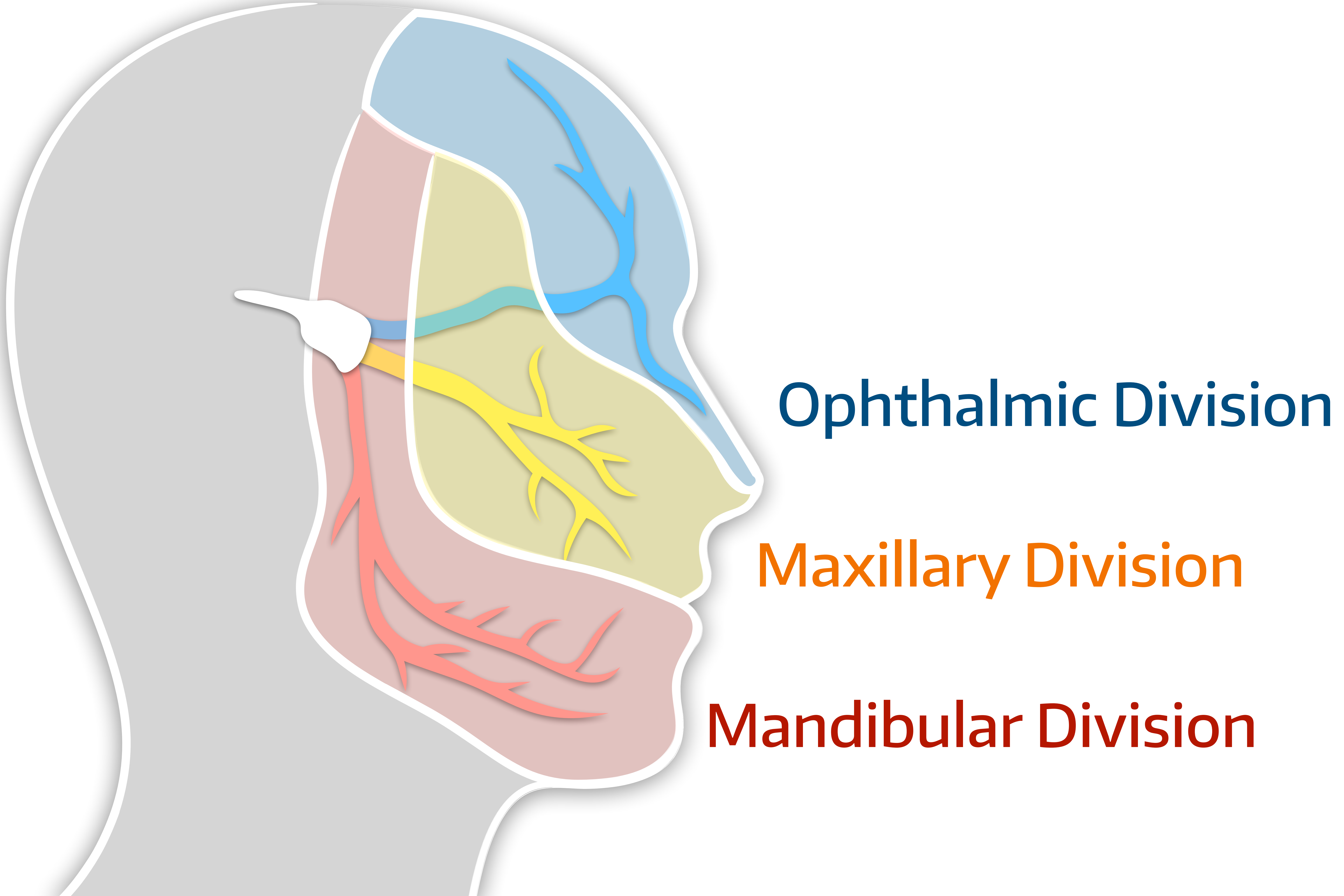
SACRUM



ANATOMY

TRIGEMINAL NERVE





ANATOMY

CIRCLE OF WILLIS