

Basic Physiology for Anaesthetists

Second Edition

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DC:

To Sally, for not vetoing this second edition.

CH:

To friends and teachers: Charles Michel, Morrin Acheson, Richard Adrian, Sir David Weatherall and John Ledingham. *In memoriam absentium, in salutem praesentium.*

GM:

To my wife, Claire, and our beautiful baby daughter, Eleanor. I also remain indebted to Professor Christopher Huang for fostering my original interest in physiology, as well as supporting me throughout my career.

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Foreword

This second edition of *Basic Physiology for Anaesthetists* has carried forward the style, depth and content that made the first edition such a great success. It covers all aspects of human physiology that are essential for the art and science that is modern anaesthesia. Patients need to be reassured that their anaesthetists are well informed of the workings of the human body in health as well as disease.

The authors are both expert physiology scientists and clinicians – this combination is clearly seen in the book's structure. Each chapter explains the physiology and is followed by the clinical applications relevant to the speciality. The illustrations are simple line drawings that are easy to follow and, importantly for trainee anaesthetists, easy to recall or even reproduce

in the exam setting. Not only should this book be essential reading for those new to the speciality or those preparing for exams, but established specialists and consultants should have access to a copy to give structure to their teaching, as well as to rekindle fading knowledge. Those sitting anaesthesia exams can be confident that many of those responsible for testing their knowledge will themselves have consulted this book!

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Preface to the Second Edition

‘Why are you writing a second edition? Surely nothing in classical physiology ever changes?’ One of us (DC) has been asked these questions several times. It is true that many of the fundamental physiological concepts described in this second edition of *Basic Physiology for Anaesthetists* remain the same. What does change, however, is how we apply that physiological knowledge clinically. In the four years since we wrote the first edition of this book, high-flow nasal oxygen therapy has revolutionised airway management, cancer surgery has become the predominant indication for total intravenous anaesthesia and new classes of oral anticoagulants have emerged, to name but a few developments. All of these changes in daily anaesthetic practice are underpinned by a thorough understanding of basic physiology.

To that end, in addition to thoroughly revising and updating each chapter, we have added six new chapters, including those on the physiology of the eye and upper airway and on exercise testing. We have also sought to include more pathophysiology, such as cardiac ischaemia and physiological changes in obesity. We have tried to remain true to the principles with which we wrote the first edition, keeping the concepts as simple as possible whilst remaining truthful and illustrating each chapter with points of clinical relevance and easily reproducible line diagrams. In response to positive feedback, the question-and-answer style remains to best help readers prepare for postgraduate oral examinations.

Preface to the First Edition

An academically sound knowledge of both normal and abnormal physiology is essential for day-to-day anaesthetic practice, and consequently for postgraduate specialist examinations.

This project was initiated by one of us (DC) following his recent experience of the United Kingdom Fellowship of the Royal College of Anaesthetists examinations. He experienced difficulty locating textbooks that would build upon a basic undergraduate understanding of physiology. Many of the anaesthesia-related physiology books he encountered assumed too much prior knowledge and seemed unrelated to everyday anaesthetic practice.

He was joined by a Professor in Physiology (CH) and a Translational Medicine and Therapeutics Research Fellow (GM) at Cambridge University, both actively engaged in teaching undergraduate and postgraduate physiology and in physiological research.

This book has been written primarily for anaesthetists in the early years of their training, and specifically

for those facing postgraduate examinations. In addition, the account should provide a useful summary of physiology for critical care trainees, senior anaesthetists engaged in education and training, physician assistants in anaesthesia, operating department practitioners and anaesthetic nurses.

We believe the strength of this book lies in our mixed clinical and scientific backgrounds, through which we have produced a readable and up-to-date account of basic physiology and provided links to anaesthetic and critical care practice. We hope to bridge the gap between the elementary physiology learnt at medical school and advanced anaesthesia-related texts. By presenting the material in a question-and-answer format, we have aimed to emphasize strategic points and give the reader a glimpse of how each topic might be assessed in an oral postgraduate examination. Our numerous illustrations seek to simplify and clearly demonstrate key points in a manner that is easy to replicate in an examination setting.

Abbreviations

ACA	anterior cerebral artery	DNA	deoxyribonucleic acid
ACE	angiotensin-converting enzyme	DOAC	direct-acting oral anticoagulant
ACh	acetylcholine	DRG	Dorsal respiratory group
AChE	acetylcholinesterase	ECF	extracellular fluid
ACI	anterior circulation infarct	ECG	electrocardiogram
AChR	acetylcholine receptor	EDPVR	end-diastolic pressure-volume relationship
ACom	anterior communicating artery	EDV	end-diastolic volume
ADH	antidiuretic hormone	EEG	electroencephalogram
ADP	adenosine diphosphate	EF	ejection fraction
AF	atrial fibrillation	EPO	erythropoietin
AGE	alveolar gas equation	ER	endoplasmic reticulum
AMP	adenosine monophosphate	ESPVR	end-systolic pressure-volume relationship
ANP	atrial natriuretic peptide	ESV	end-systolic volume
ANS	autonomic nervous system	ETT	endotracheal tube
APTT	activated partial thromboplastin time	FAD	flavin adenine dinucleotide
ARDS	acute respiratory distress syndrome	FEV₁	forced expiratory volume in 1 s
ARP	absolute refractory period	F_IO₂	fraction of inspired oxygen
ATP	adenosine triphosphate	FRC	functional residual capacity
AV	atrioventricular	FTc	flow time corrected
BBB	blood–brain barrier	FVC	forced vital capacity
BMR	basal metabolic rate	GABA	γ-amino butyric acid
BNP	brain natriuretic peptide	GBS	Guillain–Barré syndrome
BSA	body surface area	GCS	Glasgow coma scale
CA	carbonic anhydrase	GFR	glomerular filtration rate
C_aO₂	arterial oxygen content	GI	gastrointestinal
CBF	cerebral blood flow	Hb	haemoglobin
CC	closing capacity	HbA	adult haemoglobin
CCK	cholecystokinin	HbF	foetal haemoglobin
CI	cardiac index	HCN	hyperpolarisation-activated cyclic nucleotide gated
CMR	cerebral metabolic rate	HFNO	High-flow nasal oxygen
CNS	central nervous system	HPV	hypoxic pulmonary vasoconstriction
CO	cardiac output	HR	heart rate
CoA	coenzyme A	ICA	internal carotid artery
COHb	carboxyhaemoglobin	ICF	intracellular fluid
COPD	chronic obstructive pulmonary disease	ICP	intracranial pressure
CPET	cardiopulmonary exercise test	IRI	ischaemic reperfusion injury
CPP	cerebral perfusion pressure	IVC	inferior vena cava
CRPS	complex regional pain syndrome	LA	left atrium
CSF	cerebrospinal fluid	LBBB	left bundle branch block
C_vO₂	venous oxygen content	LMA	laryngeal mask airway
CVP	central venous pressure	LOH	loop of Henle
CVR	cerebral vascular resistance	LOS	lower oesophageal sphincter
DASI	Duke activity status index	LV	left ventricle
DBP	diastolic blood pressure	LVEDP	left ventricular end-diastolic pressure
DCML	dorsal column-medial lemniscal	LVEDV	left ventricular end-diastolic volume
DCT	distal convoluted tubule	LVESV	left ventricular end-systolic volume
DHPR	dihydropyridine receptor		

List of Abbreviations

LVF	left ventricular failure	RAP	right atrial pressure
MAC	minimum alveolar concentration	RBC	red blood cell
MAO	monoamine oxidase	RBF	renal blood flow
MAP	mean arterial pressure	RMP	resting membrane potential
MCA	middle cerebral artery	RNA	ribonucleic acid
MET	metabolic equivalent of a task	ROS	reactive oxygen species
MetHb	methaemoglobin	RR	respiratory rate
MG	myasthenia gravis	RRP	relative refractory period
MI	myocardial infarction	RSI	rapid sequence induction
MPAP	mean pulmonary artery pressure	RV	right ventricle
MW	molecular weight	RVEDV	right ventricular end-diastolic volume
N₂O	nitrous oxide	RVF	right ventricular failure
NSTEMI	non-ST elevation myocardial infarction	RyR	ryanodine receptor
NAD⁺	nicotinamide adenine dinucleotide	SA	sinoatrial
NMDA	<i>N</i> -methyl-D-aspartate	S_aO₂	arterial haemoglobin oxygen saturation
NMJ	neuromuscular junction	SBP	systolic blood pressure
OER	oxygen extraction ratio	SD	stroke distance
OSA	obstructive sleep apnoea	SR	sarcoplasmic reticulum
PAC	pulmonary artery catheter	SSEP	somatosensory evoked potential
P_aCO₂	arterial tension of carbon dioxide	STEMI	ST elevation myocardial infarction
P_aO₂	arterial tension of oxygen	SV	stroke volume
P_B	barometric pressure	SVC	superior vena cava
PCI	percutaneous coronary intervention	SVI	stroke volume index
PCT	proximal convoluted tubule	SVR	systemic vascular resistance
PCA	posterior cerebral artery	SVT	supraventricular tachycardia
PCom	posterior communicating artery	SVV	stroke volume variation
PCWP	pulmonary capillary wedge pressure	TF	tissue factor
PE	pulmonary embolism	TIMI	thrombolysis in myocardial infarction
PEEP	positive end-expiratory pressure	TLC	total lung capacity
PEEP_e	extrinsic positive end-expiratory pressure	TOE	trans-oesophageal echocardiography
PEEP_i	intrinsic positive end-expiratory pressure	V/Q	ventilation-perfusion
PEFR	peak expiratory flow rate	V_A	alveolar ventilation
PNS	peripheral nervous system	V_A	alveolar volume
PPP	pentose phosphate pathway	VC	vital capacity
PRV	polycythaemia rubra vera	V_D	dead space volume
PV	peak velocity	V_E	minute ventilation
PVA	pressure-volume area	V_T	tidal volume
PT	prothrombin time	VF	ventricular fibrillation
PTH	parathyroid hormone	VRG	ventral respiratory group
PVR	pulmonary vascular resistance	VT	ventricular tachycardia
RA	right atrium	VTI	velocity-time integral
RAA	renin-angiotensin-aldosterone	vWF	von Willebrand factor