The Respiratory System at a Glance

Fourth Edition

Jeremy P. T. Ward
Jane Ward
Richard M. Leach

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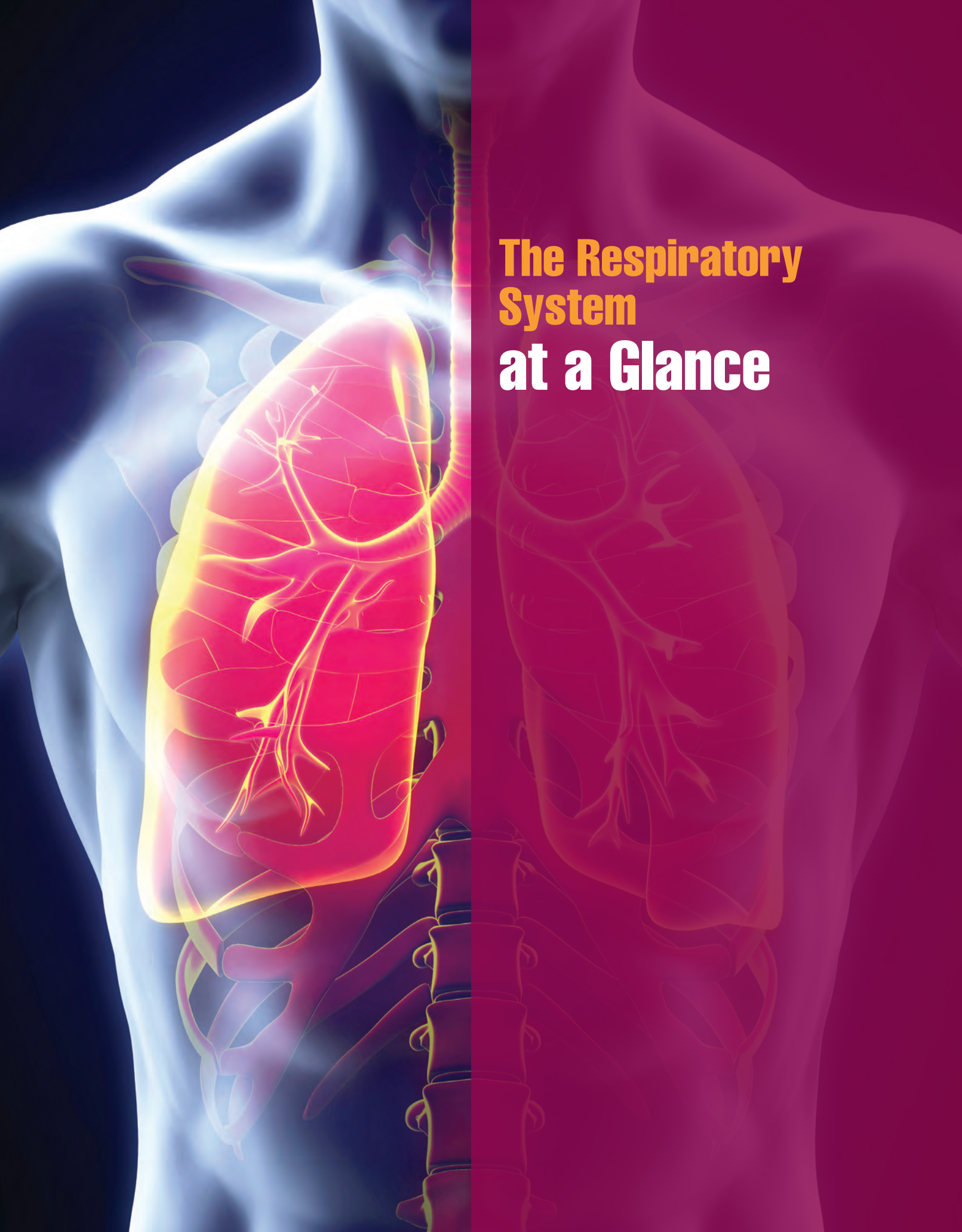

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Preface to fourth edition

The medical curriculum is constantly being reviewed, but all modern curricula interleave basic and clinical science, physiology and pathophysiology. Clinical examples and cases provide relevance to and assist understanding of the underlying basic science, and basic science concepts help in the understanding of the pathophysiology and treatment of disease. *The Respiratory System at a Glance* is designed to support students following all programmes of study that integrate core aspects of basic science, pathophysiology and clinical medicine, including treatment. As such, it should be useful to medical students throughout their training, and also to other healthcare professions, including nursing.

As with other volumes in the *At a Glance* series, it is based around a two-page spread for each main topic, with figures and text complementing each other to give an overview at a glance. Case studies based on some of the most commonly encountered conditions are also provided on the companion website, and can be used for both basic science and clinical study. Although primarily designed for revision, the book covers all the core elements of the respiratory system and its major diseases, and as such could be used as a main text in the first couple of years of the course. It is advised, however, that additional reference to more detailed textbooks will aid deeper and wider understanding of the subject. This is particularly the case for the pathophysiological chapters, as a book this concise cannot hope to provide a complete guide to clinical practice.

In this fourth edition we have significantly revised the majority of chapters and improved or replaced figures to aid comprehension. In response to requests from readers, we now provide separate chapters on lung defence mechanisms and immunology, in keeping with their importance for most respiratory diseases, and there are now two chapters covering regulation of acid-base balance and acid-base disorders, an area that many find difficult. There are several additional case studies and self-assessment MCQs, now to be found on the companion website. We have hopefully corrected all errors in the last edition. We have been greatly assisted by our many colleagues and students who have kindly advised us and commented on the contents, but any errors and omissions are entirely our responsibility. We also thank the staff at Wiley, without whom we would not have been able to produce this edition.

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Richard M. Leach

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Units and symbols

Units

The medical profession and scientific community generally use SI (Systéme International) units.

Pressure conversion: SI unit of pressure: 1 pascal (Pa) = 1 N/m^2. As this is small, in medicine the kPa (=10^3 Pa) is more commonly used. Note that millimetres of mercury (mmHg) are still the most common unit for expressing arterial and venous blood pressures, and low pressures - e.g. central venous pressure and intrapleural pressure - are sometimes expressed as centimetres of H_2O (cmH_2O). Blood gas partial pressures are reported by some laboratories in kPa and by some in mmHg, so you need to be familiar with both systems.

1 kPa = 7.5 mmHg = 10.2 cmH_2O
1 mmHg = 1 torr = 0.133 kPa = 1.36 cmH_2O
1 cmH_2O = 0.098 kPa = 0.74 mmHg
1 standard atmosphere (≈1 bar) = 101.3 kPa = 760 mmHg =1033 cmH_2O

Contents are often expressed per 100 mL (dL), and these need to be multiplied by 10 to give the standard SI unit per litre. Contents are also increasingly being expressed as mmol/L. For haemoglobin: 1 g/dL = 10 g/L = 0.062 mmol/L. For ideal gases (including oxygen and nitrogen): 1 mmol = 22.4 mL standard temperature and pressure dry (STPD; see Chapter 4). For non-ideal gases, such as nitrous oxide and carbon dioxide: 1 mmol = 22.25 mL STPD. Technically, concentrations of ions in solution (e.g. $[H^+]$, $[K^+]$) should be expressed as mole equivalents (e.g. mEq), but as there is no difference either numerically or in meaning we have mostly followed the convention of using molar concentrations.

Standard symbols

Primary symbols

F = Fractional concentration of gas
C = Content of a gas in blood
V = Volume of a gas
P = Pressure of partial pressure
S = Saturation of haemoglobin with oxygen
Q = Volume of blood

A dot over a letter means a time derivative, e.g. $\dot{V}$ = ventilation (L/min); $\dot{Q}$ = blood flow (L/min)

Secondary symbols

Gas: I = Inspired gas
E = Expired gas
A = Alveolar gas
D = Dead-space gas
T = Tidal
B = Barometric
ET = End-tidal

Blood: a = Arterial
v = Venous
c = Capillary
A dash means mixed or mean
e.g. $\bar{v}$ = Mixed venous
A′ after a symbol means end
e.g. c′ = End-capillary

Tertiary symbols

O_2 = Oxygen
CO_2 = Carbon dioxide
CO = Carbon monoxide

Examples

$\dot{V}O_2$ = Oxygen consumption
P_Aco_2 = Alveolar partial pressure of carbon dioxide

Typical values

Typical inspired, alveolar and blood gas values in healthy young adults are shown in the table below. Ranges are given for arterial blood gas values. Mean arterial P_{O_2} falls with age, and by 60 years is about 11 kPa/82 mmHg. Typical values for lung volumes and other lung function tests are given in the appropriate chapters. Ranges for many values are affected by age, sex and height, as well as by the method of measurement, and hence it is necessary to refer to appropriate nomograms.

Inspired P_{O_2} (dry, sea level)	21 kPa	159 mmHg
Alveolar P_{O_2}	13.3 kPa	100 mmHg
Arterial P_{O_2}	12.5 (11.2–13.9) kPa	94 (84–104) mmHg
A–a P_{O_2} gradient	<2kPa	<15 mmHg (greater in elderly)
Arterial oxygen saturation	>97%	
Arterial oxygen content	200 mL/L	20 mL/dL
Inspired P_{CO_2}	0.03 kPa	0.2 mmHg
Alveolar P_{CO_2}	5.3 (4.7–6.1) kPa	40 (35–45) mmHg
Arterial P_{CO_2}	5.3 (4.7–6.1) kPa	40 (35–45) mmHg
Arterial CO_2 content	480 mL/L	48 mL/dL
Arterial $[H^+]$/pH	35–45 nmol/L	7.45–7.35
Resting mixed venous P_{O_2}	5.3 kPa	40 mmHg
Resting mixed venous O_2 content	150 mL/L	15 mL/dL
Resting mixed venous O_2 saturation	75%	
Resting mixed venous P_{co_2}	6.1 kPa	46 mmHg
Resting mixed venous CO_2 content	520 mL/L	52 mL/dL
Arterial $[HCO_3^-]$	24 (21–27) mmol/L	