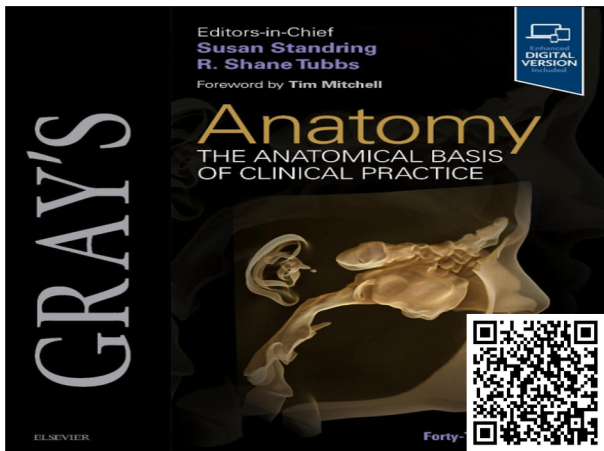


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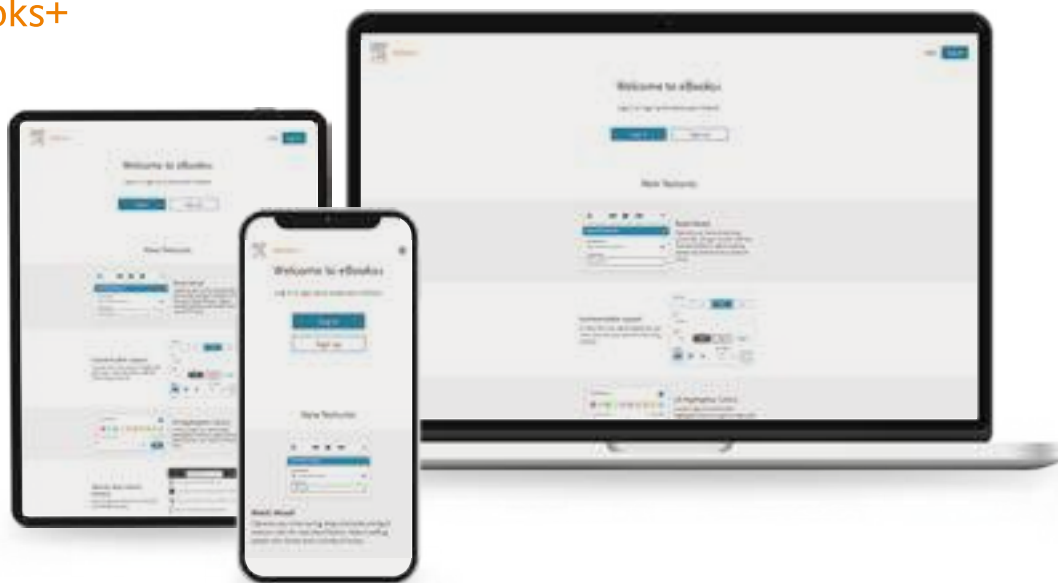
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THE ANATOMICAL BASIS
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THE ANATOMICAL BASIS OF CLINICAL PRACTICE

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COVER IMAGE

The cover image for this edition is a cinematically rendered 3D surface reconstruction of the face and air spaces within the head from a computed tomography (CT) scan performed at the Norfolk and Norwich University Hospital, Norwich, UK. Image reconstruction and post-processing were done using the SIEMENS Healthineers Cinematic Anatomy software suite by Dr Diogo Silva and Prof. Tom Turmezei. The patient gave their permission for the use of this imaging, understanding that it included some of their facial features.



CONTENTS

Foreword	xi
Preface	xii
Acknowledgements	xiv
Contributors to the forty-third edition	xv
Historical introduction	xx
Introduction to anatomy	xxv



Commentary

Ethical issues in anatomy	xxviii
<i>David Gareth Jones</i>	

SECTION 1: Cells, Tissues and Systems

Section Editor: Caroline B Wigley

1. Basic structure and function of cells	4
<i>Abraham L Kierszenbaum</i>	
2. Integrating cells into tissues	31
<i>Caroline B Wigley</i>	
3. Nervous system	46
<i>Rebecca Wright and Elisa Floriddia</i>	
4. Blood, lymphoid tissues and haemopoiesis	77
<i>Andrew John Timothy George and Uday Kishore</i>	
5. Functional anatomy of the musculoskeletal system	92
<i>Gerald James Atkins and Lucian Bogdan Solomon</i>	
6. Smooth muscle and the cardiovascular and lymphatic systems	136
<i>Larissa A Shimoda</i>	
7. Skin and its appendages	154
<i>John A McGrath and Joey Edward Lai-Cheong</i>	



Commentaries

1.1. Fluorescence microscopy today: a perspective	
<i>Dylan M Owen and Maria Makarova</i>	
1.2. Electron microscopy in the twenty-first century	
<i>Roland A Fleck</i>	
1.3. Pericytes	
<i>David Attwell, Silvia Anderle, Harvey Davis, Greg James, Svetlana Mastitskaya and Ross Nortley</i>	
1.4. The reaction of peripheral nerves to injury	
<i>Rolfe Birch (†) and Praveen Anand. Revised 2025</i>	
<i>Susan Standring</i>	



Videos

1.1 – Mitosis in a cell with fluorescently labelled chromosomes and microtubules	175
<i>Jonathon Pines and Daisuke Izawa</i>	

1.2.1 – Diagnostic histopathology by electron microscopy	175
<i>Roland A Fleck</i>	

SECTION 2: Embryogenesis and Development

Section Editor: Patricia Collins

8. Preimplantation development	181
<i>Alison Campbell and Patricia Collins</i>	
9. Implantation and placentation	189
<i>Eric Jauniaux and Graham J Burton</i>	
10. Cell populations at gastrulation	200
<i>Patricia Collins</i>	
11. Overarching concepts in development	209
<i>Patricia Collins</i>	
12. Cell populations at the start of organogenesis	216
<i>Patricia Collins</i>	
13. Development of the heart and circulation	223
<i>Bjarke Jensen, Patricia Collins and Michael Hall</i>	
14. Development of the nervous system	249
<i>Zoltán Molnár, Susan Standring, Patricia Collins and Michael Hall</i>	
15. Development of the skin and appendages	286
<i>Patricia Collins</i>	
16. Development of the eye	292
<i>Patricia Collins and Jane Sowden</i>	
17. Development of the ear	299
<i>Abigail Tucker</i>	
18. Development of the head and neck	304
<i>Patricia Collins, Susan Standring and Michael Hall</i>	
19. Development of the back	329
<i>Martin Scaal</i>	
20. Development of the limbs	340
<i>Neil Vargesson</i>	
21. Development of lungs, thorax and diaphragm	353
<i>Andy Bush, Patricia Collins and Michael Hall</i>	
22. Development of the peritoneal cavity, gastrointestinal tract and its adnexae	363
<i>Patricia Collins and Michael Hall</i>	
23. Development of the urogenital system	383
<i>Patricia Collins and Michael Hall</i>	
24. Pre- and postnatal growth and the neonate	404
<i>Patricia Collins and Michael Hall</i>	

**Commentary**

- 2.1. Inflicted or accidental injury to an infant or child:
how does the medical practitioner tell the
difference and defend it in court?

Steven Howard

**Videos**

- 8.1 – Human in vitro fertilisation and early development 423
Alison Campbell
- 9.1 – Ultrasound features of the maternal placental blood flow 423
Eric Jauniaux
- 10.1 – Cell populations in the embryo at gastrulation 423
Patricia Collins
- 12.1 – The main epithelial populations within the embryo from stage 11 during organogenesis 423
Patricia Collins
- 13.1 – Animation of the pattern of contraction of the early heart tube 423
Antoon FM Moorman
- 13.2 – Ultrasound features of a four-chambered fetal heart 423
Warren Foster
- 21.1 – Epithelial cell layers in the development of the lungs from stage 11 424
Patricia Collins
- 21.2 – Interrelationship of lung and gut development from stage 12 424
Patricia Collins
- 22.1 – Epithelial layers in the development of the gut from stage 11 424
Patricia Collins
- 22.2 – Foregut rotation 424
Patricia Collins
- 22.3 – Midgut rotation 425
Patricia Collins
- 23.1 – Epithelial cell layers in the development of the urinary tract from stage 11 425
Patricia Collins
- 23.2 – Development of the reproductive tracts 425
Patricia Collins
- 24.1 – Ultrasound features of a fetus at 26 weeks 425
Patricia Collins and Jonathan D Spratt

SECTION 3: Neuroanatomy

Section Editors: Alan R Crossman, Marco Catani

25. Overview of the nervous system 429
Alan R Crossman, Marco Catani and Richard Tunstall
26. Autonomic nervous system 436
Rosario Francesco Donato

27. Ventricular system 440
Francesco Vergani and Ranjeev Singh Bhargoo
28. Vasculature of the brain 449
Gerardo Conesa and Wieslaw L Nowinski
29. Spinal cord 464
Roger Lemon
30. Brainstem 483
Thomas P Naidich
31. Cerebellum 505
Jeremy D Schmammann
32. Diencephalon 529
Carmen Cavada
33. Basal ganglia 543
Keyoumars Ashkan
34. Cerebral hemispheres 551
Marco Catani and Katrin Amunts

Commentary

- 3.1 Comparative anatomy of the corticospinal system
Roger Lemon

Videos

- 28.1 – From angiography to anatomy: the internal carotid artery and its major branches 583
Gerardo Conesa Bertran
- 28.2 – The intracranial arterial system parcellated by colour (full rotation) 583
Wieslaw L Nowinski
- 28.3 – The intracranial venous system parcellated by colour (full rotation) 583
Wieslaw L Nowinski
- 28.4 – The intracranial and extracranial arterial supply and venous drainage (full rotation) 584
Wieslaw L Nowinski
- 28.5 – From angiography to anatomy: veins of the cerebral system 584
Gerardo Conesa Bertran
- 33.1 – Awake surgery to insert thalamic deep brain stimulation electrodes for essential tremor 584
Keyoumars Ashkan
- 34.1 – Tractography reconstruction of the corpus callosum and corticofugal pathways using spherical deconvolution tractography 584
Ahmad Beyh and Flavio Dell'Acqua

SECTION 4: Head and Neck

Section Editor: Susan Standring

35. Head and neck: overview and surface anatomy 590
Susan Standring and Richard Tunstall
- Head and neck**
36. Skull 603
Susan Standring

37. Intracranial region	613
<i>Juan Carlos Fernandez-Miranda</i>	
38. Neck	628
<i>John Carmel Watkinson and Susan Standring</i>	
39. Face and scalp	663
<i>Simon Holmes</i>	
Upper aerodigestive tract	
40. Mouth	691
<i>Barry KB Berkovitz and Joe Iwanaga</i>	
41. Infratemporal and pterygopalatine fossae and temporomandibular joint	719
<i>Juan Carlos Fernandez-Miranda</i>	
42. Nose, nasal cavity and paranasal sinuses	741
<i>Claire Hopkins</i>	
43. Pharynx	757
<i>Petra Ambrosch</i>	
44. Larynx	773
<i>Nicholas Gibbins</i>	
Special senses	
45. External and middle ear	793
<i>Alex Huber</i>	
46. Internal ear	810
<i>Helge Rask-Andersen</i>	
47. Orbit and accessory visual apparatus	828
<i>John G Lawrenson and Michael B Powner</i>	
48. Eye	850
<i>John G Lawrenson and Michael B Powner</i>	



Commentary

- 4.1 Middle ear mechanics
Alex Huber



Videos

- 41.1 – Temporomandibular joint arthroscopy demonstrating intracapsular anatomy 875
Gary Warburton
- 41.2 – Endoscopic anatomy of the infratemporal and pterygopalatine fossae 875
Carl H Snyderman and Juan C Fernandez-Miranda
- 44.1 – Stroboscopic examination of vocal folds 875
Declan Costello

SECTION 5: Back

Section Editor: Neel Anand

49. Back	878
<i>Eli Baron, Christopher Alan Yeung and Richard Tunstall</i>	
50. Spinal cord and spinal nerves: gross anatomy	920
<i>Eli Baron</i>	

SECTION 6: Pectoral Girdle and Upper Limb

Section Editor: Alistair Ross

51. Pectoral girdle and upper limb: overview and surface anatomy	935
<i>Alistair Ross and Richard Tunstall</i>	
52. Shoulder girdle and arm	954
<i>John Norman and Amar Rangan</i>	
53. Elbow and forearm	997
<i>Adam C Watts</i>	
54. Wrist and hand	1022
<i>Martin Langer</i>	

Commentaries

- 6.1 Anatomical variation of the brachial plexus and its implications
Alistair Ross
- 6.2 Instability of the shoulder – a neurological disease
Simon Lambert
- 6.3 Rotator cuff tendinopathy spectrum
John Norman and Amar Rangan

Videos

- 51.1 – Upper limb surface anatomy 1055
Rolfe Birch(†)
- 51.2 – Cadaveric dissection of the superficial veins and nerves of the anterior arm and forearm 1055
R Shane Tubbs and Joe Iwanaga
- 51.3 – Cadaveric dissection of the superficial veins and nerves of the posterior arm and forearm 1055
R Shane Tubbs and Joe Iwanaga
- 51.4 – Cadaveric dissection of the axillary and radial nerves in the arm 1055
R Shane Tubbs and Joe Iwanaga
- 51.5 – Cadaveric dissection of the brachial plexus and its branches with related arteries 1056
R Shane Tubbs and Joe Iwanaga

SECTION 7: Thorax

Section Editor: Richard Tunstall

55. Thorax: overview and surface anatomy	1060
<i>Richard Tunstall</i>	
56. Thoracic wall and breast	1067
<i>Erin P Fillmore</i>	
Lungs and diaphragm	
57. Pleura, lungs, trachea and bronchi	1091
<i>Quentin Fogg and Joseph B Shrager</i>	
58. Diaphragm and phrenic nerves	1110
<i>Albert van Schoor</i>	

Heart and mediastinum

59. Mediastinum 1121
Peter Jason Ward
60. Heart 1141
Marios Loukas
61. Great and major systemic blood vessels 1174
Marios Loukas

**Commentary**

- 7.1 Computed tomography coronary angiography (CTCA) of variant and anomalous coronary vasculature
Julia Sun and Jonathan Weir-McCall

SECTION 8: Abdomen and Pelvis**Section Editor:** R Shane Tubbs and Ranee Thakar

62. Abdomen and pelvis: overview and surface anatomy 1187
Richard Tunstall and R Shane Tubbs
63. Anterolateral abdominal wall 1202
Eric M Pauli
64. Posterior abdominal wall and retroperitoneum 1217
R Shane Tubbs
65. Mesentery, peritoneum and peritoneal cavity 1230
John Calvin Coffey, Peter Dockery, Kevin Gerard Byrnes and Dara Walsh

Gastrointestinal tract

66. Abdominal oesophagus and stomach 1242
Eduardo Guimarães Hourneaux de Moura Sr. and Alexandre Moraes Bestetti
67. Small intestine 1254
Antonino Morabito and Riccardo Coletta
68. Large intestine 1266
James W Fleshman Jr.

Abdominal viscera

69. Liver 1286
Charles B Rosen
70. Gallbladder and biliary tree 1299
Daisy Sahni
71. Pancreas 1305
Ugo Boggi
72. Spleen 1314
Koichi Watanabe
73. Suprarenal gland 1322
Eren Berber

Urogenital system

74. Lesser pelvis and perineum 1328
R Shane Tubbs
75. Kidney and ureter 1344
Andrew D Rule and Richard Glasscock
76. Urinary bladder, prostate and urethra 1362
Leonard G Gomella and Paul H Chung

77. Male reproductive system 1377
Ryan Flannigan
78. Female reproductive system 1392
Bernard T Haylen and Dzung Huu Vu

Commentaries

- 8.1 Common misconceptions regarding abdominal wall anatomy
Charlotte M Horne and Eric M Pauli
- 8.2 Anatomical considerations for the development of uterine and vaginal prolapse
Bernard T Haylen

Videos

- 62.1 — Dissection of the posterior abdominal wall 1418
R Shane Tubbs and Joe Iwanaga
- 62.2 — Dissection of the lumbosacral junction 1418
R Shane Tubbs
- 73.1 — Robotic transabdominal lateral adrenalectomy 1418
Eren Berber
- 73.2 — Robotic posterior retroperitoneal adrenalectomy 1418
Eren Berber
- 74.1 — Dissection of the sacral plexus 1419
R Shane Tubbs
- 76.1 — Laparoscopic view of bladder filling and emptying in relation to the recto-vesical pouch 1419
Serge Ginzburg, Anthony T Corcoran and Alexander Kutikov
- 76.2 — Laparoscopic view of the anterolateral abdominal wall and ligaments 1419
Serge Ginzburg, Anthony T Corcoran and Alexander Kutikov
- 77.1 — Dissection of the male pelvis and perineum 1419
R Shane Tubbs and Joe Iwanaga
- 78.1 — Dissection of the female pelvis and perineum 1419
R Shane Tubbs and Joe Iwanaga

SECTION 9: Pelvic Girdle and Lower Limb**Section Editor:** Stephanie J Woodley

79. Pelvic girdle and lower limb: overview and surface anatomy 1423
Nihal Apaydin, Stephanie J Woodley and Richard Tunstall
80. Pelvic girdle, hip, gluteal region and thigh 1442
Donald Anthony Neumann
81. Knee and leg 1486
Aaron J Krych and Robert J Hinchliffe
82. Ankle and foot 1521
Anthony C Redmond



Commentaries

- 9.1 Functional anatomy and biomechanics of the pelvis with emphasis on the sacro-iliac joints
Andry Vleeming and Frank H Willard
- 9.2 Sexual dimorphism in lower limb sports injuries
Meghan Bishop
- 9.3 Tensor vastus intermedius
Shigehito Yamada

Videos



- 79.1 – Walking gait cycle 1559
Stephanie J Woodley, Stuart MacKenzie and Thomas Heaton
- 79.2 – Running gait cycle 1559
Stephanie J Woodley, Stuart MacKenzie and Thomas Heaton
- 79.3 – Manual muscle testing of the lower limb 1559
Rolfe Birch (†)
- 82.1 – Ankle block: surface anatomy 1559
Dominic Harmon

Systemic anatomy



- 83. The systemic anatomy of the peripheral nervous system
Susan Standring
- 84. The systemic anatomy of the vascular and lymphatic systems
Susan Standring

Imaging Commentaries



Special Imaging Editor: Tom Turmezei

- I.1 A note on anatomy from an imaging perspective
Tom Turmezei
- I.2 Technical aspects and applications of diagnostic radiology
Louis Saada, Mark Forde, James Parkin and Tom Turmezei
- I.3 Imaging the ageing musculoskeletal system
Andoni P Toms
- I.4 Cinematic rendering offers entirely new possibilities for studying human anatomy
Klaus Engel, Fabian Necker
- I.5 Peripheral nerve visualisation with magnetic resonance neurography
Ek T Tan, Yenpo Lin and Darryl B Sneag
- I.6 Hierarchical Phase-Contrast Tomography: Advancing High-Resolution Imaging of Intact Human Organs
Joseph Brunet, Claire L Walsh, Paul Tafforeau, Andrew C Cook, Klaus Engel, Florian Länger, Joseph Jacob, Maximilian Ackermann, Danny D Jonigk and Peter D Lee
- I.7 The role of imaging in the identification of variant anatomy and its clinical implications
Hamza Abu-Jabeh, Diogo Silva and Tom Turmezei



Eponyms

Susan Standring

Index

1560

FOREWORD

It is 170 years since Henry Gray approached his colleague Henry Vandyke Carter with the intention of producing an affordable, accessible anatomy textbook for medical students. The first edition was published a few years later in 1858, dedicated to Sir Benjamin Collins Brodie, a previous President of the Royal College of Surgeons, President of the Royal Society and later the first President of the General Medical Council. It consisted of 750 pages and included 363 illustrations. An American version followed a year later.

Gray's death from smallpox in 1861 meant that he would not come to appreciate the iconic status that his textbook would acquire. Despite the proliferation of many excellent anatomy textbooks over the intervening period, *Gray's Anatomy* remains pre-eminent. It is a title known and revered in the medical and especially surgical world, but also widely recognised by the public at large.

Whilst human anatomy may have remained constant since the nineteenth century, there has been a need to update previous editions. This 43rd edition includes anatomical terminology that aligns more closely with the second edition of *Terminologia Anatomica* to ensure greater standardisation and accuracy in nomenclature. The artwork has been revised to enhance consistency, clarity and anatomical precision, reinforcing its role as a gold-standard reference in anatomy. Several chapter titles have been adapted with the addition of new international collaborators.

Anatomy remains an important discipline in its own right, but its relevance to clinicians, and most especially to surgeons, is in its underpinning of pathological conditions and their treatment. As imaging modalities continue to develop, this edition incorporates radiological images using the latest medical imaging technology. There are more endoscopic views, including those used to approach herniated intervertebral discs and the stomach and gastro-oesophageal junction, reflecting developments in diagnostic and surgical techniques.

Alongside the print version, the enhanced e-Book is an invaluable adjunct, with additional text, figures and videos. It also includes a series of 'Gray's Commentaries', consisting of short articles on topical and emerging subjects related to clinical anatomy. New Commentaries include ethical issues related to anatomy, imaging (including hierarchical phase contrast imaging), assessment of accidental or inflicted injuries to infants and children, and middle ear mechanics. The e-Book contains some remarkable new 3D embryology videos that

help bring the subject to life, as well as new dissection videos of the upper limb and intraoperative adrenalectomy.

As a surgeon, I understand the importance of a detailed knowledge of anatomy. This provides the framework for understanding normal physiology and how that is affected by pathological processes. It is also critical to the interpretation of radiological investigations. Moreover, the surgeon must be able to identify and anticipate the location of anatomical structures during an operation in order to perform it successfully and avoid damage to adjacent structures.

It is my very great privilege, as President of the Royal College of Surgeons of England, to have been invited to write a foreword for this historic text. The College is intimately associated with John Hunter, whose statue sits proudly in the atrium of our refurbished headquarters in London, gazing quizzically towards the entrance to the Hunterian Museum, which houses his collection and details his life and the history of surgery. Hunter, like Gray and Vandyke Carter, was a surgeon-anatomist associated with St George's Hospital in London. He shared their passion for training the next generation, a mission that remains central to the Royal College of Surgeons of England today.

I congratulate the Editors-in-Chief, Professor Susan Standring and Professor R Shane Tubbs, as well as all the many contributors, for producing a remarkable 43rd edition of *Gray's Anatomy*. It continues the rich tradition of this extraordinary textbook but with many new additions that enhance it further. It will be an invaluable resource to medical students, doctors and other healthcare professionals at any stage of their career, whether they are studying anatomy and its related disciplines for the first time or returning to refresh their memory.

Henry Gray – and Henry Vandyke Carter – would marvel at how clinical knowledge has expanded since their time, with incredible developments in diagnostics and treatment. They would also be amazed by how new technology can enhance learning and the experience of the learner. However, I have no doubt that they would take great pride that their brainchild persists and continues to provide high-quality, accessible anatomical education. They would undoubtedly approve of this excellent 43rd edition.

Tim Mitchell

President

Royal College of Surgeons of England

PREFACE

A common definition of a preface is that it is 'an introduction to a book, typically stating its subject, scope or aims'. It is often the only place where an author or editor speaks directly to their readership, and in this respect, a preface is akin to an actor breaking the conceptual 'fourth wall' in the theatre or on film. In the Preface to the first edition in 1858 Henry Gray wrote, 'This Work is intended to furnish the Student and Practitioner with an accurate view of the Anatomy of the Human Body, and more especially the application of this science to Practical Surgery'. Subsequent editions of *Gray's Anatomy* not only upheld that intention, but developed it, in order to embrace and engage a wider readership.

The first two editors to succeed Gray were Timothy Holmes (1863–1880) and Thomas Pickering Pick (1883–1905). They both wondered in their Prefaces whether it was appropriate to include findings from the burgeoning discipline of anatomical science in a book intended specifically for students of surgery: 'so long as the Examining Bodies do not exact a knowledge of this branch of science as a necessary part of Medical Education, it would be unwise to encumber the pages of a work designed specifically for students with matter which, however interesting and valuable in itself, could hardly be regarded as essential' (Holmes, 3rd edition, 1863). Pickering Pick pointed out that microscopical anatomy had been revised in the 10th edition (1883) 'in order to keep pace with the ever-increasing activity of research in the branch of the science of Anatomy', and while not intending the 13th edition (1893) for the 'scientific anatomist', he was anxious not 'to disparage, for an instant, the study of Philosophical or Scientific Anatomy'.

Future editions slowly assimilated findings in the fields of cell biology, embryology, neuroanatomy and imaging: just as the discipline it describes has evolved, so a book originally intended for students of surgery has morphed into the great reference book that is published today. Our current view of the detailed internal landscape of the body, from molecular to the whole body and from conception onwards, owes much to the enormous technological advances that have taken place in the last half-century. Our 'anatomical gaze' has been enlightened by progress in bioinformatics, molecular biology, experimental genetics, light and electron microscopy, diagnostic imaging (including X-rays, magnetic resonance imaging, computed tomography and ultrasonography), and the use of 'soft' perfusion techniques and frozen-thawed, unembalmed cadavers for dissection-based studies and surgical training. That gaze is not only informed by, but also informs, the design and negotiation of minimally invasive surgical access routes to structures and regions that were once regarded as inaccessible 'tiger territories'. The momentum created by these changes powered the radical modernising revisions seen in the 36th to 38th editions under the editorship of Roger Warwick and Peter Williams: 'The discipline of Anatomy has changed out of all recognition because it is no longer just "Descriptive and Applied"' (Editorial team, Preface to the 38th edition, 1995), and has continued to drive subsequent editions.

Terminological disputes have long entertained anatomists: 'one cynic has commented that anatomists would rather use each other's toothbrushes than employ their terminology' (Tansey 1995).¹ Henry Gray's anatomical terminology in the first edition can be little different from the language he used when teaching and operating at St George's Hospital: his words were written long before the publication of the *Basle Nomina Anatomica* (BNA) in 1895. The exasperated comments of TB Johnston, in his Preface to the 25th edition (1932), have a familiar ring over a century later: 'It is my earnest hope that before another edition of this work is published, the question of terminology will have been settled and an unproductive subject will have ceased to occupy attention'. These hopes have not been entirely satisfied. An early attempt to reconcile differing terminologies in *Gray's Anatomy* was described as 'stultifying' (Tansey 1995).¹ The text of the 43rd edition of *Gray's Anatomy* is almost

entirely *Terminologia Anatomica* 2-compliant.² However, on occasion, the preferred term that is used is a synonym that may not be TA2-compliant: it has been chosen either because it is the agreed term in the relevant clinical consensus document or because it enjoys widespread clinical usage, whereas the TA-compliant term does not.³ Wherever this occurs, all terms are included at first meeting, with synonyms in parentheses.

The use of eponyms is contentious: detractors argue that they are inherently inaccurate, non-scientific and often undeserved, while proponents point out that eponyms are deeply embedded in the anatomical and clinical literature and that they remind us of the giants on whose shoulders we stand. On balance, we believe *Gray's Anatomy* is an appropriate repository for anatomical eponyms: they are cited in parentheses on first usage of a preferred term in the text and an updated list of eponyms is available in the e-book for reference purposes. We recognise the irony in the exclusion of Henry Vandyke Carter's name from the eponymous title of *Gray's Anatomy*, particularly since Carter's drawings invariably attracted praise: 'those excellent images which have ... contributed so materially to smooth the thorny path of the student of human anatomy' (Carter's obituary, *BMJ*, May 15 1897); 'The splendid illustrations in Gray have long been known as the most effective and intelligible presentations of anatomical structure ever produced ...' (Preface to the American 15th edition, 1901); 'Superb drawings that captured the human anatomy with a pristine clarity and simplicity of expression that are worth continued regard'. (Adams 1981)⁴.

As a general rule, the orientation of diagrams and photographs throughout the book has been standardised to show the left side of the body, irrespective of whether a lateral or medial view is presented. Transverse sections have been drawn from below to facilitate comparison with axial clinical images: the conventional 'top down' orientation has been retained in diagrams in Section 3 (neuroanatomy). Clinicopathological examples have been selected where the pathology is either a direct result, or a consequence, of the anatomy, or where the anatomical features are instrumental in the diagnosis/treatment/management of the condition. Unless otherwise indicated, the photomicrographs illustrate human histology and embryology.

We acknowledge that some of the figures in this and previous editions of *Gray's Anatomy*, which are attributed to the *Sobotta Atlas of Human Anatomy*, are the work of artists such as Erich Lepier, a member of the National Socialist German Workers' Party, who had worked with Eduard Pernkopf in producing *Pernkopf's Atlas of Topographical and Applied Human Anatomy*. We are extremely mindful of the ongoing ethical debate within the anatomy, healthcare, Jewish and wider academic communities around whether the detail provided in these figures (and others with a recognisably similar artistic provenance and anatomical 'gaze') provides sufficient, morally defensible justification for their continued use. (Readers may wish to refer to the Commentary 'Ethical Issues in Anatomy' (see page xxviii), specially commissioned for this edition of *Gray's Anatomy*, for some of the wider context and debate). As *Gray's* editors, we continue to wrestle with these considerations and endeavour to come to a balanced view. In this 43rd edition some images produced by artists from the Pernkopf era have been replaced with contemporary illustrations based on ethically derived, fully consented human material, and we will revisit replacing further images when preparing any subsequent edition(s).

2 FIPAT (Federative International Programme for Anatomical Terminology). *Terminologia Anatomica* 2, 2019 <https://fipat.library.dal.ca/TA2/>; *Terminologia Histologica*, Philadelphia: Lippincott Williams & Wilkins, 2008; *Terminologia Embryologica* 2, 2017 <https://fipat.library.dal.ca/>; *Terminologia Neuroanatomica*, 2017 <https://fipat.library.dal.ca/>.

3 Jeppson PC, Balgobin S, Washington BB, et al. Recommended standardized terminology of the anterior female pelvis based on a structured medical literature review. *Am J Obstet Gynecol*. 2018;219:26-39.

4 Adams LB. Letter re: Henry Gray's *Anatomy Descriptive and Surgical*. 1981. The Classics of Medicine Library, Birmingham, AL, USA.

1 Tansey EM. A brief history of *Gray's Anatomy*. In: Williams PL et al, eds. *Gray's Anatomy*. 38th ed. Edinburgh: Churchill Livingstone; 1995: xvii-xx.

In the Preface to the 39th edition it was explained that the editorial team had decided that, in order to provide the greatest benefit to clinicians, *Gray's Anatomy* would better mirror their daily practice if anatomy was described in the way that they use it, i.e. regionally. That said, including regional and systemic descriptions of topographical anatomy has remained our goal and we are therefore delighted that the anatomy of the nervous and vascular and lymphatic systems is included in the online version of the 43rd edition (in Chapters 83 and 84).

Neel Anand, Marco Catani, Pat Collins, Alan Crossman, Alistair Ross, Raneer Thakar, Richard Tunstall, Caroline Wigley and Stephanie Woodley brought a wealth of scholarship and experience as anatomists, cell biologists, research scientists, educators and clinicians to their roles as Section Editors. They recognise that knowledge of clinically relevant and evidence-based anatomy is essential for safe and effective clinical practice across all specialisms. It is with great pleasure that we thank them for their dedication and enthusiastic support, both in selecting and interacting with the authors in their Sections and meeting Elsevier's deadlines, despite the ever-increasing demands on their time from their university and/or clinical managers. Richard Tunstall and Caroline Wigley also worked closely with many authors to update the text and artworks for evidence-based surface anatomy and microstructure, respectively, across Sections 3 to 9. Tom Turmezei has been an enthusiastic 'go to' editor for sourcing images throughout the book. Owen Arthurs and his colleagues at Great Ormond Street Hospital provided microCT images for Section 2 (Embryogenesis and development). Over a hundred highly experienced clinicians and anatomists have contributed new text and/or artworks, original micrographs or other images and videos to individual chapters and we thank them all for their input – as ever, it has been an enriching experience to read their revisions.

We offer our sincere thanks to the editorial team at Elsevier, under the leadership of Jeremy Bowes, for their guidance, professionalism, good humour and unfailing support at all times. We thank Katie

DeFrancesco, Rebecca Gruliow, Nick Henderson, Elaine Leek and Cindy Thoms, for being at the end of a phone or available by e-mail whenever advice or support was needed. We thank the artists who have worked to produce new artworks under Richard Tibbitts' leadership, Ethan Danielsen for his long-standing contributions to the artworks in Section 2, and Jennifer Dooley and her team for preparing the new embryology videos: all of these colleagues have continued the tradition of Henry Vandyke Carter, the first great illustrator of *Gray's Anatomy*.

Finally, as our knowledge of human anatomy is significantly based on postmortem observations, we express our deepest gratitude to the generous cadaver donors whose invaluable contributions have profoundly advanced our understanding. Their selfless gifts have enabled countless learners and professionals to explore the intricacies of the human body, fostering discoveries that enhance education, research and clinical practice. Their legacy is woven into the fabric of scientific progress, and their impact will resonate through generations of medical and anatomical advancements.

I dedicate my work on this edition of *Gray's Anatomy* to my daughters, Helen and Caroline.

Susan Standing
March 2025

I would like to dedicate my contributions to this 43rd edition of *Gray's Anatomy* to my wife, Susan, whose patience and selflessness made my time commitment to this project possible. I am deeply grateful to my son, Isaiah, for his unwavering support and to my parents, Richard and Karon Tubbs, who gifted me my first copy of *Gray's Anatomy* when I was a student, igniting a lifelong passion. Finally, I extend my heartfelt thanks to my mentors – Drs W Jerry Oakes, George and Frank Salter, and Emily Christian – whose guidance and encouragement shaped my journey in anatomy.

R Shane Tubbs
March 2025

PROFESSOR ROLFE BIRCH, MCHIR, FRCP&S (GLAS), FRCS (EDIN), FRCS (ENG) (18 FEBRUARY 1944–22 MAY 2023)



Rolfe Birch significantly contributed to the 41st edition of *Gray's Anatomy* and was one of the world's leading peripheral nerve surgeons. He was educated at Haberdashers Aske's, Hampstead, Cambridge University and St George's Hospital, gaining his MBChB in 1969. His higher surgical training was undertaken on the South-West London orthopaedic training scheme.

He was initially appointed as Consultant Orthopaedic Surgeon to St Mary's Hospital in 1979, but in 1991 he moved to the Royal National Orthopaedic Hospital, where he established the Peripheral Nerve Injuries Unit. He became

Honorary Orthopaedic Consultant at the Hospital for Sick Children, Great Ormond Street and the National Hospital for Nervous Diseases, both in London, and Honorary Orthopaedic Surgeon to all three armed services. He was appointed Professor of Neurological Orthopaedic Surgery at University College London. Later in his career he became a Consultant in Charge of the War Nerve Injuries Clinic at the Defence Medical Rehabilitation Centre, Headley Court, Leatherhead, Surrey.

He made an outstanding contribution to our understanding of the science and surgery of peripheral nerve disorders, initially with George Bonney and Christopher Wynn Parry in their revision of Sir Herbert Seddon's *Surgical Disorders of the Peripheral Nerves* (1998) and latterly in a much-revised 2nd edition, published in 2011. It is of note that references to this are found in most contemporary papers on the management of peripheral nerve disorders. He also wrote or contributed to numerous papers on various aspects of peripheral nerve surgery, in

particular the management of brachial plexus injuries, both obstetric and adult, disorders of the peripheral nerves and the scientific basis of pain.

He was always meticulous in acknowledging the contribution of others, both when lecturing and in print. His literary and oratorical styles were dazzling in their clarity and tended to be Edwardian in manner, often quoting from classical authors but always underpinned by his extensive clinical experience.

It was entirely typical of him that for his funeral he requested the Cranmer Book of Common Prayer and readings from Tyndale's translation of the New Testament, both of which are characterised by their elegance of language and clarity of expression.

Rolfe passed away peacefully on Monday, 22 May 2023, at the age of 79. He will be greatly missed by his family, friends, colleagues and patients.

Alistair Ross
2025

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We would also like to thank the team led by Professor Peter Lee and Dr Claire Walsh (Department of Mechanical Engineering, University

College London, UK) and their collaborators, for providing a Commentary on hierarchical phase-contrast tomography (HiP-CT). The technology they describe sets a new standard in our ability to multiscale image human organs and tissues.

The following images were sourced by the Department of Radiology at the Norfolk and Norwich University Hospital:

35.1B,C; 35.2B; 38.4C; 38.24H-L; 40.11B; 40.40B,C; 40.41; 40.45D,E; 41.13C-E; 42.6B-F; 43.2B; 47.5B; 47.6C; 47.7B; 47.13B-E; 49.6B,C; 49.21C; 49.24B; 49.26C; 49.48A-C; 49.53C-G; 49.63B-D; 49.66B,C; 49.72B; 49.80; 50.1G; 51.3B,C; 51.4B-E; 51.7B-G; 52.15B; 52.22C; 52.23A,B; 53.13E-G; 53.16; 53.17B; 53.26B; 53.30B; 53.31B; 54.19D; 54.20A-D; 56.12B; 57.4C-H; 57.5B; 57.6F-O; 58.1B-E; 59.17B-E; 60.7BC; 60.17B; 60.21B; 60.27B; 60.46; 60.47; 60.48; 60.49; 60.50; 60.51; 60.59C; 61.3A-G; 62.5B; 63.1B; 63.3C; 63.9C,D; 67.14A; 68.37A; 68.44C; 69.12; 70.10; 75.6A-D; 76.1B; 76.2D; 76.15C; 80.2B; 80.17B; 80.24B; 80.28B; 80.43C,D; 80.48B,C; 81.15B; 81.25B; 82.4B; 82.10B; 82.15B-F; 82.17B.

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HISTORICAL INTRODUCTION

Gray's Anatomy is now more than 165 years old. The book is a rarity in textbook publishing in having been in continuous publication on both sides of the Atlantic Ocean since 1858, an exceptionally long era for a textbook. Of course, the volume now is very different from the one Mr Henry Gray first created with his colleague Dr Henry Vandyke Carter in mid-Victorian London. In this introductory essay, I shall explain the long history of *Gray's*, from those Victorian days right up to today.

The shortcomings of existing anatomical textbooks probably impressed themselves on Henry Gray when he was still a student at St George's Hospital Medical School, near London's Hyde Park Corner, in the early 1840s. He began thinking about creating a new anatomy textbook a decade later, while war was being fought in the Crimea. New legislation was being planned that would establish the General Medical Council (1858) to regulate professional education and standards.

Gray was 28 years old, and a teacher himself at St George's. He was very able, hard-working and highly ambitious, already a Fellow of the Royal Society and of the Royal College of Surgeons. Although little is known about his personal life, his was a glittering career so far, achieved while he served and taught on the hospital wards and in the dissecting room (Fig. 1) (Anon 1908).

Gray shared the idea for the new book with a talented clinical colleague on the teaching staff at St George's, Henry Vandyke Carter, in November 1855. Carter was from a family of Scarborough artists, and was himself a talented artist and experienced microscopist (Fig. 2). He had produced fine illustrations for Gray's scientific publications before, but could see that this idea was a much more complex project. Carter recorded in his diary:

Little to record. Gray made proposal to assist by drawings in bringing out a Manual for students: a good idea but did not come to any plan ... too exacting, for would not be a simple artist. (Carter 1855)

Neither of these young men was interested in producing a pretty book, or an expensive one. Their purpose was to supply an affordable,



Fig. 1 Henry Gray (1827–1861) is shown here in the foreground, seated by the feet of the cadaver. The photograph was taken by a medical student, Joseph Langhorn. The room is the dissecting room of St George's Hospital Medical School in Kinnerton Street, London. Gray is shown surrounded by staff and students. When the photo was taken, on 27 March 1860, Carter had left St George's to become Professor of Anatomy and Physiology at Grant Medical College in Bombay (nowadays Mumbai). The second edition of *Gray's Anatomy* was in its proof stages, to appear in December 1860. Gray died just over a year later, in June 1861, at the height of his powers.



Fig. 2 Henry Vandyke Carter (1831–1897). Carter was appointed Honorary Physician to Queen Victoria in 1890. (Self-portrait painted while Carter was in India, courtesy of Professor Susan Standing.)

accurate teaching aid for people like their own students, who might soon be required to operate on real patients, or on soldiers injured at Sebastopol or some other battlefield. The book they planned together was a practical one, designed to encourage youngsters to study anatomy, help them pass exams and assist them as budding surgeons. It was not simply an anatomy textbook, but a guide to dissecting procedure and to the major operations.

Gray and Carter belonged to a generation of anatomists ready to infuse the study of human anatomy with a new, and respectable, scientificity. Disreputable aspects of the profession's history, acquired during the days of body-snatching, were assiduously being forgotten. The Anatomy Act of 1832 had legalised the requisition of unclaimed bodies from workhouse and hospital mortuaries, and the study of anatomy (now with its own Inspectorate) was rising in respectability in Britain. The private anatomy schools that had flourished in the Regency period were closing their doors, and the major teaching hospitals were erecting new, purpose-built dissection rooms (Richardson 2000).

The best-known student works when Gray and Carter had qualified were probably Erasmus Wilson's *Anatomist's Vade Mecum* and *Elements of Anatomy* by Jones Quain. Both works were small – pocket-sized – but Quain came in two thick volumes. Their small pages of dense type, and even smaller illustrations, were somewhat daunting, seeming to demand much nose-to-the-grindstone effort from the reader.

The planned new textbook's dimensions and character were serious matters. Pocket manuals were commercially successful because they appealed to students by offering much knowledge in a small compass. But pocket-sized books had button-sized illustrations. Knox's *Manual of Human Anatomy*, for example, was only 6 × 4 inches (15 × 10 cm) and few of its illustrations occupied more than one-third of a page. Gray and Carter must have discussed this matter between themselves, and with Gray's publisher, JW Parker & Son, before decisions were taken about the size and girth of the new book, and especially the size of its illustrations. While Gray and Carter were working on the book, a new edition of Quain's was published; this time it was a 'triple-decker' – in three volumes – of 1740 pages in all.

The two men were earnestly engaged for the following 18 months in work for the new book. Gray wrote the text and Carter created the illustrations; all the dissections were undertaken jointly. Their working days were long – all the hours of daylight, eight or nine hours at a stretch – right through 1856 and well into 1857. We can infer from the

warmth of Gray's appreciation of Carter in his published acknowledgements that their collaboration was a happy one.

The Author gratefully acknowledges the great services he has derived in the execution of this work, from the assistance of his friend, Dr. H. V. Carter, late Demonstrator of Anatomy at St George's Hospital. All the drawings from which the engravings were made, were executed by him. (Gray 1858)

With all the dissections completed, and Carter's inscribed wood-blocks at the engravers, Gray took six months' leave from his teaching at St George's to work as a personal doctor for a wealthy family. It was probably as good a way as any to get a well-earned break from the dissecting room and the dead-house (Nicol 2002).

Carter sat the examination for medical officers in the East India Company, and sailed for India in the spring of 1858, when the book was still in its proof stages. Gray had left a trusted colleague, Timothy Holmes, to see it through the press. Holmes's association with the first edition would later prove vital to its survival. Gray looked over the final galley proofs, just before the book finally went to press.

THE FIRST EDITION

The book Gray and Carter had created together, *Anatomy, Descriptive and Surgical*, appeared at the very end of August 1858, to immediate acclaim. Reviews in *The Lancet* and the *British Medical Journal* were highly complimentary and students flocked to buy the book.

It is not difficult to understand why it was a runaway success. *Gray's Anatomy* knocked its competitors into a cocked hat. It was considerably smaller and more slender than the doorstopper with which modern readers are familiar. The book held well in the hand, it felt substantial and it contained everything required. To contemporaries, it was small enough to be portable, but large enough for decent illustrations: 'royal octavo' – 9½ × 6 inches (24 × 15 cm) – about two-thirds of modern A4 size. Its medium-size, single-volume format was far removed from *Quain's*, yet double the size of *Knox's Manual*.

Simply organised and well designed, the book explains itself confidently and well; the clarity and authority of the prose are manifest. But what made it unique for its day was the outstanding size and quality of the illustrations. Gray thanked the wood engravers Butterworth and Heath for the 'great care and fidelity' they had displayed in the engravings, but it was really to Carter that the book owed its extraordinary success.

The beauty of Carter's illustrations resides in their diagrammatic clarity, quite atypical for their time. The images in contemporary anatomy books were usually 'proxy-labelled': dotted with tiny numbers or letters (often hard to find or read) or bristling with a sheaf of numbered arrows, referring to a key situated elsewhere, usually in a footnote, which was sometimes so lengthy it wrapped round on to the following page. Proxy labels require the reader's eye to move to and fro: from the structure to the proxy label to the legend and back again. There was plenty of scope for slippage, annoyance and distraction. Carter's illustrations, by contrast, unify name and structure, enabling the eye to assimilate both at a glance. We are so familiar with Carter's images that it is hard to appreciate how incredibly modern they must have seemed in 1858. The volume made human anatomy look new, exciting and accessible.

The first edition was covered in a brown bookbinder's cloth embossed all over in a dotted pattern, and with a double picture-frame border. Its spine was lettered in gold blocking:

GRAY'S ANATOMY

with 'DESCRIPTIVE AND SURGICAL' in small capitals underneath. *Gray's Anatomy* is how it has been referred to ever since. Carter was given credit with Gray on the book's title page for undertaking all the dissections on which the book was based, and sole credit for all the illustrations, though his name appeared in a significantly smaller type, and he was described as the 'Late Demonstrator in Anatomy at St George's Hospital' rather than being given his full current title, which was Professor of Anatomy and Physiology at Grant Medical College, Bombay. Gray was still only a Lecturer at St George's and he may have been aware that his words had been upstaged by the quality of Carter's anatomical images. He need not have worried: Gray is the famous name on the spine of the book.

Gray was paid £150 for every thousand copies sold. Carter never received a royalty payment, just a one-off fee at publication, which may

have allowed him to purchase the long-wished-for microscope he took with him to India.

The first edition print-run of 2000 copies sold out swiftly. A parallel edition was published in the United States in 1859, and Gray must have been deeply gratified to have to revise an enlarged new English edition in 1859–60, though he was surely saddened and worried by the death of his publisher, John Parker junior, at the young age of 40, while the book was going through the press. The second edition came out in the December of 1860 and it too sold like hot cakes.

The following summer, in June 1861, at the height of his powers and full of promise, Henry Gray died unexpectedly at the age of only 34. Gray had contracted smallpox while nursing his nephew. A new strain of the disease was more virulent than the one with which Gray had been vaccinated as a child; the disease became confluent and Gray died in a matter of days.

Within months, the whole country would be pitched into mourning for the death of Prince Albert. The creative era over which he had presided – especially the decade that had flowered since the Great Exhibition of 1851 – would be history.

THE BOOK SURVIVES

Anatomy Descriptive and Surgical could have died too. With Carter in India, the death of Gray, so swiftly after that of the younger Parker, might have spelled catastrophe. Certainly, at St George's there was a sense of calamity. The grand old medical man Sir Benjamin Brodie, Sergeant-Surgeon to the Queen, and to whom *Anatomy* had been dedicated, was a great supporter of Gray and cried forlornly: 'Who is there to take his place?' (Anon 1908).

But old John W Parker ensured the survival of *Gray's* by inviting Timothy Holmes, the doctor who had helped proofread the first edition, and who had filled Gray's shoes at the medical school, to serve as Editor for the next edition. Other long-running anatomy works, such as that of Quain, remained in print in a similar way, co-edited by other hands (Quain 1856).

Holmes (1825–1907) was another gifted St George's man, a scholarship boy who had won an exhibition to Cambridge, where his brilliance was recognised. He was a Fellow of the Royal College of Surgeons at 28. John Parker junior had commissioned him to edit *A System of Surgery* (1860–1864), an important essay series by distinguished surgeons on subjects of their own choosing. Many of Holmes's authors remain important figures, even today: John Simon, James Paget, Henry Gray, Ernest Hart, Jonathan Hutchinson, Charles-Édouard Brown-Séquard and Joseph Lister. Holmes had lost an eye in an operative accident, and he had a gruff manner that terrified students, yet he published a lament for young Parker that reveals him capable of deep feeling (Holmes 1860).

John Parker senior's heart, however, was no longer in publishing. His son's death had closed down the future for him. The business, with all its stocks and copyrights, was sold to Messrs Longman, and Parker retired to the village of Farnham, where he later died.

With Holmes as editor, and Longman as publisher, the immediate future of *Gray's Anatomy* was assured. The third edition appeared in 1864 with relatively few changes, Gray's estate receiving the balance of his royalty after Holmes was paid £100 for his work.

THE MISSING OBITUARY

Why no obituary appeared for Henry Gray in *Gray's Anatomy* is curious. Gray had referred to Holmes as his 'friend' in the preface to the first edition, yet it would also be true to say that they were rivals. Both had just applied for a vacant post at St George's, as Assistant Surgeon. Had Gray lived, it is thought that Holmes may not have been appointed, despite his seniority in age (Anon 1908).

Later commentators have suggested, as though from inside knowledge, that Holmes's 'proofreading' included improving Gray's writing style. This could be a reflection of Holmes's own self-regard, but there may be some truth in it. There can be no doubt that, as Editor of seven subsequent editions of *Gray's Anatomy* (3rd to 9th editions, 1864–1880), Holmes added new material, and had to correct and compress passages, but it is also possible that, back in 1857, Gray's original manuscript had been left in a poor state for Holmes to sort out. In other works, Gray's writing style was lucid, but he always seems to have paid a copyist to transcribe his work prior to submission. The original manuscript of *Gray's Anatomy*, sadly, has not survived, so it is impossible to be sure how much of the finished version had actually been written by Holmes.

It may be that Gray's glittering career, or perhaps the patronage that unquestionably advanced it, created jealousies among his colleagues, or that there was something in Gray's manner that precluded affection, or that created resentments among clever social inferiors like Carter and Holmes, especially if they felt their contributions to Gray's brilliant career were not given adequate credit. Whatever the explanation, no reference to Gray's life or death appeared in *Gray's Anatomy* itself until the twentieth century (Howden et al 1918).

A SUCCESSION OF EDITORS

Holmes expanded areas of the book that Gray himself had developed in the second edition (1860), notably in 'general' anatomy (histology) and 'development' (embryology). In Holmes's time as Editor, the volume grew from 788 pages in 1864 to 960 in 1880 (9th edition), with the histological section paginated separately in roman numerals at the front of the book. Extra illustrations were added, mainly from other published sources.

The connections with Gray and Carter, and with St George's, were maintained with the appointment of the next editor, T Pickering Pick, who had been a student at St George's in Gray's time. From 1883 (10th edition) onwards, Pick kept up with current research, rewrote and integrated the histology and embryology into the volume, dropped Holmes from the title page, removed Gray's preface to the first edition, and added bold subheadings, which certainly improved the appearance and accessibility of the text. Pick said he had '*tried to keep before himself the fact that the work is intended for students of anatomy rather than for the Scientific Anatomist*' (13th edition, 1893).

Pick also introduced colour printing (in 1887, 11th edition) and experimented with the addition of illustrations using the new printing method of half-tone dots: for colour (which worked) and for new black-and-white illustrations (which did not). Half-tone shades of grey compared poorly with Carter's wood engravings, still sharp and clear by comparison.

What Henry Vandyke Carter made of these changes is a rich topic for speculation. He returned to England in 1888, having retired from the Indian Medical Service full of honours, and in 1890 he was made Honorary Physician to Queen Victoria. Carter had continued researching throughout his clinical medical career in India and became one of India's foremost bacteriologists/tropical disease specialists before there was really a name for either discipline. He made some important discoveries, including the fungal cause of mycetoma, which he described and named, and he was a key figure in confirming scientifically in India some major international discoveries, such as Hansen's discovery of the cause of leprosy, Koch's discovery of the organism causing tuberculosis and Laveran's discovery of the organism that causes malaria. Carter married late in life, and his wife was left with two young children when he died in Scarborough in 1897, aged 65. Like Gray, he received no obituary in the book, but unlike Gray, Carter received an obituary in the *British Medical Journal* that celebrated not only his achievements in India but also '*those excellent illustrations for Gray's Anatomy which have ... contributed so materially to smooth the thorny path of the student of human anatomy*' (BMJ 1897).

When Pick was joined on the title page by Robert Howden (a professional anatomist from the University of Durham) in 1901 (15th edition), the volume was still easily recognisable as the book Gray and Carter had created. Although many of Carter's illustrations had been revised or replaced, many others still remained. Sadly, though, an entire section (embryology) was again separately paginated, because its revision had taken longer than anticipated. *Gray's Anatomy* had grown, seemingly inexorably, and was now quite thick and heavy: 1244 pages, weighing 5 lb 8 oz (2.5 kg). Both co-editors, and perhaps also its publisher, were dissatisfied with it.

KEY EDITION: 1905

Serious decisions were taken well in advance of the next edition, which turned out to be Pick's last with Howden. Published 50 years after Gray had first suggested the idea to Carter, the 1905 (16th) edition was a landmark one.

The period 1880–1930 was a difficult time for anatomical illustration, because the new techniques of photo-lithography and half-tone were not as yet perfected, and in any case could not provide the bold simplicity of line required for a book like *Gray's*, which depended so heavily on clear illustration and clear lettering. Recognising the inferiority of half-tone illustrations by comparison with Carter's wood-engraved originals, Pick and Howden courageously decided to jettison

the second-rate half-tones altogether. Most of the next edition's illustrations were either Carter's, or old supplementary illustrations inspired by his work, or newly commissioned wood engravings or line drawings, intended 'to harmonise with Carter's original figures'. They successfully emulated Carter's verve. Having fewer pages and lighter paper, the 1905 edition weighed less than its predecessor, at 4 lb 11 oz (2.1 kg). Typographically, the new edition was superb.

Howden took over as sole editor in 1909 (17th edition) and immediately stamped his personality on *Gray's*. He excised 'Surgical' from the title, changing it to *Anatomy Descriptive and Applied*, and removed Carter's name altogether. He also instigated the beginnings of an editorial board of experts for *Gray's*, by adding to the title page 'Notes on Applied Anatomy' by AJ Jex-Blake and W Fedde Fedden, both St George's men. For the first time, the number of illustrations exceeded one thousand. Howden was responsible for the significant innovation of a short historical note on Henry Gray himself, nearly 60 years after his death, which included a portrait photograph (1918, 20th edition).

THE NOMENCLATURE CONTROVERSY

Howden's era, and that of his successor TB Johnston (of Guy's), was overshadowed by a cloud of international controversy concerning anatomical terminology. European anatomists were endeavouring to standardise anatomical terms, often using Latinate constructions, a move resisted in Britain and the United States. *Gray's* became mired in these debates for over 20 years. The attempt to be fair to all sides by using multiple terms doubtless generated much confusion amongst students, until a working compromise was at last arrived at in 1955 (32nd edition, 1958).

Johnston oversaw the second retitling of the book (in 1938, 27th edition): it was now, officially, *Gray's Anatomy*, finally ending the fiction that it had ever been known as anything else. *Gray's* suffered from paper shortages and printing difficulties in World War II, but successive editions nevertheless continued to grow in size and weight, while illustrations were replaced and added as the text was revised.

Between Howden's first sole effort (1909, 17th edition) and Johnston's last edition (1958, 32nd edition), *Gray's* expanded by over 300 pages – from 1296 to 1604 pages, and almost 300 additional illustrations brought the total to over 1300. Johnston also introduced X-ray plates (1938) and, in 1958 (32nd edition), electron micrographs by AS Fitton-Jackson, one of the first occasions on which a woman was credited with a contribution to *Gray's*. Johnston felt compelled to mention that she was 'a blood relative of Henry Gray himself', perhaps by way of mitigation.

AFTER WORLD WAR II

The editions of *Gray's* issued in the decades immediately following World War II give the impression of intellectual stagnation. Steady expansion continued in an almost formulaic fashion, with the insertion of additional detail. The central historical importance of innovation in the success of *Gray's* seems to have been lost sight of by its publishers and editors: Johnston (1930–1958, 24th to 32nd editions), J Whillis (co-editor with Johnston, 1938–1954), DV Davies (1958–1967, 32nd to 34th editions) and F Davies (co-editor with DV Davies 1958–1962, 32nd to 33rd editions). *Gray's* had become so pre-eminent that perhaps complacency crept in, or editors were too daunted or too busy to confront the 'massive undertaking' of a root and branch revision (Tansey 1995). The unexpected deaths of three major figures associated with *Gray's* in this era, James Whillis, Francis Davies and David Vaughan Davies – each of whom had been ready to take the editorial reins – may have contributed to retarding the process. The work became somewhat dull.

KEY EDITION: 1973

DV Davies had recognised the need for modernisation, but his unexpected death left the work to other hands. Two Professors of Anatomy at Guy's, Roger Warwick and Peter Williams, the latter of whom had been involved as an indexer for *Gray's* for several years, regarded it as an honour to fulfil Davies's intentions.

Their 35th edition of 1973 was a significant departure from tradition. Over 780 pages (of 1471) were newly written, almost a third of the illustrations were newly commissioned, and the captions for the illustrations were freshly written throughout. With a complete re-typesetting of the text in larger double-column pages, a new index and

the innovation of a bibliography, this edition of *Gray's* looked and felt quite unlike its 1967 (34th edition) predecessor, and much more like its modern incarnation.

This 1973 edition departed from earlier volumes in other significant ways. The editors made explicit their intention to try to counter the impetus towards specialisation and compartmentalisation in twentieth-century medicine, by embracing and attempting to reintegrate the complexity of the available knowledge. Warwick and Williams openly renounced the pose of omniscience adopted by many textbooks, believing it important to accept and mention areas of ignorance or uncertainty. They shared with the reader the difficulty of keeping abreast in the sea of research, and accepted with a refreshing humility the impossibility of fulfilling their own ambitious programme.

Warwick and Williams's 1973 edition had much in common with Gray and Carter's first edition. It was bold and innovative – respectful of its heritage, while also striking out into new territory. It was visually attractive and visually informative. It embodied a sense of a treasury of information laid out for the reader (Williams and Warwick 1973). It was published simultaneously in the United States (the American *Gray's* had developed a distinct character of its own in the interval), and sold extremely well there (Williams and Warwick 1973).

The influence of the Warwick and Williams edition was forceful and long-lasting, and set a new pattern for the following quarter-century. As has transpired several times before, wittingly or unwittingly, a new editor was being prepared for the future: Professor Susan Standring (of Guy's and subsequently King's College London), who created the new bibliography for the 1973 edition of *Gray's*, went on to serve on the editorial board, and has served as Editor-in-Chief for the last four editions before this one (2005–2021, 39th, 40th, 41st and 42nd). The Editors-in-Chief for the 43rd edition are Professors Susan Standring and R. Shane Tubbs. These editions are important for different reasons.

For the 39th edition, the entire content of *Gray's* was reorganised, from systemic to regional anatomy. This great sea-change was not just organisational but historic, because, since its outset, *Gray's* had prioritised bodily systems, with subsidiary emphasis on how the systems interweave in the regions of the body. Professor Standring explained that this regional change of emphasis had long been asked for by readers and users of *Gray's*, and that new imaging techniques had raised the clinical importance of regional anatomy (Standring 2005). The change was facilitated by an enormous collective effort on the part of the editorial team and the illustrators. The subsequent and current editions, consolidate that momentous change (see Table 1).

TABLE 1 *Gray's Anatomy Editions*

Edition	Date	Author/Editor(s)	Publisher	Title
1st	1858	Henry Gray <i>The drawings by Henry Vandyke Carter. The dissections jointly by the author and Dr Carter</i>	JW Parker & Son	<i>Anatomy Descriptive and Surgical</i>
2nd	1860	Henry Gray	JW Parker & Son	
3rd	1864	T Holmes	Longman	
4th	1866	T Holmes	Longman	
5th	1869	T Holmes	Longman	
6th	1872	T Holmes	Longman	
7th	1875	T Holmes	Longman	
8th	1877	T Holmes	Longman	
9th	1880	T Holmes	Longman	
10th	1883	TP Pick	Longman	
11th	1887	TP Pick	Longman	
12th	1890	TP Pick	Longman	
13th	1893	TP Pick <i>Gray's preface removed</i>	Longman	
14th	1897	TP Pick	Longman	
15th	1901	TP Pick & R Howden	Longman	
16th	1905	TP Pick & R Howden	Longman	
17th	1909	Robert Howden <i>Notes on applied anatomy by AJ Jex-Blake & W Fedde Fedden</i>	Longman	<i>Anatomy Descriptive and Applied</i>
18th	1913	Robert Howden & Blake & Fedden	Longman	
19th	1916	Robert Howden & Blake & Fedden	Longman	
20th	1918	Robert Howden & Blake & Fedden <i>First edition to feature a photograph and obituary of Henry Gray</i>	Longman	
21st	1920	Robert Howden <i>Notes on applied anatomy by AJ Jex-Blake & John Clay</i>	Longman	
22nd	1923	Robert Howden <i>Notes on applied anatomy by John Clay & John D Lickley</i>	Longman	
23rd	1926	Robert Howden	Longman	
24th	1930	TB Johnston	Longman	
25th	1932	TB Johnston	Longman	
26th	1935	TB Johnston	Longman	<i>Gray's Anatomy</i>
27th	1938	TB Johnston & J Whillis	Longman	
28th	1942	TB Johnston & J Whillis	Longman	
29th	1946	TB Johnston & J Whillis	Longman	
30th	1949	TB Johnston & J Whillis	Longman	
31st	1954	TB Johnston & J Whillis	Longman	
32nd	1958	TB Johnston & DV Davies & F Davies	Longman	
33rd	1962	DV Davies & F Davies	Longman	

TABLE 1 *Gray's Anatomy* Editions—cont'd

Edition	Date	Author/Editor(s)	Publisher	Title
34th	1967	DV Davies & RE Coupland	Longman	
35th	1973	Peter L Williams & Roger Warwick	Longman	
		With a separate volume: <i>Functional Neuroanatomy of Man</i> – being the neurology section of <i>Gray's Anatomy</i> , 35th edition, 1975		
36th	1980	Roger Warwick & Peter L Williams	Churchill Livingstone	
37th	1989	Peter L Williams	Churchill Livingstone	
38th	1995	Peter L Williams & Editorial Board	Churchill Livingstone	
39th	2005	Susan Standring & Editorial Board	Elsevier	<i>The Anatomical Basis of Clinical Practice</i>
40th	2008	Susan Standring & Editorial Board	Elsevier	
41st	2016	Susan Standring & Editorial Board	Elsevier	
42nd	2021	Susan Standring & Editorial Board	Elsevier	
43rd	2025	Susan Standring & R Shane Tubbs & Editorial Board	Elsevier	

THE DOCTORS' BIBLE

Neither Gray nor Carter, the young men who – by their committed hard work between 1856 and 1858 – created the original *Gray's Anatomy*, would have conceived that so many years after their deaths their book would not only be a household name, but also be regarded as a work of such pre-eminent importance that a novelist half a world away would rank it as cardinal – alongside the Bible and Shakespeare – to a doctor's education (Lewis 1925, Richardson 2008). From this 43rd edition of *Gray's Anatomy*, we can look back to appraise the long-term value of their efforts. We can discern how the book they created triumphed over its competitors, and has survived pre-eminent. *Gray's* is a remarkable publishing phenomenon. Although the volume now looks quite different to the original, and contains so much more, its kinship with the *Gray's Anatomy* of 1858 is easily demonstrable by direct descent, every edition updated by Henry Gray's successor. Works are rare indeed that have had such a long history of continuous publication on both sides of the Atlantic, and such a useful one.

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INTRODUCTION TO ANATOMY

THE ANATOMICAL BASIS OF CLINICAL PRACTICE

Anatomy is a branch of natural science concerned with the study of the structure of the body. In the Preface to *De Humani Corporis Fabrica* (1543), Vesalius wrote that ‘Anatomy should rightly be regarded as the firm foundation of the whole art of medicine and its essential preliminary ...’ (Farrington 1932).

Conventionally, anatomy is divided into topographical anatomy (regional anatomy, surface anatomy, neuroanatomy, endoscopic and imaging anatomy); developmental anatomy (embryogenesis and subsequent organogenesis); and the anatomy of cellular and subcellular structure (histology). In the Preface to the first edition of what became known as *Gray’s Anatomy*, Henry Gray wrote, ‘This Work is intended to furnish the Student and Practitioner with an accurate view of the Anatomy of the Human Body, and more especially the application of this science to Practical Surgery’ (Gray 1858). Gray’s words remain apposite: an appropriate knowledge of clinically relevant, evidence-based anatomy is an essential component of the armamentarium of a practising clinician, informing the interpretation of presenting signs and symptoms and their subsequent management, particularly (but not exclusively) in the emergency department, imaging suite and operating theatre.

Anatomical terminology

Anatomical language is one of the fundamental languages of medicine. The unambiguous description of thousands of structures is only possible with an extensive and often highly specialised vocabulary. In an ideal world, these terms, derived mainly from Classical Latin or Greek (Turmezei 2012), would be used exclusively. In the real world, this goal is achieved with varying degrees of success; alternative terms (co)exist and may (and frequently do) confuse or frustrate. The text of the 43rd edition of *Gray’s Anatomy* is almost entirely compliant with the terminology set out in the 2nd edition of *Terminologia Anatomica* drawn up by the Federative International Programme for Anatomical Terminology (FIPAT) (FIPAT 2019). However, the term used may not always be TA2-compliant, and may not appear in TA2 although clinically relevant (Chmielewski 2024). Where this occurs, and in recognition that *Gray’s Anatomy* is dedicated to providing the anatomical basis of clinical practice, a term has been chosen either because it appears in the relevant clinical consensus document (e.g. Caggiati et al 2002, Lund et al 2014, Kupinski 2019, Navarrete-Dechent et al 2020) or because it enjoys widespread clinical usage, whereas the TA-compliant term does not. All appropriate terms are used at their first appearance in a chapter when synonyms and eponyms are included in parentheses after the preferred term.

Eponyms

The continued use of eponyms is contentious (Fargen and Ho 2014), and the use of possessive eponyms is discouraged (Ayesu et al 2018). Proponents of retention argue that some eponyms are entrenched in medical language and are (therefore) indispensable, that they facilitate communication because their use is so pervasive and that they remind us of the humanism of medicine and the giants on whose shoulders we stand. Detractors argue that eponyms are inherently inaccurate, non-scientific, often undeserved and some are used to identify more than a single structure. For example, the name of the prolific German anatomist Hubert von Luschka (1820–1875) has been attached to no fewer than 23 anatomical structures (Tubbs et al 2011). In this edition of *Gray’s Anatomy*, synonyms and eponyms are given in parentheses on first appearance in a chapter and do not appear thereafter in the text; an updated list of eponyms is searchable in the e-book for reference purposes.

Anatomical variation

Sir William Osler emphasised that no two humans are alike saying, ‘Variability is the law of life ...’ (Tubbs 2013). Medical students appreciate this when they begin dissection classes and are often surprised by the range of anatomical variation that they encounter amongst the cadavers or even between sides of the same cadaver in the wet laboratory. As they progress to clinical examination and study their patients’ X-ray, CT, MRI or ultrasound images, they encounter further variations that prompt the age-old question, ‘What is normal, and what is beyond the range of anatomical normality?’ Clinicians must be aware of common anatomical variants to diagnose and interpret imaging studies more accurately and to perform invasive procedures while avoiding iatrogenic injury. Many common anatomical variations are described throughout *Gray’s Anatomy*, 43rd edition. However, a comprehensive discussion of this topic is beyond the scope of this text. Therefore, for additional details on human anatomical variants, the reader is directed to *Bergman’s Comprehensive Encyclopedia of Human Anatomic Variation*, which ‘attempts to capture many of the known variants of the human form’ (Tubbs et al 2016).

Planes

To avoid ambiguity, and unless otherwise specified, all anatomical descriptions assume that the body is in the conventional ‘anatomical position’, i.e. an individual is standing erect and facing forwards, upper limbs by the side with the palms facing forwards, and lower limbs together with the toes facing forwards (Fig. 1). Descriptions are based on four planes – median, sagittal, coronal and transverse – applied to a body in the anatomical position. The median plane passes longitudinally through the body and divides it into right and left halves. The sagittal plane is any vertical plane parallel with the median plane; although often used, the terms midsagittal and parasagittal are therefore superfluous and should be avoided (O’Rahilly 1997). The coronal (frontal) plane is orthogonal to the median plane and divides the body into anterior (front) and posterior (back). The transverse (horizontal) plane is orthogonal to the median and sagittal planes. Radiologists refer to transverse planes as (trans)axial; convention dictates that axial anatomy is viewed as though looking from the feet towards the head when the patient is supine, unless otherwise specified.

Relationships (positional descriptors)

Structures nearer the head are described as superior, cranial or (sometimes) cephalic/cephalad, whereas structures closer to the feet are described as inferior. Caudal/caudad is most often used in developmental anatomy to refer to the hind end of an embryo. The terms medial and lateral indicate closeness to the median plane, medial being closer than lateral. In the anatomical position, the little finger is medial to the thumb, and the great toe is medial to the little toe. Specialised terms may be used to indicate medial and lateral. Thus, in the upper limb, the terms ulnar and radial are often used to indicate medial and lateral, respectively; in the lower limb, the terms tibial and fibular are often used to indicate medial and lateral, respectively. Terms may be based on developmental relationships; the border of the upper limb that includes the thumb, and the border of the lower limb that includes the great toe, are called the preaxial borders, whilst the opposite borders are identified as the postaxial borders. Various degrees of obliquity are acknowledged using compound terms, e.g. posterolateral.

Dorsal/ventral (rather than posterior/anterior, respectively) and rostral/caudal, are terms most frequently encountered in developmental anatomy (both as positional descriptors and as axes) and in postnatal neuroanatomy (see Sections 2 and 3). They are used less frequently in clinical practice, although there are exceptions. Thus, dorsal is used when referring to structures related to the dorsum of the hand or foot, e.g. dorsalis pedis artery, dorsal interossei. The terms palmar and plantar

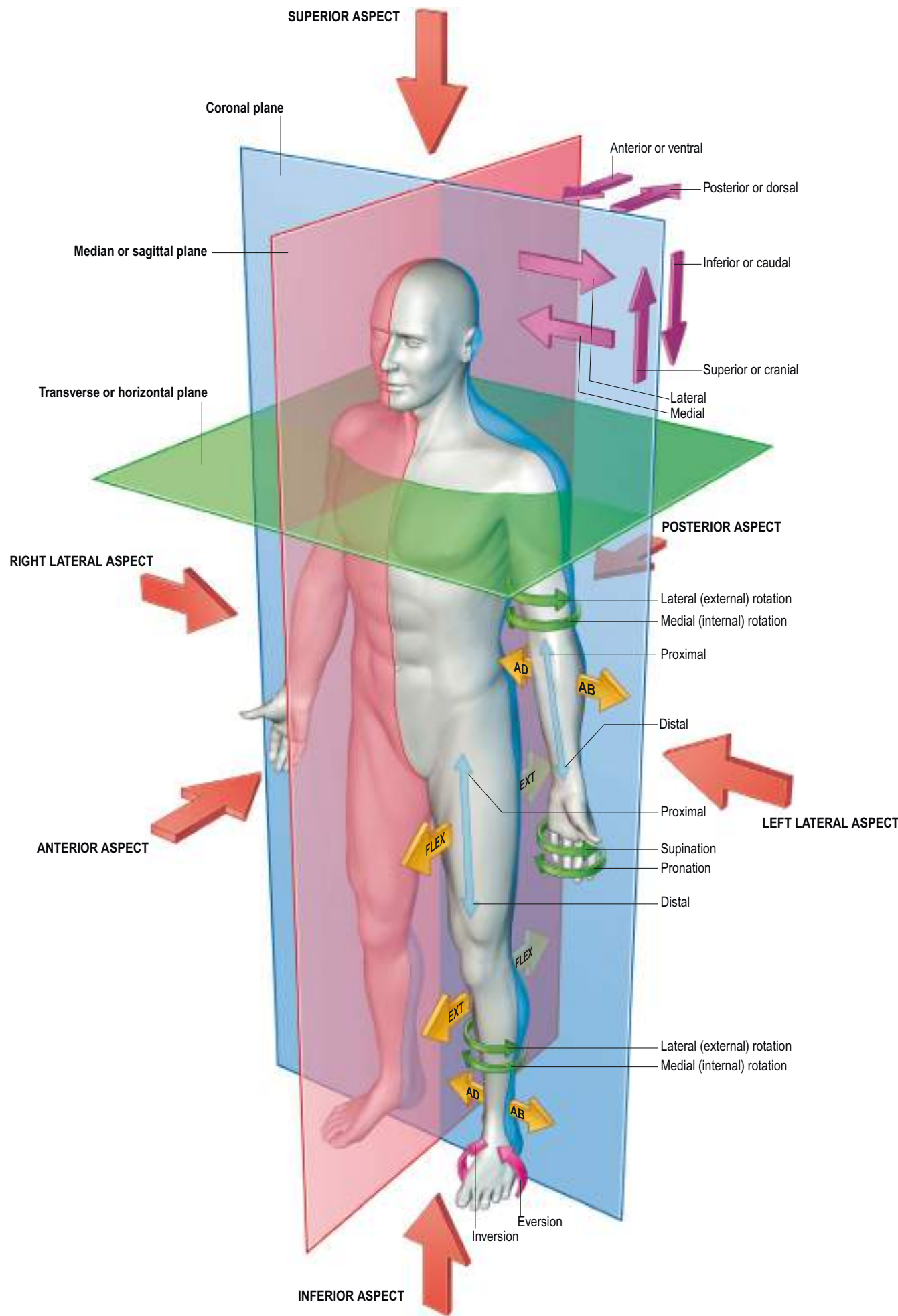


Fig. 1 The terminology widely used in descriptive anatomy. Abbreviations shown on arrows: AD, adduction; AB, abduction; FLEX, flexion (of the thigh at the hip joint); EXT, extension (of the leg at the knee joint).

refer to structures related to the palm of the hand and the sole of the foot, respectively; ventral is not commonly used in this context.

The terms proximal and distal are used when referring to the relationship of structures along a limb, taking the datum point as the attachment of a limb to the trunk (sometimes referred to as the root of that limb), such that a proximal structure is closer to the attachment of the limb to the trunk than a more distal structure. The terms proximal and distal are also used to describe the hierarchical branching of structures such as the bronchi, vessels and nerves, where distal is the furthest branch from the main trunk. The terms external (outer) and internal (inner) refer to the distance from the centre of an organ or cavity, e.g. the layers of the body wall, the three major regions of the ear, or the parts of the globus pallidus. External (lateral) and internal (medial) can also be used to describe both the direction of rotation and/or the muscles producing that rotation at the hip or glenohumeral joint. The terms superficial and deep are used to describe the relationships between adjacent structures, tissue planes or layers. Ipsilateral refers to the same side (of the body, organ or structure), bilateral to both sides, and contralateral to the opposite side.

The teeth are described using specific terms that indicate their relationship to their neighbours and to their position within the dental arch; these terms are described in Chapter 40.

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COMMENTARY: ETHICAL ISSUES IN ANATOMY

Ethics assessments fall on a trajectory from serious ethics misdemeanours in the past to adherence to high ethical standards today. This presents anatomists with a two-pronged challenge: confronting a dubious legacy and mapping an ethically sustainable future. Walking this line between the past and the future is a challenging exercise, and anatomists' task today is to rehabilitate their discipline by establishing it as an example of ethical best practice.

Even when anatomists have moved in ethical directions, the initial drawcard has invariably been a pragmatic one. An example is the move from using the bodies of criminals, those exhumed from graveyards and use of the unclaimed in poor houses and hospitals, to today's expectation that only those donated explicitly for anatomical purposes will be used (Jones and Whitaker 2012). This path towards increasing ethical best practice has been hard won.

The beginnings of modern anatomy were characterised by ethical duplicity, as illustrated by Andreas Vesalius (1514–1564), the Father of Modern Anatomy. Over the years he gained access to a relatively large number of bodies, ranging from condemned criminals and hanged prostitutes, to the graves of those who had recently died. Despite these practices considered dubious by current standards, his immense contributions to the development of modern anatomy endure. The ethical question is to determine when the negative associations of these dubious practices can be legitimately separated from the benefits of the anatomical data and concepts that resulted. Vesalius in the sixteenth century had no option but to use the unconsented bodies of the recently deceased. By contrast, the Nazi anatomists in the mid-twentieth century had well-established alternatives to using the bodies of religious and political prisoners put to death under appallingly unethical circumstances. This is the distinction between necessary research as a basis of scientific best practice, and unethical means of obtaining bodies for teaching.

In neither instance was there informed consent on the part of those whose bodies were being dissected. This was unremarkable since informed consent has only been recognised as an ethical driver in biomedical ethics since the latter part of the twentieth century (Jones and Whitaker 2009). This was when, in an increasing number of countries, donations became the pre-eminent source of bodies for anatomy. Prior to this, from the early nineteenth century onwards, unclaimed bodies dominated the anatomical lexicon as the preferred source of bodies for dissection. This meant that bodies were taken rather than donated, with no regard to the reasons why the bodies were being unclaimed by close relatives. The result was that in practice it was the bodies of the marginalised – the poor and mentally incapacitated – that ended up in dissecting rooms (Richardson 2000). In more extreme circumstances, the bodies of those deliberately put to death for political reasons were passed on to anatomy schools.

A case study in ethical dereliction in the use of unclaimed bodies is that of Nazi Germany, where anatomy departments benefited from a prolific supply of the bodies of victims of Nazi persecutions. One outcome of this was the publication of a masterpiece among anatomical atlases, Pernkopf's four-volume *Atlas of Topographical and Applied Human Anatomy* (Pernkopf's Atlas). This highly regarded atlas was prepared by Eduard Pernkopf and several illustrators over a 20-year period: 1937–1960 (Czech et al 2021). Eduard Pernkopf, Head of the Anatomy Department and Dean of the Medical School in Vienna, was actively involved in the acquisition of 1377 executed people, including members of the anti-Nazi resistance. Approximately 800 plates in the atlas are based on examination of the bodies of executed prisoners, some displaying Nazi symbols. A small number of other atlases, such as the 15th and 16th editions of the *Handatlas der Anatomie des Menschen* by Werner Spalteholz, also benefited from Nazi associations.

Once this background to Pernkopf's Atlas became public knowledge in the 1980s, it became the subject of ethical debate and fell into disrepute, although the originals are retained in the historical collection of the Medical University of Vienna. Its beauty, however, is tainted by its origin in ethical malfeasance. This raises the question of whether

ethically tainted illustrations (like unethically derived data) should be used today. Those opposing its continued educational use stress the fundamental evil involved in the creation of the atlas. The argument is that nobody should profit from the exploitation of human life, while other atlases (even if of lesser quality) are readily available. Those in favour of its continued educational use argue that victims of the Nazi regime are most appropriately honoured by continued use of the atlas, on condition that it serves as a source of ethical instruction (Hildebrandt 2016). However, there is consensus that the atlas should continue to be accessible as a historical artifact, as a means of commemorating the victims and as a reminder of anatomists' tragic involvement in Nazi crimes.

This debate is a salutary reminder that continued use of unethically derived human material, including images, blemishes anatomy as a discipline. The calamity of anatomists' behaviour during the Nazi era was that they overlooked core ethical values such as human dignity, equality and justice. They had learned little from anatomy's mottled history and had not discovered how to balance scientific objectivity with ethical behaviour.

An ongoing tragedy is that the influence of Pernkopf's Atlas continues through use without attribution of some of its illustrations in other anatomy atlases. This practice highlights the link between past unethical attitudes and current practice and could be halted if the authors of these atlases knew the provenance of the illustrations they were employing and replaced all illustrations originating in the Pernkopf era with contemporary illustrations untainted by Nazi contributions. Acknowledging that this will not be accomplished in the short term, it is an important goal, except possibly for limited neurosurgery use. In this latter instance, the conclusion reached by Jewish authorities is that in some unusually complex cases, it can be justified if its use will help save lives on condition that the history of the atlas is made known. This is a moral enigma, where data originating in evil acts can be employed for good ends. This tenuous balance between moral complicity and pragmatism has been encountered sporadically in the history of anatomy, as disputed means of obtaining dead bodies for dissection have led to revolutionary insights into the understanding of human anatomy.

Over a period of 40 years in the twentieth century, the world changed as the role of informed consent moved increasingly into the centre of bioethics, and into the world of anatomy. This transformation commenced in the early 1960s, marked in legislation by the 1961 Human Tissue Act in the United Kingdom. This represented a step forward with its recognition that the next of kin have rights marked by the emergence of the phrase 'lack of objection'. This means that following a postmortem, organs and body parts can only be removed and subsequently retained if the family does not object. Unfortunately, this move in an ethical direction encountered a major problem – the family did not have to be informed of the details of the postmortem. This still allowed brains to be routinely removed at postmortem for use, for example, in the teaching of neuroanatomy to medical students. Nevertheless, an ethical norm of lack of objection had been established, and it was the start of increasing awareness of the far more demanding ethical imperative of informed consent.

Throughout the 1980s and 1990s there was a gradual increase in the need to take next of kin into consideration. The 1988 Cartwright Inquiry in New Zealand was significant. Experimental treatment undertaken on patients was condemned because of the absence of their informed consent. A 1995 report by the Nuffield Council of Bioethics in the United Kingdom on human tissue reflected on ethical issues that were coming to light internationally in the 1980s and 1990s. It emphasised the importance of respect for the dead body in clinical medicine, and by implication, in anatomy.

The floodgates opened in the years 2000 and 2001, with a range of inquiries into medical scandals over the 1970s to 1990s in the United Kingdom, with that at Liverpool's Alder Hey Hospital standing out as an extreme example of unethical practices. Various guiding principles

head (*Continued*)

- mandible, 590
- skull, 590
- development of, 304–328, 304f, 305f
 - anomalies of face and neck
 - development, 328–328.e2
 - embryonic pharynx and pharyngeal arches, 305–311, 305f, 306f
 - face, 317–322, 318f, 319f
 - head-neck transition zone, 316–317
 - pharyngeal derivatives, 311–316, 313f
 - skull, 322–328, 322f
- fascia, 590
 - face, 590
 - neck, 590
 - scalp, 590
- innervation, 593–595
 - ciliary ganglion, 594
 - cranial nerves, 593
 - otic ganglion, 594
 - parasympathetic nerves, 593–594, 595f
 - pterygopalatine ganglion, 594
 - reflexes, 593
 - spinal nerves, 593, 595f
 - submandibular ganglion, 594
 - sympathetic nerves, 594–595
- lymphatic drainage, 590–592, 594f
- muscles, 590
- skeletal landmarks, 595–598, 596f, 597f
 - anterior aspect, 598f
 - lateral aspect, 596f
- skin, 590
 - face, 590
 - neck, 590
 - scalp, 590
- soft tissues, 598–600, 599f
- surface anatomy, 590–602
- vascular supply, 590–592
 - arteries, 590, 591–591.e1f, 591–591.e1f
 - carotid arteries, 590–592
 - subclavian artery, 592
 - veins, 592, 592f, 593f
- viscera, 598–600, 599f
- head folding, 204, 206f
- head-neck transition zone, 316–317
- hearing
 - anatomy of, 824–827, 824f
 - loss of, 826–827
- heart, 1144–1173
 - apex of. *see* apex, of heart
 - atrium
 - left, 1153–1155, 1154f, 1156f
 - right, 1147–1150
 - base, 1147
 - borders of, 1147
 - cardiac valve development, 233–235.e1
 - chambers, 1146f
 - compartments of, 227–230.e1, 227f
 - common atrium, 228–229.e1
 - inflow tract, 227–228.e1
 - sinu-atrial junction, 228–228.e1
 - ventricles, 229–230
 - conduction system, 1152f, 1161–1163.e1, 1162f
 - conduction tissues, 1161–1163.e1
 - congenital cardiac malformations, 1161–1161.e1
 - connective tissue of, 1160–1161.e1
 - development of, 223–248, 223f
 - cardiac valve development, 233–235.e1
 - compartments of heart, 227–230.e1, 227f

heart (*Continued*)

- embryonic blood, blood vessels and early circulation, 235–236
- fetal circulation, 243–248
- formation of heart tube, 223–227, 223f, 224f
- non-myocardial additions to, 235
- septation of embryonic
 - cardiac compartments, 230–233.e1
- external features, 1146–1147
- fibrous skeleton of, 1160–1161.e1
- general organisation of, 1145–1160.e1
- inferior border of, 1147
- innervation, 1170–1173
- lymphatic drainage of, 1170, 1171f
- pericardium. *see* pericardium
- plasticity, 153
- plexus, 1171–1173, 1172f
- right border of, 1147
- shape, 1146–1147
- size, 1146–1147
- superior border of, 1147
- surface anatomy of, 1064–1065
- surfaces of, 1147
 - anterior (sternocostal), 1147
 - inferior (diaphragmatic), 1147
 - left (pulmonary), 1147
 - right (pulmonary), 1147
 - sulci (grooves), 1145f, 1147
- vascular supply and lymphatic drainage, 1163–1170
- veins, 1169–1170, 1169f
- heart tube, formation of, 223–227, 223f, 224f
 - cardiac gene expression, differentiation, contraction, conduction and automaticity, 226–227, 226f, 227f
 - endocardial cushions, 225
 - looping of, 225–226, 225f, 226f
- Hedgehog (Hh) signalling pathway, 213
- heel bursae, 1546–1547
- heel region pain, 1523–1523.e1
- height
 - maternal, macrosomia in fetus, 411
 - velocity curves for, 418, 419f
- helicotrema, 300
- helper T cells, 81–82
- hemi-azygos vein, 1123
 - accessory, 1123
- hemidesmosomes, 28
- hemidiaphragms, 1111
- Hensen's node, 200
- hepatic artery, 1292, 1293–1293.e1f
- hepatic ducts, 1300–1301
- hepatic plates, 1297
- hepatic plexus, 1296
- hepatic portal vein, 1193, 1292–1293, 1294f
 - tributaries of, 1193
- hepatic portal venous system, 1193, 1193f
- hepatic stellate cells, 1298
- hepatic stem cells, 1298
- hepatic veins, 1293–1295.e1, 1295f
- hepatocytes, 1297–1298
- hepatoduodenal ligament, 1291–1292
- hepatopancreatic ampulla, 1301
- hernia/herniation
 - of anterolateral abdominal wall, 1214–1216
 - congenital diaphragmatic, 1115
 - epigastric, 1216
 - femoral, 1216–1216.e1
 - hiatal, 1115–1115.e1
 - incisional, 1216

hernia/herniation (*Continued*)

- of myopectineal orifice, 1214–1216.e1, 1215f
- Spigelian, 1216
- herpes zoster, 69
- hiatal hernia, 1115–1115.e1
- hiatus, in mylohyoid, 694
- hiatus hernia, 1136
- high endothelial venules, 143, 146, 146f
- highest (supreme) nasal concha, 747
- hilar plate, 1291–1292
- hilum, of lungs, 1104
- hindbrain. *see* rhombencephalon
- hindgut
 - development of, 370f
 - enteric, 374
 - mesenteries, 379–381
 - primitive, 373–375.e1
- hinge joints, 112
- hinge point, of neural plate, 255
- hip
 - pain, 1460–1461
 - perforator flaps in, 1480
 - surface anatomy of, 1437
- hip bone, 1444–1449, 1445f, 1446f
 - acetabulum, 1444
 - ilium, 1447–1448
 - innervation, 1445
 - ischium, 1448–1449
 - muscle attachments, 1445
 - obturator foramen, 1444
 - ossification, 1445–1446, 1446f
 - pubis, 1446–1447
 - structure, 1444–1445
 - vascular supply, 1445
- hip joint, 1457–1461, 1458–1458.e1f
 - arthroscopy, 1439
 - articulating surfaces, 1457
 - biomechanics of, 1461–1462
 - acetabulum, 1462
 - femur, 1461, 1461f
 - stability and movement, 1461
 - bursae, 1460
 - fibrous layer of articular capsule, 1457–1458
 - injection and aspiration, 1439
 - innervation, 1460
 - ligaments, 1458–1460, 1459f
 - movements, 1462–1465, 1462f, 1463f, 1464f
 - forces acting on, 1462–1464, 1464f
 - muscles producing, 1464–1465
 - relations, 1458, 1459–1459.e1f
 - synovial membrane, 1460, 1460–1460.e1f
 - vascular supply and lymphatic drainage, 1460
- hippocampal commissure, 579
- hippocampal formation, of brain, 562f, 563–564.e1, 563f
- hippocampus, development, 268–270
- Hirschsprung disease, 69, 283, 375–375.e1
- Hjortsjö's crook, 1299–1300
- homunculus, in human brain, 568f
- horizontal cells, of retina, 867–868
- horizontal lines and planes, abdomen, 1196–1198
- Horner syndrome, 656
- horseshoe kidney, 1345–1346, 1346f
- housekeeping proteins, 210–211
- HOX* genes, 305
- HOX* (*Hox*) genes
- human cerebellar neuroimaging, structure and function, 525–527.e1, 526f

human preimplantation embryos, in vitro

- culture of, 189
- Human Protein Atlas, 214
- humero-radial joints, 1003–1005
 - movements of, 1007–1008
- humero-ulnar joints, 1003–1005
 - movements of, 1007–1008
- humerus, 962–964, 962f, 997–999
 - body of, 963–964
 - distal end of, 964, 997, 998f
 - ossification of, 964, 965f, 999
 - proximal end of, 963
- Huntington disease, 543
- hyaline cartilage, 93–94
 - biomechanics of, 130, 130f
- hyaluronic acid, media, 147
- hyaluronidase, in morphogenesis, 212f
- hydrocele, 1381–1381.e1
- hyoepiglottic ligaments, 777
- hyoglossus muscle, 696–697
- hyoid bone, 590, 629–630, 629f
 - body of, 629
 - greater horns (cornua) of, 629–630
 - lesser horns (cornua) of, 630
 - ossification, 630
- hypaxial muscle, development, 338
- hypoblast, 187, 200, 207
- hypodermis, 160, 161f
- hypogastric nerves, 1191
- hypoglossal nerve, 655, 699
 - communicating branches, 655
 - distribution branches, 655
 - lesions, 655
 - meningeal branches, 655
 - muscular branches, 655
- hypoglossal nucleus, 488–489
- hyponychium, 166
- hypopharyngeal diverticula, 767–768
- hypophyseal placode, 253
- hypophysis (pituitary gland), 539–541, 539f
 - adenohypophysis, 540–541, 540f
 - arteries and veins, 541
 - epithalamus, 541–542
 - fields of Forel, 541
 - habenular nuclei, 541–542
 - neurohypophysis, 540, 540f, 540t
 - pineal gland, 542.e1f, 542
 - posterior commissure, 542
 - stria medullaris thalami, 541–542
 - subthalamic nucleus, 541
 - subthalamus, 541
 - zona incerta, 541
- hypothalamospinal fibres, 477
- hypothalamus, 535–539, 535f
 - afferent connections, 538–539
 - arcuate nucleus, 537–538
 - connections, 538–539
 - dorsomedial nucleus, 538
 - efferent connections, 539
 - lateral zone, 538
 - mammillary bodies, 538
 - paraventricular nucleus, 537–537.e1
 - periventricular zone, 537–538
 - suprachiasmatic nucleus, 536–537
 - supra-optic nucleus, 537–537.e1
 - ventromedial nucleus, 538
 - zones and nuclei, 535–538, 536f, 537f, 537t
- Ig-CAMs, 27–28.e1
- ileo-caecal fold, 1235
- ileo-caecal junction, in caecum, 1270–1271
- ileo-caecal mesentery, 1235

- ileum, 1258–1261, 1259f
-  anatomical differences between, 1258–1258.e2, 1259f
- innervation of, 1261
- vascular supply and lymphatic drainage, 1258–1261
- iliac arteries, 1200
- iliac fascia, 1217
- iliac nodes, 1226
- iliacus muscle, 1220, 1466
- iliocapsularis muscle, 1458–1460
- iliococcygeal raphe, 1339
- iliococcygeus muscle, 1329
- iliocostalis muscle, 909–910
- iliofemoral ligament, 1458–1460
- iliohypogastric nerve, 1228
- ilio-inguinal nerve, 1228
- iliolumbar artery, 1332
- iliolumbar ligament, 907, 1456–1457
- iliopsoas fascia, 1217, 1443
- iliotibial tract, 1442–1443
- ilium, 1447–1448
- anterior border, 1447
- gluteal surface, 1448
- iliac crest, 1447
- iliac fossa, 1448
- innervation, 1448
- medial border, 1448
- muscle attachments, 1448
- ossification, 1448
- posterior border, 1448
- sacropelvic surface, 1448
- vascular supply, 1448
-  immunoglobulin-like cell adhesion molecules (Ig-CAMs), 27–28.e1
- impingement injury, 1457–1458
-  implantation, 189–190.e1, 190f, 209
- amniotic fluid, 198
-  anomalies of, 190–190.e1
- fetal membranes, 195–197
- allantois, 196, 197f
- amnion, 196–197
- chorion, 196
- yolk sac, 195–196, 196f
- site of, 185–186
- umbilical cord, 198–199
-  impressions, on lungs, 1095–1096.e1
- in vitro fertilisation, 182–183
- incisional hernia, 1216
- incisivus labii inferioris muscle, 681
- incisivus labii superioris muscle, 681
- incremental lines, of dentine, 707–708
- incus, 301, 805
- ossification, 805
-  indirect inguinal hernia, 1214–1215.e1
- induction, embryonic cells, 209–213, 210f, 211f
- infant(s)
- ear, 303
- growth of, 415–418, 417f
- gut maturation, 412
- injury to, 422
- infection(s)
-  in arm, 956–956.e1
-  of hand, 1027–1026.e2
-  in shoulder girdle, 956–956.e1
- inferior alveolar artery, 711, 733
- inferior alveolar nerve, 711–712, 736
- inferior anal nerve, 1343
- inferior anorectal artery, 1278, 1342
- inferior border
- of pancreas, 1306
- of spleen, 1315
-  inferior cerebellar peduncle, 486–487.e1
- inferior cervical ganglion, 656
- inferior colliculus, 497–498
- inferior concha, 745–746
- inferior deep cervical nodes, 649
- inferior epigastric artery, 1198, 1203–1205, 1204f, 1334
- inferior epigastric iliac nodes, 1336
- inferior epigastric vein, 1203–1205, 1204f, 1336
- inferior extensor retinaculum, of ankle, 1521–1522
- inferior fibular retinaculum, 1522
- inferior fronto-occipital fasciculus, 577
- inferior gemellus muscle, 1470, 1470f
- inferior genicular arteries, 1515
- inferior gluteal artery, 1334
- inferior gluteal nerve, 1484
- inferior gluteal veins, 1336
- inferior hypogastric plexus, 1191
- inferior labial artery, 683
- inferior laryngeal artery, 645, 789
- inferior laryngeal vein, 789
- inferior lateral brachial cutaneous nerve, 993
- inferior longitudinal fasciculus, 577
- inferior longitudinal lingual muscle, 697
- inferior meatus, 745–746
-  inferior mesenteric artery, 1221, 1277–1277.e1f, 1277–1278, 1277f
- inferior mesenteric nodes, 1226
- inferior mesenteric plexus, 1190
- inferior mesenteric vein, 1278–1279, 1279f
- inferior nasal concha, 604f, 669f, 670–671
- ossification, 671
- inferior oblique muscle, 834
-  inferior olivary complex, 487–488.e1
- inferior ophthalmic vein, 840
- inferior orbital fissure, 829
- inferior pancreatic artery, 1310
- inferior pancreaticoduodenal artery, 1257, 1308–1309
- inferior petrosal sinus, 621–622, 647
- inferior pharyngeal constrictor muscle, 767
- inferior phrenic arteries, 1115–1116, 1115f, 1221
- inferior phrenic veins, 1224
- inferior rectus muscle, 833
- inferior (lower) subscapular nerve, 990
- inferior suprarenal arteries, 1324
- inferior surface
- of heart, 1147
- of liver, 1287f, 1288
- inferior thyroid artery, 645
- muscular branches of, 645
- inferior tibiofibular joint, 1537–1539
-  inferior transverse scapular ligament, of scapula, 962–962.e1
- inferior tympanic artery, 640
- inferior ulnar collateral artery, 989
- inferior vena cava, 240, 1179–1180, 1200, 1223–1224
- collaterals developing, 1224
- relations of, 1223
- tributaries of, 1223–1224, 1223f
- inferior vesical artery, 1334
- in urinary bladder, 1365
- inflammation
- endothelial permeability and, 143
- wound healing and, 169–170
- inflammatory cells, into brain, entry of, 61f, 62
- infrahyoid artery, 640
- infrahyoid muscles, 636
- infrahyoid prelaryngeal nodes, 649
- inframesocolic region, 1240
- infraorbital artery, 684, 737
- infraorbital nerve, 687, 738, 843
- infraorbital veins, 685, 840
- infrapinnatus fascia, 956
- infrapinnatus muscle, 982
- infratemporal fossa, 606, 719–725, 719f, 740b
-  bones, 719–725.e1
-  mandible, 722–725.e1
-  sphenoid, 719–722.e1, 720f
- spread of infection from, 737
- infratrochlear nerve, 686, 842
- ingression, 201, 216
- inguinal canal, 217–218, 1213–1214, 1213f
- inguinal hernia
- direct, 1215
-  indirect, 1214–1215.e1
- inguinal ligament, 1210–1211
- inguinal region pain, 1460–1461
- injection(s), joint, retropatellar approach, 1439
- injury
- to infant, 422
- mechanobiology, 134
- inner hair cells, 818
- innervation
- of arm, 990–993
- extrinsic, 1195–1196
- of face, 685–688
- of head, 593–595
- intrinsic, 1196, 1196f
- maturation of, 288–289
- of neck, 593–595, 650–655
- parasympathetic, 1189
- of pectoral girdle, 940–946
- of serous pericardium, 1144
- sympathetic, 1187–1189
- of thoracic skin, 1067–1068, 1068f
- of upper limb, 940–946
- instructive interactions, embryonic tissue, 211–212
- insular lobe
- of brain, 574–575, 574f
- internal structure and connectivity, 575
- insulin-like growth factor (IGF-2), 418–419
-  integrins, 27–28.e1, 207
- interalveolar pores, 1108
- interalveolar septum, 1107–1108
- intercalated discs, 151, 151f
- intercavernous sinuses, 624
- intercellular junctions, 26–29, 27f
- anchoring, 28–29
- fascia adherens, 28
- focal adhesion plaques, 28–29
- hemidesmosomes, 28
- maculae adherentes, 28
- zonula adherens, 28
- communicating, 29
- gap, 29
- specialised, 28–29
- tight, 28
- interchondral joints, 1076
- interclavicular ligament, 964
- intercoccygeal joints, 907
- intercostal arteries, 1115
- intercostals, 1077–1078, 1077f
- intercuneiform joint, 1543
- interdigitating dendritic cells, 89–90
- INTERGROWTH-21st project, 412, 413f
- interlobar arteries, 1350–1352, 1351f
- interlobular arteries, 1350–1352, 1351f
- intermediate cuneiform bone, 1533
- intermediate filaments, 16–17
- intermediate layer, of spinal cord, 923
- intermediate mesenchyme, 222
- intermesenteric plexus, 1190
- intermetacarpal joints, 1037
- intermetatarsal joints, 1543–1544
- intermuscular septa, 1443
- internal abdominal oblique muscle, 1211
- internal acoustic meatus, 796, 812–813, 812f
- internal anal sphincter, 1282
- internal capsule, 457, 579–580
- internal carotid artery, 449–451f, 449–454, 641–643, 642f, 807
- cavernous part, 451
- intracranial (cerebral) part, 451–452, 453f
- petrous part, 451
- internal ear, 299–300, 299f, 810–827
- arteries of, 819
- fluids, composition of, 812
- innervation of, 819–824
- surgical approaches to, 827
- vascular supply of, 819
- veins of, 819
- internal iliac artery, 1331–1334, 1332f, 1333f
- anterior division branches of, 1333–1334
- posterior division branches of, 1331–1333
- internal iliac nodes, 1336
- internal iliac vein, 1335–1336, 1335f
- internal jugular vein, 601–602
-  catheterisation, 648–648.e1
- internal laryngeal nerve, 790
- internal pudendal artery, 1334, 1342
- internal pudendal veins, 1335, 1343
- internal thoracic artery, 645, 1123
- internal thoracic veins, 1123
- internal urethral orifice, 1365
- internal vertebral venous plexus, 885
- interneurons, cerebellar cortical, 510
- internodal atrial myocardium, 1162–1163
- interoceptors, 71
- interossei muscle, 1045–1046
- dorsal, 1046, 1046f
- palmar, 1045–1046, 1045f
- interosseous ligament, 1543
- of distal carpal row, 1034
- of proximal carpal row, 1034
- interosseous membrane, 1007, 1488–1489, 1488f
- interosseous nerve
-  anterior, 1018–1019, 1020–1020.e1f
- posterior, 1021
- interosseous sacro-iliac ligament, 1456–1457
- interosseous talocalcaneal ligament, 1539
- interosseous tibiofibular ligament, 1538
-  interphalangeal joints, 1038–1039.e1, 1039f, 1545
- interplexiform cells, 868
- intersphincteric space, 1282
- interspinales muscle, 912
- interspinous ligaments, 899f, 900
- interstitial cell groups, 522
- interstitial cells of Cajal, 1195, 1253, 1265
- interstitial cells of Cajal-like cells, 1367
- interstitial endocrine cells, 1381
- Interstitial nucleus of Cajal, 499
- interstitial tissue, 1381
- interstitiospinal tracts, 477
- intertransversarii muscle, 912
- intertransverse ligaments, 900
- intertrochanteric crest, 1453
- intertrochanteric line, 1453
- intervertebral disc, 901–902, 901f
- ‘at risk’ structures of, 902
- development, 333–338
- innervation of, 902, 902f
- ligaments of, 902

intervertebral disc (*Continued*)

- mechanical properties of, 131
-  prolapsed, 902–903, 902f, 903–903.e1f, 903f
- vascular supply of, 902
- intervertebral foramina, 888–889, 888f
- intervertebral joints, 901–904
 - articulating surfaces of, 901–902, 901f
- intervertebral veins, 885, 886f
- intervillous space, 193–195, 193f
- intestinal glands
 - large intestine, 1283
 - small intestine, 1263–1264
- intestinal intraepithelial lymphocytes (IEL), 90f
- intestinal stomas, 1200
- intestinal villi, 1262, 1263f, 1264f
- intima, 141
 - microstructure of, 144–147
 - tunica, 141
- intra-articular ligament, 1075
- intra-articular menisci, 111
- intra-articular sternochondral ligaments, 1076
- intracellular proteolytic mechanism, 30
- intracranial region, 613–627
- intracranial venous sinus thrombosis, 461–462
- intraembryonic coelom, 204–206, 206f
- pleural cavity development, 357–358, 358f, 359f
- intraflagellar transport (IFT), 49
- intraflagellar transport pathways, 26
-  intrahepatic biliary tree, 1299–1300.e1
 - segmental and sectoral ducts, 1299–1300, 1300f, 1300t
- intralaminar nuclei, 534
- intramanchette transport (imT) pathway, 26
- intramedullary arteries, 929
- intramembranous ossification, 103
- intramural part, of urethra, 1367
- intramuscular injection, in lower limb, 1439
- intrapulmonary vasculature development, 356
- intratemporal vestibular nerve, 820, 821f
-  intrauterine maturation, respiratory system development, 356–357.e1
- intrinsic muscles, 697–698, 698f
- intrinsic neurons, 437–438
- intrinsic synapses, 545
- iris, 858–860, 860f
 - differentiation of, 295, 296f
 - innervation of, 858–859
 - muscles of, 858–859
 - vascular supply of, 859–860
- irregular connective tissues, 43
- ischaemic stroke, 457–459
- ischio-anal fossa, 1338–1339
- ischiocavernosus muscle, 1342, 1342f
- ischiofemoral ligament, 1458–1460
- ischium, 1448–1449
 - innervation, 1449
 - ischial ramus, 1449
 - ischial spine, 1449
 - ischial tuberosity, 1449
 - muscle attachments, 1449
 - ossification, 1449
 - vascular supply, 1449
- isocortex, 557f, 566–570
 - frontal lobe, 566–570
 - insular lobe, 574–575, 574f
 - layers of, 553f
 - occipital lobe, 571–572
 - parietal lobe, 570–571
 - temporal lobe, 572–574, 573f
- isthmus, oropharyngeal, 693

J

jaw

- eccentric closing, 730
- eccentric opening, 730
-  movements, 729–730.e1
- symmetrical closing, 730
- tissue spaces around, 716–718, 717f
- jaw jerk reflex, 496
- jejunal artery, branches, 1257
-  jejunum, 1257–1258.e1, 1257f, 1258f
-  anatomical differences between, 1258–1258.e2, 1259f
- branches, 1259f, 1260, 1260f
- joint lubrication, of temporomandibular joint, 727
- joint receptors, 74
 - type I, 74
 - type II, 74
 - type III, 74
 - type IV, 74
- joints, 107–115
 - of ankle
 - arthroscopy, 1440
 - injection and aspiration, 1439
 - skin incision, 1440
 -  of arm, 964–975.e1
 - ball-and-socket, 112–113
 - carpometacarpal, 1036–1037
 - second to fifth, 1036–1037
 - of thumb, 1036
 - cartilaginous, 108–109, 109f
 - primary, 108, 109f
 - secondary, 108–109, 109f
 - costotransverse, 1075–1076
 - costovertebral, 1074–1077
 - development of, 115
 - of digits
 - innervation of, 1040
 - movements of, 1038
 -  of elbow, 1003–1008, 1004–1004.e1f, 1005f
 - ellipsoid, 112
 - fibrous, 107–108, 108f
 - of foot, skin incision, 1440
 - of hand, vascular supply of, 1039–1040, 1040f
 - of head, 590
 - hinge, 112
 - of hip
 - arthroscopy, 1439
 - injection and aspiration, 1439
 - interchondral, 1074–1077
 - intermetacarpal, 1037
 -  interphalangeal, 1038–1039.e1, 1039f
 - of knee
 - arthroscopy, 1439–1440
 - injection and aspiration, 1439
 - skin incision, 1440
 - limb development, 343–344
 - of lower limbs, 1423
 - manubriosternal, 1074
 - metacarpophalangeal, 1037–1038, 1037f
 - midcarpal, 1032
 - force transmission of, 1035
 - of neck, 590, 630
 - of pectoral girdle, 935, 936f
 - pivot, 112
 - plane, 112
 -  radiocarpal, 1031, 1032–1032.e1f, 1033–1033.e1f
 - force transmission of, 1035, 1035f, 1036f
 -  loading of, 1034–1036.e1

joints (*Continued*)

-  movements of, 1034–1036.e1
 -  of rib heads, 1074–1075, 1074f, 1075–1075.e1f
 - saddle, 112
 - sternochondral, 1074–1077, 1076f
 - sternoclavicular, 1074
 - sternocostal, 1074–1077, 1076f
 - synovial, 109–115, 110f
 - classification of, 112–113, 112f
 - innervation of, 111–112
 - lymphatic drainage of, 111
 - mechanical properties of, 131, 131f
 - vascular supply of, 111
 - of thorax, 1060, 1060f, 1074–1077
 - of thumb, movements of, 1038
 - ulnocarpal, force transmission of, 1035, 1035f, 1036f
 - of upper limb, 935, 936f
 - of vertebral column, 901–907, 901f
 - of wrist, 1031–1040
 - force transmission of, 1035
 - innervation of, 1040
 - loading, kinetics, 1035
 - movements of, 1034–1035
 - vascular supply of, 1039–1040, 1040f
 - xiphisternal, 1074
 -  jugular vein catheterisation, internal, 648–648.e1
 - juxtaparanodes, 65
- K
-  karyotyping, 19–19.e1, 19f
 - keratin(s), 158, 158f
 - keratinised epithelium, 34, 34f
 - keratinocytes, 155–158
 -  kidney, 1199, 1344–1356.e2
 - absent, 1345, 1345f
 - calyces, 1349–1350.e1, 1350f, 1356
 - corpuscle, 1354, 1354f
 - development of
 - ascent, 387, 396f
 - metanephric, 384–385, 386f
 - ectopic, 1345, 1345f
 - glomerular tuft, 1355–1356, 1355f, 1356f
 - horseshoe, 1345–1346, 1346f
 - innervation in, 1354
 - internal macrostructure of, 1348–1350.e1, 1350f
 - lymphatic drainage, 1349–1352
 - microstructure of, 1354–1356
 - nephron, 1354
 - other cells, 1356
 -  relations of, 1344f, 1346–1348, 1347–1347.e1f, 1348–1348.e1f, 1349f
 - renal fascia, 1346, 1347f
 -  renal pelvis, 1349–1350.e1, 1350f, 1356
 - surfaces of, 1349f
 - vascular supply, 1349–1352
 - afferent glomerular arterioles, 1350–1352, 1351f, 1353f
 - arcuate arteries, 1350–1352, 1351f
 - efferent glomerular arterioles, 1350–1352, 1351f, 1353f
 - interlobar arteries, 1350–1352, 1351f
 - interlobular arteries, 1350–1352, 1351f
 - lobar arteries, 1350–1352, 1351f
 - renal arteries, 1349–1352, 1351f
 - renal veins, 1352, 1354f

kidney (*Continued*)

-  segmental arteries, 1349–1350, 1352–1352.e1f
 - vessels, 1356
 -  Kienböck disease, 1029–1029.e1
 - kinematics
 - of carpal bones, 1034–1035
 - during gait, 1433–1434.e4
 -  Kirk's arcade, 1310
 - knee, 1486–1520
 - biomechanics of, 1502–1506
 - knee joint kinematics, 1503–1505, 1504f, 1505f
 - movements, 1502–1503
 - soft tissue mechanics, 1506
 - innervation, 1518–1520
 - common fibular nerve, 1519–1520, 1519f
 - knee joint, 1518
 - saphenous nerve, 1518
 - tibial nerve, 1518–1519
 - joints, 1494–1502
 - arthroscopy, 1439–1440
 - injection and aspiration, 1439
 - patella, 1494–1495
 - skin incision, 1440
 - superior tibiofibular joint, 1494
 - tibiofemoral articulation, 1495–1502, 1496–1496.e1f, 1497f
 - muscles, 1506–1507
 - skin, 1486–1487
 - innervation, 1486–1487
 - vascular supply and lymphatic drainage, 1486, 1486f
 -  soft tissues, 1487–1489.e1
 -  deep fascia, 1488–1489.e1
 -  popliteal fossa, 1487–1487.e1f, 1487–1488, 1487f, 1488f
 - surface anatomy of, 1434, 1435f, 1437
 - vascular supply and lymphatic drainage, 1514–1518
 - arteries, 1514–1517
 - lymphatic drainage, 1518
 - veins, 1517–1518
 - knee reflex, 1432
- L
- labia majora, 1392
 - labia minora, 1392
 - labour, 1413–1415
 - vaginal delivery, 411
 - labyrinthine artery, 819
 - labyrinthine segment, facial nerve, 808
 - lacrimal apparatus, 297
 - lacrimal artery, 684, 838–839
 - lacrimal bone, 604f, 671
 - ossification, 671
 - lacrimal drainage pathway, 847–849
 - lacrimal gland, 296–298, 847
 - innervation of, 847
 - microstructure of, 847, 848f
 - vascular supply of, 847
 - lacrimal nerve, 686, 842
 - lacrimal system, 846–849, 847f
 - lacrimation reflex, 849
 - lactation, breast, 1089, 1089f
 - lacunar ligament, 1214, 1214f
 - lamellar bone, 99, 100f
 - lamina marginalis (lamina I), 466–467, 467f
 - lamina propria, 1195, 1253
 - oesophagus, 1134
 - small intestine, 1264–1265
 - urinary bladder, 1367
 - lamina vitrea (Bruch's membrane), 855

- laminae
I–IV, 465
IX, 465
V and VI, 465
VII, 465
VIII, 465
- laminar zone, of optic nerve head, 871
- laminin, 42, 207
- Langerhans cells, 159, 159f, 288
- laparoscopy, pneumoperitoneum for, 1200
- large intestine, 1266–1285
anal canal, 1280–1283, 1281f
anal continence, 1283
anal incontinence, 1283
hindgut-derived region of, 1275–1280
descending colon, 1275, 1275f
left colic flexure, 1275, 1275f
mesocolon, 1276
mesorectum, 1276–1277.e1
motor function of, 1280
rectal fasciae, 1276–1277.e1
rectum, 1276
vascular supply and lymphatic drainage of, 1277–1279
innervation of, 1279–1280
maturation of, 374
microstructure of, 1283–1285, 1284f
mucosa, 1283–1284
muscularis externa, 1284
serosa, 1284–1285
submucosa, 1284
midgut-derived part, 1269–1274
caecal volvulus, 1271
caecum, 1269–1271, 1271f
- laryngeal artery, inferior, 645
- laryngeal carcinoma, 781–781.e1
- laryngeal cartilages, 590
calcification of, 775–776
- laryngeal cavity, 778–782, 779–779.e1f
laryngeal obstruction and trauma, 781–782
laryngoscopic examination, 781
lower part, 781
middle part, 779–781
upper part, 778–779
- laryngeal inlet, 763–764, 778–779
- laryngeal vestibular diverticulum, 312–313, 313f
- laryngeal vestibule, 779
- laryngoceles, 780–780.e1
- laryngopharynx, 763–768.e1
anatomical landmarks in, 772
laryngeal inlet, 763–764
obstructive sleep apnoea and snoring, 768–768.e1
pharyngeal plexus, 768
piriform fossa, 763
tumours, 772
- larynx
anatomy of speech, 792
development of, 312–313
functional anatomy of, 786–789
innervation, 789–792, 790f
autonomic, 792
interconnections (anastomoses)
between laryngeal nerves, 791
lesions of the vagus nerve and recurrent laryngeal nerve paralysis, 791–792
recurrent laryngeal nerve, 790–791, 791f
superior laryngeal nerve, 790
joints, 776
arytenocorniculate joints, 776
cricoarytenoid joint, 776
cricothyroid joint, 776, 776f
innervation of, 776
- larynx (*Continued*)
microstructure of, 778
muscles, 782–786
extrinsic muscles, 782–783
intrinsic muscles, 783–786, 785f
nodal spread of laryngeal tumours, 789
paediatric, 782
paralumenal spaces, 782
paraglottic space, 782
pre-epiglottic space, 782, 783f
subglottic space, 782
sacculi of, 780–780.e1
skeleton of, 773–776, 773f, 774f
arytenoid cartilage, 775
calcification of laryngeal cartilages, 775–776
corniculate cartilages, 775
cricoid cartilage, 775–775.e1
cuneiform cartilages, 775
epiglottis, 773–774
thyroid cartilage, 775
triticeal cartilages, 775
soft tissues, 776–778
extrinsic ligaments and membranes, 777
intrinsic ligaments and membranes, 777–778, 777f
vascular supply and lymphatic drainage, 789, 789f
arteries and veins, 789
lymphatic drainage, 789
ventricle of, 780
vestibular folds and ligaments, 779–780
vocal folds and ligaments, 780–781.e1, 780f
lateral antebrachial cutaneous nerve, 1021
lateral aortic (para-aortic) nodes, 1226
lateral arcuate ligament, 1111
lateral canthus, 845
lateral circumflex femoral artery, 1479
lateral collateral ligament, 1536, 1537f, 1538–1538.e3f
lateral costotransverse ligament, 1075
lateral cricoarytenoid muscle, 784
lateral cuneiform bone, 1533
lateral dorsal nucleus, 534
lateral epicondyle, 998–999
lateral femoral cutaneous nerve, 1228–1229, 1481
lateral geniculate nucleus, 533–534, 533f
lateral intermuscular septum, 1524
lateral lemniscal nuclei, 493–494
lateral ligaments, soft tissues and, 1499–1500
lateral longitudinal arch, 1545
lateral nasal artery, 683
lateral (superior/upper lateral) nasal cartilage, 741
lateral nuclei, thalamus, 530–534
lateral patellar dislocation, 1495
lateral pectoral nerve, 990
lateral plantar artery, 1516, 1553
lateral plantar nerve, 1554
lateral plate, of embryo, 202–203, 204–205, 206f, 222
lateral posterior nucleus, 534
lateral pterygoid muscle, 732–733
lateral pterygoid nerve, 736
lateral pterygoid plate, 721
lateral rectus muscle, 834
lateral rotation
of flexed leg, 1503
of hip, 1464–1465
lateral sacral arteries, 1332
lateral sacral veins, 1336
- lateral sesamoid bone, of first metatarsophalangeal joint, 1535
- lateral soft tissue area, 741
- lateral splanchnic arteries, 238
- lateral talocalcaneal ligament, 1539
- lateral temporomandibular ligament, 726
- lateral thoracic artery, 987
- lateral ventricle, of brain, 440–442, 441f, 442f
- lateral vertebral muscles, 637–638
- lateral vestibular nucleus, 523
- lateral zone, hypothalamus, 538
- lateroconal fascia, 1219
- latissimus dorsi muscle, 980–982
vascular supply, 980–981
- L-DOPA induced dyskinesia, 543
- least thoracic splanchnic nerve, 1188
- left atrium, 1153–1155, 1154f, 1156f
- left colic artery, 1277–1278, 1278f
- left colic flexure, 1275, 1275f
- left colic vein, 1279
- left common carotid artery, 1178
- left common iliac artery, 1331
- left coronary artery, 1166–1168, 1167f, 1168f
- left coronary plexus, 1172
- left gastric artery, 1245–1246, 1246f
- left gastro-omental artery, 1246
- left hepatic veins, 1295
- left lobe, of liver, 1288
- left marginal veins, of heart, 1170
- left phrenic nerve, 1116
- left portal fissure, 1288
- left suprarenal gland, 1322–1323
- left surfaces, of heart, 1147
- left ventricle, 1155–1159
general and external features, 1155–1156, 1156f, 1157f
inferior vein of, 1170
internal features of, 1156–1159, 1157f, 1158f
papillary muscles of, 1159
- leg(s)
bones, 1486–1494
fibula, 1492–1493
patella, 1493–1494, 1493f, 1494f
tibia, 1489–1492, 1490f
innervation, 1518–1520
common fibular nerve, 1519–1520, 1519f
knee joint, 1518
saphenous nerve, 1518
tibial nerve, 1518–1519
joints, 1494–1502
patella, 1494–1495
superior tibiofibular joint, 1494
tibiofemoral articulation, 1495–1502, 1496–1496.e1f, 1497f
muscles, 1507–1514
anterior (extensor) compartment, 1507–1510, 1508f
deep flexor group, 1512–1514, 1513f
lateral (fibular, peroneal) compartment, 1510
posterior (flexor) compartment, 1510
superficial flexor group, 1510–1512, 1511f
skin, 1486
innervation, 1486
vascular supply and lymphatic drainage, 1486
soft tissues, 1487–1489.e1
deep fascia, 1488–1489.e1
popliteal fossa, 1487–1487.e1f, 1487–1488, 1487f, 1488f
- leg(s) (*Continued*)
surface anatomy of, 1434–1435, 1435f, 1436f, 1437
vascular supply and lymphatic drainage, 1514–1518
arteries, 1514–1517
lymphatic drainage, 1518
veins, 1517–1518
- lens, 860–863, 861f
capsule of, 861–862, 861f
epithelium of, 861f, 862
fibres, 862, 862f, 863f
- lens vesicles
endothelial channels surrounding, 294
formation of, 292, 293f
- lentiform complex, in basal ganglia, 543, 543f
- lesser curvature, stomach, 1243, 1244f
- lesser occipital nerve, 629
- lesser omentum, 1233–1234
of liver, 1291
peritoneal attachments of, 1237
- lesser pelvis, 1328–1343
coccygeal plexus, 1337
fasciae, 1328–1331
innervation of, 1336–1338, 1337f
lumbosacral trunk, 1336–1337
lymphatic drainage, 1331–1336, 1336f
muscles, 1328–1331
sacral plexus, 1336–1337
vascular supply, 1331–1336
arteries, 1331–1334, 1332f, 1333f
veins, 1334–1336, 1335f
- lesser sac
development
early stages of, 376–377
later stages of, 377–379, 378f
maturation of, 379
- lesser sciatic foramen, 1457
- lesser thoracic splanchnic nerve, 1188
- lesser trochanter, 1453
- leukocytes, 78–82, 86f
endothelial cell interactions, 146, 146f
- levator anguli oris muscle, 679
- levator ani muscle, 1329–1330, 1329f
- levator labii superioris alaeque nasi muscle, 679, 744
- levator labii superioris muscle, 679
- levator palpebrae superioris muscle, 832–834
- levator scapulae muscle, 977
- levator veli palatini muscle, 764, 764f, 765f, 766f
- levatores costarum muscle, 1078
- levodopa, for Parkinson disease, 549
- ligamenta flava, 899–900, 899f, 900f
- ligaments, 128
annular, 1007
biomechanics of, 130
connecting axis and occipital bone, 905, 905f, 906f
of face, 665
instability of, 900–901
of pelvis, 1398–1403
of temporomandibular joint, 726–727
of Testut, 1034
of wrist, 1032–1034
- ligamentum teres, 1458–1460, 1460f
- ligamentum venosum, 1291
- light-sheet microscopy, 173
- limb, length of, 419
- limb development, 340–352, 340f
apical ectodermal ridge, 342–343, 342f
arteries, 344–345
axes specification, 341–343.e1, 341f
ectodermal axial specification, 343

- limb development (*Continued*)
embryonic movements, 346
fetal movements, 346
genes and molecules in, 343–343.e1
lower, 349–351
arteries, 349–350, 350t
nerves, 350
veins, 350
vessels, 349–350
muscles, 344
nerves, 345–346
tissues, 343–346
upper, 347–348
arteries, 347, 348f
neonatal, 348–348.e1
nerves, 347–348
ultrasound antenatal imaging, 348
veins, 347
vessels, 347
veins, 345
vessels, 344–345, 345f
- limbic lobe, development, 268–270
linea alba, 1198, 1209
lingual artery, 640–641, 698, 698f, 757
lingual frenulum, 694
lingual nerve, 699–700, 700f, 736
lingual nodes, 649
lingual papillae, 695–696
lingual tonsil, 763
lingual vein, 648, 698–699
lipid droplets, 11
lipocytes, 39
lips, 663–664, 691–692
movements of, 681–682, 682f
vascular supply and innervation, 692
liquids, biomechanics, 129
liver, 366f, 368–369, 1199, 1286–1298, 1286f
at birth, 369
blood supply, 1297
cells of, 1297–1298
development of biliary ducts, 369
early development of, 368–369
fissures, 1288–1289
functional anatomical divisions, 1288–1292, 1289f
innervation, 1296
ligaments of, 377, 1290–1291
lobes of, 1288
lobulation of, 1297, 1297f
lymphatic drainage of, 1295
maturation of, 369
microstructure of, 1296–1298, 1296f
parenchyma, 1296
peritoneal attachments of, 1237, 1290–1291
sectors and segments of, 1289–1290, 1290f, 1291f
supports of, 1288–1288.e1
surfaces of, 1286–1288, 1287f
vascular supply of, 1292–1295
veins, 1292–1295.e1
- lobar arteries, 1350–1352, 1351f
lobes
of brain, 596, 597f
of lungs, 1096–1097, 1096f
local circuitry mediating pain transmission, 467
long bones, mechanical properties of, 130, 130f, 131f
long ciliary nerves, 842, 843f
long plantar ligament, 1541, 1542–1542.e1f
long radiolunate ligament, 1034
long thoracic nerve, of upper limb, 940
longissimus muscle, 909
longitudinal fibres, of palmar fascial complex, 1025
longus capitis, 637
longus colli muscle, 637
loose (areolar) connective tissues, 43
lower genital tract, 1392–1398.e2
lower joint compartments, 727–727.e1
lower limb, 349–351, 1423–1441, 1440b
arterial perforators of, 1425–1426, 1428f
arteries of, 349–350, 350t, 1425–1426, 1426–1426.e1f, 1427f, 1438–1439
bones of, 1423, 1423–1423.e2f
clinical procedures of, 1439–1440
dermatomes of, 1431f, 1432, 1432f
fasciae of, 1423–1425, 1424f
innervation of, 1428–1434.e1, 1430f
autonomic, 1432
cutaneous, 1431–1432, 1431f
segmental, 1432–1434.e1
joints of, 1423
lesion, neurological localisation, 1433–1434.e1
ligamentous landmarks of, 1436–1438
lymphatic drainage of, 1427–1428, 1429f
movements of, 1432–1434.e1
muscle pumps of, 1427
muscles of, 1425, 1432–1434.e1
musculotendinous landmarks of, 1436–1438
nerve blocks of, 1439
nerves of, 350, 1439, 1439t
reflexes of, 1432
skeletal landmarks of, 1433–1436
skin of, 1423–1425
surface anatomy of, 1433–1440
vascular supply of, 1425–1428
veins of, 350, 1426–1427, 1428f, 1438
vessels, 349–350
- Lugaro cell, 513
lumbar artery, 1205–1206, 1205f, 1221–1223
lumbar parasympathetic system, 1229
lumbar plexus, 1226–1229, 1428–1429.e1, 1430f, 1481–1482
accessory obturator nerve, 1482
femoral nerve, 1228, 1481–1482
genitofemoral nerve, 1228
iliohypogastric nerve, 1228
ilio-inguinal nerve, 1228
lateral femoral cutaneous nerve, 1228–1229, 1481
muscular branches, 1228
obturator nerve, 1229, 1482
lumbar posterior spinal rami, 927, 927f
lumbar splanchnic nerves, 1189, 1191f
lumbar sympathetic system, 1188, 1229
lumbar veins, 1223–1224
ascending, 1224
gonadal, 1224
inferior phrenic, 1224
renal, 1224
suprarenal, 1224
lumbar vertebrae, 337, 894–895, 894f, 895f
fascial attachments to, 895
fifth, 895, 896f
general features of, 894–895
muscle attachments to, 895
ossification of, 895
lumbocostal triangles, 1111
lumbocostal venous line, 240
lumbosacral junction, 906–907
articulating surfaces of, 906
‘at risk’ structures of, 907
innervation of, 907
ligaments of, 907, 907f
vascular supply of, 907
lumbosacral trunk, 1336–1337
lumbrical muscles, 1046–1047, 1046f, 1548–1549
lunate bone, 1028–1029.e1
lungs, 1095–1097
antenatal imaging, 360
apex of, 1095
arteries, 1105–1106.e1
at birth
functional changes, 360–361, 361f
in preterm infants, 361
borders, 1096
congenital anomalies, 357–357.e1
costal surface, 1095
defensive mechanisms, 1106–1106.e2
development, 353, 353f
intrauterine maturation, 356–357.e1
postnatal, 362
diaphragmatic surface, 1095
fissures of, 1096–1097
hilum, 1104
impressions on, 1095–1096.e1
intrauterine maturation, 356–357.e1
lobes of, 1096–1097, 1096f
medial surface, 1095
perinatal period, 360–362
root, 1104
surface anatomy of, 1065–1066
vascular supply and drainage, 1104–1106.e1, 1105–1105.e1f
veins, 1106–1106.e1
lunules, of aortic valve leaflets, 1160
lymph nodes, 83–84, 83f, 243
cells/cellular zones, 83–84, 84f
lymphatics, 83
mantle zone in, 84, 84f
mediastinal, 1123–1125.e1, 1124f, 1125t
microstructure, 83–84
paracortex, 84, 89f
of upper limb, 951
vascular supply, 83
lymphangitis, acute, 149
lymphatic channels, limb development, 345
lymphatic drainage, 590–592, 594f, 735, 939–940
abdominal part of oesophagus, 1242–1243
of anal canal, 1283
of arm, 990
of diaphragm, 1116
of duodenum, 1257–1257.e1
of face, 685, 685f
of head, 590–592
of heart, 1163–1170
of large intestine, 1279, 1279f
of lesser pelvis, 1331–1336, 1336f
of neck, 590–592, 594f, 638–650, 649f
of orbit, 838–840
of pectoral girdle, 937–940
of pelvic girdle, 1481
of pericardium, 1141–1144
of skin of neck, 628, 628f
of thoracic skin, 1067
of tongue
central vessels, 699
dorsal vessels, 699
marginal vessels, 699, 699f
taste, 700–701
of upper limb, 937–940
of ureter, 1358
of urinary bladder, 1365
of vertebral column, 885–886
lymphatic ducts, right, 1125f, 1126
lymphatic endothelial cells, 241–243
lymphatic system, 140–149
lymphatic vessels, 149, 149f
lymphatics development, 356
lymphocytes, 40, 80–82, 80f
B cells, 80–81
cell lineages of, 86f, 87
large, 80
lifespan, 80
phenotypic markers of, common, 77t
small, 80, 80f
small intestine, 1263
T cells, 81–82
lymphoedema, 149
lymphoid cells, innate, 154
lymphoid tissues, 77–85, 243
lymphovenous portals, cervical, 649–650, 650f
lysosome, 8–9.e1
dysfunction, 9–9.e1
- M**
macrophages, 39–40, 40f, 88–89
alveolar, 1108–1109
phagocytosis, 88–89, 89f
secretory activities, 89
macroscopia, 411
macula(e), of utricle, 813–814, 813f
head movements of, 821–822, 822f
macula lutea, 869–870
maculae adherentes, 28
magnetic resonance imaging (MRI)
of cerebellum, 506f
fetal, 407
of reproductive system, 403
of suprarenal gland, 391
of urinary system, 390
of uterus, 1405, 1405f
of vagina, 1405, 1405f
main portal fissure, 1288
major alar (lower lateral) cartilage, 741–742
major blood vessels, 1174–1180, 1174f
arteries, 1174–1178
veins, 1178–1180
malaris muscle, 679–680
male
breast, 1089–1090
neck of bladder in, 1365
urethra, 1367–1370, 1368f
anterior, 1369
congenital anomalies of, 1369–1369.e1
innervation in, 1369
intramural part of, 1367
lymphatic drainage, 1369
membranous, 1368
microstructure of, 1369–1370
posterior, 1367–1368
prostatic, 1367–1368, 1369f
traumatic injury to, 1369–1369.e1
vascular supply, 1369
urinary continence in, 1371–1372, 1372f
male reproductive system, 1377–1391, 1391b
mallet finger, 1039–1039.e1
malleus, 805, 806f
ossification, 805
mamillary bodies, 538
mandible, 590, 597–598, 604f, 722–725.e1, 723f
age changes in, 724–725.e1, 725f
blood supply of, 725–725.e1
body of, 722
coronoid process, 724–724.e1
envelope of motion, 730

- mandible (*Continued*)
-  mandibular canal (inferior alveolar canal), 724–724.e1
 - potential tissue spaces around, 716
 -  ramus, 724–724.e1
 -  mandibular canal (inferior alveolar canal), 724–724.e1
 -  mandibular nerve, 687, 735–736.e1, 735f
 - anterior division of, 736
 - posterior division of, 736
 - mantle zone, 84, 84f
 - manubriosternal joints, 1074
 - manubrium, 1069
 - marginal sinus, 625
 - marginal zone B cells, 90f
 -  Martin-Gruber nerve connection, 1019–1019.e1
 -  masseter muscle, 731–731.e1, 731f
 - actions, 731
 - innervation, 731
 - nerve to, 736
 - vascular supply, 731
 - masseteric artery, 735
 - mast cells, 40
 - mastication, muscles of, 682
 - masticatory mucosa, 692
 - mastoid air cells, 804–805
 - mastoid antrum, 300, 803–804
 - aditus to, 803
 - mastoiditis, 805
 - maxilla, 604f, 672–674, 673f
 - alveolar process, 673
 - body, 672
 - anterior surface, 672
 - infratemporal surface, 672
 - nasal surface, 672
 - orbital surface, 672
 - frontal process, 673
 - maxillary sinus, 674
 - ossification, 674
 - palatine process, 673–674
 - potential tissue spaces around, 716
 - zygomatic process, 672
 -  maxillary artery, 733–735, 734f, 737–738.e1, 757
 - anterior tympanic branch of, 807
 - buccal artery of, 684
 - deep auricular branch of, 807
 - facial branches of, 684
 - infraorbital branch of, 840
 -  maxillary nerve, 687, 738–739.e1, 739f, 843
 - ganglionic branches, 738
 - orbital branches, 738
 - maxillary sinus, 755
 - maxillary vein, 735
 - mechanobiology, 128, 134
 - mechanotransduction, 134
 - hair cells of, 818–819
 - Meckel's cartilage, 301
 - media, tunica, 147
 - medial antebrachial cutaneous nerve, 992, 1021
 - medial arcuate ligament, 1111
 - medial brachial cutaneous nerve, 992
 - medial calcaneal nerve, 1553
 - medial canthus, 845
 - medial circumflex femoral artery, 1479
 - medial collateral ligament (deltoid ligament), 1536, 1537f
 - medial cuneiform bone, 1533
 - medial epicondyle, 998
 - medial geniculate nucleus, 533
 - medial intermuscular septum, 1524
 - medial ligaments, soft tissues and, 1498–1499
 - medial longitudinal arch, 1545
 - medial longitudinal fasciculus, 492–493
 - rostral interstitial nucleus of, 499
 - medial malleolar branches, posterior tibial artery, 1516
 - medial nuclei, thalamus, 530
 - medial palpebral arteries, 684, 840
 - medial patellofemoral ligament, 1495
 - medial patellomeniscal ligament, 1495
 - medial pectoral nerve, 990
 - medial plantar artery, 1516, 1552–1553
 - medial plantar nerve, 1553–1554
 - medial pterygoid nerve, 736
 - medial pterygoid plate, 721–722
 - medial rectus muscle, 833–834
 - medial rotation
 - of flexed leg, 1503
 - of hip, 1464
 - medial sesamoid bone, of first metatarsophalangeal joint, 1535
 - medial stability, factors maintaining, 1499
 - medial talocalcaneal ligament, 1539
 - median cricothyroid ligament, 778
 - median fissure, of medulla oblongata, 484
 - median nerve, 942–944, 943f, 944f, 992
 -  compression, 1019–1019.e1
 -  in forearm, 1018–1019.e1, 1019–1019.e1f
 - in hand, 1050–1052
 - median pharyngeal raphe, 757
 - median sacral artery, 1223
 - median sacral veins, 1335
 - median vein, 1018
 - mediastinal branches, descending thoracic aorta, 1178
 -  mediastinal lymph nodes, 1123–1125.e1, 1124f, 1125t
 -  mediastinoscopy, 1125–1125.e1
 -  mediastinum, 1061–1061.e1, 1121–1140, 1121f
 - anterior, 1121–1122
 - anteroposterior thoracic radiograph, 1137f
 - CT, 1138–1140, 1138f, 1139f
 - imaging, 1136–1137
 - inferior, 1061–1061.e1, 1121–1122
 - lateral thoracic radiograph, 1137, 1137f
 - lymph nodes, 1123–1125.e1, 1124f, 1125t, 1127f
 - lymphatic drainage, 1122–1125.e1
 - middle, 1122
 - MRI, 1138–1140
 - neck communication, 1122
 - posterior, 1122
 - posteroanterior thoracic radiograph, 1136f
 - superior, 1061–1061.e1, 1121
 - thorax systemic vessels, 1122
 - vagus nerve in, 1128
 - vascular supply, 1122–1125.e1
 - medulla
 - microcirculation, 1131
 - of suprarenal glands, development, 396
 -  medulla oblongata, 429, 484–491.e1
 - anterolateral system of, 488
 - caudal end, 485, 490f
 - external features, 484
 - hypoglossal nucleus, 488–489
 -  inferior cerebellar peduncle, 486–487.e1
 -  inferior olivary complex, 487–488.e1
 - internal organisation, 484–485
 - medial lemniscus system, 486–486.e1
 -  medullary reflexes, 491–491.e1
 - nucleus ambiguus, 489
 -  olivary complex, 486–487.e1
 -  pathways and nuclei of, 486–491.e1
 -  perihypoglossal nuclei, 489–489.e1
 - medulla oblongata (*Continued*)
 -  posterior funiculus nuclei, 486–486.e1
 - posterior (dorsal) nucleus of vagus nerve, 489
 -  restiform body, 486–487.e1
 - sensory decussation, 485
 - solitary nucleus, 489–490
 -  spinal trigeminal nucleus, 490–491.e1
 -  transverse section, 484–485, 487–487.e1f, 488–488.e1f, 489–489.e1f, 490–490.e1f
 - medullary chromaffin cells, 1326
 -  medullary reflexes, 491–491.e1
 - meiosis, 22–23, 23f
 - meiosis I, 22–23
 - meiosis II, 23
 - Meissner corpuscles, 72, 72f
 - melanin, 154
 - melanocytes, 158–159, 158f, 159f, 288
 - melanosomes, 158–159, 159f
 - membranous labyrinth, 299–300, 813–819
 - membranous layer, subcutaneous tissue and, 1202
 - membranous urethra, 1368
 - menarche, 418
 - Ménière's disease, 827
 - meningeal arteries, 626–627, 626f
 - accessory, 627
 - middle, 626–627, 626f
 - meningeal branch
 - of ascending pharyngeal artery, 640
 - of hypoglossal nerve, 655
 - of mandibular nerve, 736
 - meningeal nerves, 738, 925–926, 925f
 - meninges, 617–627
 - arteries, 626–627
 - accessory, 627
 - middle, 626–627, 626f
 - dura mater, 617–627
 - veins, 627
 - diploic, 627
 - middle, 627
 - sinus pericranii, 627
 - venous sinuses and, 324–325, 324f
 - menopause, 1409–1410
 - menstrual cycle, 1410–1411, 1410f
 - during breast, 1089
 - menstrual phase, 1411
 - proliferative phase, 1410
 - secretory phase, 1410–1411
 - vascular changes, 1411
 - menstruation, 1410
 - mental artery, 684
 - mental nerve, 687
 - mental veins, 685
 - mentalis muscle, 680
 - meralgia paraesthetica, 1481
 - Merkel cells, 159, 288
 - Merkel tactile endings, 72
 - mesencephalon. *see* midbrain
 - mesenchymal cells, 207
 - mesenchymal progenitor cells, 39
 - mesenchyme, 202–203, 207, 304
 - angioblastic, 222
 - axial, 220, 221f
 - early development of, 286–288, 287f
 - epithelial to mesenchyme transition, 208
 - epithelial transformation of (mesenchyme to epithelial), 204–205
 - extraembryonic, 200, 204–205
 - at gastrulation, 207
 - intermediate, 222
 - intraembryonic, 202–203
 - lateral plate, 202–203, 204–205, 216
 - mesenchyme (*Continued*)
 - nephrogenic, 387
 - paraxial, 202–203, 220
 - segmentation, 329
 - somite development, 329–332, 329f, 330f, 331f, 332f
 - primary, 207
 - sclerotomal cell populations, 332–338.e1, 333f, 334f, 335f
 - intervertebral disc development, 333–338
 - vertebrate development, 332–333, 335f
 - secondary, 207
 - somatopleuric, 222
 - splanchnopleuric, 222
 - synthesis of extracellular matrix, 207
 - mesentery, 1230–1231, 1233f, 1240b
 - of gallbladder, 1303
 - general organisation and regional anatomy, 1230–1231
 -  ileocaecal, peritoneal relationships of, 1238–1238.e1
 - innervation of, 1231
 - lower (post-fold) region of, 1230–1231, 1236
 - lymphatics, 1231
 - mid-region fold of, 1230, 1235
 - regional anatomy of components, 1231–1236
 - of small intestine, peritoneal relationships of, 1238
 - upper region of, 1230, 1232–1235, 1234f
 - cystoduodenal ligament, 1234
 - falciform ligament, 1234
 - greater omentum, 1232–1233
 - inferior pole of neck, 1234–1235
 - lesser omentum, 1233–1234
 - mesoduodenum, 1235
 - omental foramen, 1234
 - vasculature, 1231
 - meso-appendix
 - mid-region fold, 1235
 -  peritoneal relationships of, 1238–1238.e1
 - mesoblast, 203, 207
 - cardiogenic, 203
 - definition/terminology, 207
 - extraembryonic, 200, 203
 - formation, 202–203, 207
 - mesenchyme-to-epithelial transition, 208
 - trilaminar disc, 203
 - mesocolon, 1276
 - periphery of mid-region
 - ileocaecal mesentery, 1235
 - left mesocolon, 1235
 - meso-appendix, 1235
 - transverse, 1235
 - right (ascending)
 - periphery of mid-region, 1235
 - peritoneal relationships of, 1238
 - sigmoid, 1236
 - peritoneal relationships of, 1238
 - mesoderm, 207
 - mesoduodenum, 1235
 - meso-ileum, 1235
 - mesojejunum, 1235
 - mesolimbic dopamine pathway, 547
 - mesometrium, 1402, 1403f
 - mesonephric (Wolffian) duct, 383–384, 392f
 - evagination of, 384
 - mesonephric tubules, 383–384
 - mesonephros (Wolffian body), 383–384, 383f, 384f

- mesorectum, 1236
mesosalpinx, 1399–1402, 1402f
mesovarium, 1399–1402, 1402f, 1407
 metacarpal bone, 1029–1030.e1, 1030f
first, 1030
fourth, 1030
individual, 1030
 ossification of, 1030–1030.e1
second, 1030
third, 1030
metacarpophalangeal joints, 1037–1038, 1037f
metamyelocyte, 87
metanephros, 384–386, 386f
metaplasia, 44
 metatarsophalangeal joints, 1544–1545.e1
metatarsus, 1533
metencephalon, development, 263–266, 264f
 microbiome, skin, 154–154.e1
microcirculation
medulla, 1131
spleen, 1319–1320
thymus, 1130–1131
microfilaments, 13–14, 13f
microfold (M) cells, 1263
microglia, 59–61, 60f
of retina, 869
microglial precursor cells, 257
microtubule-based cargo transport systems, 26
microtubules, 15–16
associated proteins, 15
basal bodies, 15–16, 15f, 16f
centrioles, 15–16, 15f, 16f
centrosome, 15–16, 15f, 16f
microvillar cells, 748
microvilli, 26
micturition, 1370–1372, 1371f
mid-abdomen, peritoneum of, 1238
midbrain (mesencephalon), 429
anterior (ventral) tegmental area, 500–501
brainstem, 496–503
development, 266
external features and relations, 496
internal organisation, 497
 lateral column of reticular nuclei, 502–503.e1
 lower, transverse section at the level of the inferior colliculi, 497, 497–497.e1f
medial column of reticular nuclei, 502
median column of reticular nuclei, 501–502, 502f
pathways and nuclei of, 497–501
pedunculopontine nucleus, 503
periaqueductal grey substance, 499–500
reticular formation, 501–503, 501f
 tectum, 497–498.e1
tegmentum, 498–499
 transverse section, 483–484.e2f
 upper, transverse section at the level of the superior colliculi, 497, 498–498.e1f
midcingulate cortex, 566
middle anorectal artery, 1278, 1334
middle anorectal vein, 1336
middle cardiac vein, 1170
middle cerebellar peduncle, 508
middle cerebral artery, 453–454, 453f
middle cervical ganglion, 656
middle concha, 747
middle cranial fossa, 615–616, 616f
middle ear, 300–302, 301f, 800–801f, 800–809
auditory ossicles, 805–807
incus, 805
malleus, 805, 806f
ossicular articulations, 806–807
ossicular ligaments, 806
stapes, 805–806
external surgical approaches to, 799–800
innervation, 807–808
facial nerve, 808, 809f
tympanic plexus, 807–808, 808f
muscles, 807
stapedius, 807
tensor tympani, 807
tympanic mucosa, 808–809
cholesteatoma, 809
vascular supply and lymphatic drainage, 807
middle genicular artery, 1515
middle hepatic veins, 1295
middle longitudinal fasciculus, 578
middle meatus, 747
middle meningeal artery, 597, 626–627, 626f, 733, 734f
petrosal branch of, 807
superior tympanic branch of, 807
middle pharyngeal constrictor muscle, 767
middle suprarenal arteries, 1324
middle temporal artery, 684
middle thyroid vein, 648
middle turbinate, attachments of basal lamella of, 747
middle ulnar collateral artery, 989
midgut, 369–373, 371f
development of, 370f
formation of anterior abdominal wall, 372–373
maturation of small intestine, 373
mesenteries, 379–381
 primary intestinal loop, 372–372.e1
 rotation, anomalies of, 372–372.e1
 umbilical cord, 372–373.e1
mid-inguinal point, 1198
midline nuclei, 534
mid-region fold, origin (central zone) of, 1235
 mid-vagina, 1398–1398.e2
migrant cells, 39–40
mini-puberty, 403
minor hepatic veins, 1295
 mitochondria, 10–11.e1, 10f
 replacement therapies, 11–11.e1
mitosis, 21–22, 21f, 22f
 mobile spleen, 1315–1315.e1
modified Allen test, 951
modiolus, 682, 811–812
 modules, of cerebral hemisphere, 554–554.e2
molecular layer, of cerebellar cortex, 510–511
moments, 128, 128f
monoaminergic inputs, 515
 monoaminergic receptors, 555–556.e16
monoaminergic spinal pathways, 477
monoamines, 55–56
monocytes, 80
cell lineages of, 88
nuclear indentation, 80
phagocytosis, 80
mononuclear leukocytes, 80–82
monozygotic twins, 186
morphogenesis, 212–213, 212f
mossy fibres, 513–514, 514f
inputs to the cerebellum, 517–519
mossy fibres (*Continued*)
primary and secondary
vestibulocerebellar, 518, 519f
reticulocerebellar, 518
spinal and trigeminocerebellar, 517–518, 517f
motor cortex, of frontal lobe, 566–568, 568f
motor neuron
lower, 432
upper, 432
mouth, 691–718, 718b
cheeks, 691
oral mucosa, 692
oral vestibule, 692, 692f
palate, 694–695
tissue spaces around the jaws, 716–718, 717f
tongue, 695–701
movement(s)
 accessory, 1008–1008.e1
of articular surfaces, 132–133, 133f, 133t
of bones, 132, 133f
of costotransverse ligament, 1075–1076
coupled, 134
of eye, 834–838
of joints, 113
abduction, 113
adduction, 113
axial rotation, 113
circumduction, 114
complexity of form, 113
degrees of freedom, 113, 113f
flexion, 113
imaging to, 114–115, 114f
translation, 113, 114f
types, 113–114
of sternochondral joints, 1076
of vertebral column, 913–915
mucoid tissue, 43–44
mucosa, 44, 44f, 366–367, 1194–1195
epithelium, 1194–1195
lamina propria, 1195
of large intestine, 374, 1283–1284
lining, 692
muscularis, 1195
oesophagus, 1134
of small intestine, 373
of urinary bladder, 1364
mucosa-associated lymphoid tissue (MALT), 84–85
epithelium covering, 85
small intestine, 1265
mucosal folding, 760
mucosal-associated invariant T (MAIT)
cells, 90f
mucous (goblet) cells, 1263, 1283
mucous membrane, 44, 44f
mucus, 44–45
Müller cells, 868
Müllerian inhibiting (MIS) substance, 394
multifidus muscle, 910, 911f
multilaminar epithelia, 32–35
multinucleated syncytiotrophoblast, 194
muscle(s), 115–126
anterolateral abdominal wall, 1207–1214
architecture of, collagenous, 131
of back, 907–912, 907f
cardiac, 149–153
 contractile protein isoforms of, 151–151.e1
 excitation-contraction coupling in, 152–153.e1
innervation of, 152
muscle(s) (*Continued*)
microstructure of, 150–151, 150f, 151f
neurovascular supply of, 152
origin of, 153
regeneration of, 153
vascular supply of, 152
classification of, 115
forces of
direction of, 124, 125f
internal, 131, 132f
range of contraction *versus*, 124–125, 125f
 of forearm, 1008–1016.e1
anterior compartment, 1008–1011
deep extensor compartment, 1014–1016
deep flexor compartment, 1011
posterior compartment, 1011–1016
superficial extensor compartment, 1012–1014
superficial flexor compartment, 1008–1011
of hand, 1040–1047
intrinsic, 1043–1047
of head, 590
of iris, 858–859
innervation of, 858–859
lever systems, 131, 132f, 133f
limb development, 344
 long flexor tendon apparatus, 1040–1042.e1
 of lower limbs, 1425, 1432–1434.e1
 of lungs, 1107–1107.e1
naming of, terms in, 124t
of neck, 590, 634–638
anterior vertebral, 637, 637f
infrayoid, 636
lateral vertebral, 637–638
platysma, 634
posterior vertebral, 638
sternocleidomastoid, 634–635, 635f
of pectoral girdle, 936–937
of pelvic girdle, 1465–1477
gluteal region, 1466–1471
iliac region, 1465–1466
thigh, 1471–1477
of posterior abdominal wall, 1219–1220, 1219f
of shoulder girdle and arm, 975–985, 975t
of thorax, 1060–1061
of upper limb, 936–937
 muscle fasciae (deep fascia), of arm, 954–956.e1
muscle fibres
architecture, 124, 125f
development, 122–123
differentiation, 121t
fast twitch, slow twitch *versus*, 120–121
formation of, 121–123, 122f, 123f
length of, 123
slow twitch, fast twitch *versus*, 120–121
transformation, 121
muscle proteins, 116–117
muscle stretch reflex, 478, 478f
muscular arteries, 141–142
muscular branch
anterior tibial artery, 1516
cervical plexus of neck, 651
fibular artery, 1517
glossopharyngeal nerve, 653
hypoglossal nerve, 655
posterior tibial artery, 1516

- muscularis, 367
 of large intestine, 374
 of small intestine, 373
-  muscularis externa muscle, 1134–1135.e1, 1135f, 1195, 1284
- muscularis mucosae, 1195, 1253
- oesophagus, 1134
- small intestine, 1265
- muscularis propria, 1367
- musculocutaneous nerve, 945, 945f, 991–992, 992f
- musculophrenic artery, 1080, 1115
-  musculoskeletal injury, upper limb
 nerves at risk from, 946–946.e14
- musculoskeletal system, 92–135, 134b
- musculus uvulae, 766
-  myasthenia gravis, 1131–1131.e1
- myelencephalon, development, 262–263
- myelin, 65–67
- myelinated axons, 64–65, 65f, 66f
- myelination, 65–66
 of spinal and cranial nerves, 281
- myenteric plexus, 69
- mylohyoid muscle, 694
- myoblasts, pelvic floor muscle
 development and, 401
- myocytes, 115
- myoepithelial cells, 32, 33f
 of salivary glands, 715
-  myofascial flaps, 1214–1214.e1
- myofibril(s), of skeletal muscle, 115–116
- myometrium, 1404, 1404f
- myosins
 cytoskeleton, 14–15
 of skeletal muscle, 116
- myotomes, 433–435
 of upper limb, 952
- myringoplasty, 803
- N**
- nail(s), 290
-  apparatus, 165–166.e1, 165f, 1023
- bed, 165–166
-  growth of, 166–166.e1
- matrix, 165
- plate, 165
- nasal bone, 604f, 671
 fractures of, 741
 ossification, 671
-  nasal cavity, 318–320, 319f, 744–751.e1, 745f
- floor, 745
-  innervation, 750–751.e1, 751f
 autonomic innervation, 750
 olfactory nerves, 750, 752f
 sensory innervation, 750
-  vomeronasal organ, 750–751.e1
- lateral wall, 745–747, 746f
 highest (supreme) nasal concha, 747
- inferior concha and inferior meatus, 745–746
- middle concha and middle meatus, 747
- nasal turbinates, 747
- superior concha and superior meatus, 747
- medial wall, 745
 bony septum, 745
 cartilaginous septum, 745
-  nasal airflow and, 747–747.e1
-  nasal cycle, 747–747.e1
- nasal mucosa, 747
- nasal vestibule, 744
-  olfactory mucosa, 747–749.e1, 748–748.e1f
- roof, 745
- nasal cavity (*Continued*)
 vascular supply and lymphatic drainage, 749–750
- arteries, 749, 749f, 750f
- lymphatic drainage, 749–750
-  nose bleeds, 749–749.e1
- veins, 749, 750f
- nasal mucosa, 747
- nasal muscle group, in face, 679
- nasal turbinates, 747
- nasalis muscle, 742–744
- nasociliary nerve, 842–843
- nasolacrimal duct, 848–849
- nasopalatine nerve, 738
- nasopharyngeal carcinoma, 759
- nasopharyngeal epithelium, 759
- nasopharynx, 758–761, 759f
- auditory tube, 760–761
 equalisation of pressure, 761
 innervation, 760
 relations, 760
 vascular supply, 760
- innervation, 759
- microstructure of non-tonsillar, 759
- pharyngeal tonsil, 759–760.e1, 760f
-  adenoidectomy, 760–760.e1
-  microstructure, 760
- vascular supply and lymphatic drainage, 759–760
- relations, 759
- natatory ligament, 1025
- natural killer T cells (NKT), 80f, 82, 90f
- navicular bone, 1532, 1532f
- naviculocuneiform joint, 1541–1542
- neck, 590, 628–662
- arteries, 638–646
- bones and joints, 590
- cervical vertebrae, 590
- hyoid bone, 590
- laryngeal cartilages, 590
- mandible, 590
- skull, 590
- cartilages of, 629–630
- cartilaginous landmarks of, 600, 600f
- cellulitis in, 633–634
- cervical fascia of, 631–634
- cervical sympathetic trunk of, 655–656
- course of nerves, 602
- course of vessels, 601–602
- development of, 304–328, 304f, 305f
- anomalies of face and neck
 development, 328–328.e2
- embryonic pharynx and pharyngeal arches, 305–311, 305f, 306t
- face, 317–322, 318f, 319f
- head-neck transition zone, 316–317
- pharyngeal derivatives, 311–316, 313f
- postnatal, 328
- skull, 322–328, 322f
- fascia, 590
- face, 590
- neck, 590
- scalp, 590
- hyoid bone of, 629–630, 629f
- infection spread, 633–634
- innervation, 593–595, 650–655
- ciliary ganglion, 594
- cranial nerves, 593
- otic ganglion, 594
- parasympathetic nerves, 593–594, 595f
- pterygopalatine ganglion, 594
- reflexes, 593
- spinal nerves, 593, 595f
- submandibular ganglion, 594
- sympathetic nerves, 594–595
- neck (*Continued*)
 joints, 630
- lymphatic drainage, 590–592, 594f, 638–650, 649f
- malignant disease spread, 649
- muscles of, 590, 634–638
- nerves of, 651f
- root, 600–601, 652f, 661–662
- skeletal landmarks, 600, 600f
- skin of, 590, 628–629
 cutaneous innervation, 628–629, 628f
- cutaneous vascular supply, 628, 628f
- face, 590
- lymphatic drainage, 628, 628f
- neck, 590
- scalp, 590
- soft tissues, 600–601, 600f
- subclavian artery, 643–646
- surface anatomy, 590–602
- tissue spaces, 633–634
- triangles, 600–601, 630–631, 630f
- anterior, 601
- posterior, 601
- of urinary bladder, 1365
- vascular supply, 590–592, 638–650
- arteries, 590, 591–591.e1f, 591–591.e1f
- carotid arteries, 590–592
- subclavian artery, 592
- veins, 592, 592f, 593f
-  veins in, 646–648.e1, 646f, 647f
- vessels of, 651f
- viscera, 600–601, 600f, 656–660
-  nectins, 27–28.e1
-  needle thoracocentesis, 1083–1083.e1
- neocerebellum (pontocerebellum), 505
- neocortex, 546
- neonatal, development, 283–285
 full-term neonate, 283–285
 preterm neonate, 283
- neonatal auditory (pharyngotympanic, Eustachian) tube, 796
- neonatal blood vessels, catheterisation of, 247–248
- neonatal hearing tests, 303
-  neonatal heart, 246–247.e1
- neonatal period, 404–406
- neonatal skin, 290–291
- neonatal thorax, 362
- neonate(s), 404–426, 420b
- ear, 303
-  full-term, 390, 413–415, 414–414.e1f, 415–415.e1f, 416f
- low birth weight, 412
- post-term, 415
- preterm, 412–413, 413f
- nephrogenesis, 387
- nephrogenic mesenchyme, 387
- nephrogenic zone, 387
- nephron, 1354
 development, 208
- nerve(s)
 in limb development, 345–346
- of lower limbs, 350, 1439, 1439t
- postganglionic, 435
- preganglionic, 435
- of pterygoid canal (Vidian nerve), 808
- to stapedius, 808
- of upper limb, 347–348, 950–952, 951t
- nerve blocks, of upper limb, 952
- nerve entrapment syndromes, in foot, 1554
- nerve fibres
 corticofugal, 432, 433f
- efferent, 437
- nerve fibres (*Continued*)
 postganglionic, parasympathetic, 437
- primary afferent, 431
- visceral afferent, 438
-  nerve injuries, at elbow, 1021–1021.e1
- nerve lesions
 to femoral nerve, 1482
- to obturator nerve, 1482
- to sciatic nerve, 1483
- nervi vasorum, 148
- nervous impulse, conduction, 50–52, 51f
- nervous system, 46–76, 429–435
 autonomic, 435
- axons in, 47–49
- central, 429–433, 430f
- central glia in, 56–63, 56f
- dendrites in, 47, 49f
- development of, 249–285
 central nervous system, 259–276
- cerebral vascular supply, 276–279
- ectodermal placode, 252–254.e1, 253f, 254f
- neonatal, 283–285
-  neural crest, 251–252, 251f, 253–253.e1f, 253f
-  neurulation, 249–250.e1
- peripheral nervous system, 279–283
- segmentation of the neural tube
 and early brain regions, 254–259
- neurons in, 46–56
- peripheral, 433–435
- peripheral nerves in, 63–69, 63f
- sensory endings in, 70–76
- soma in, 46–47, 47f, 48f, 49f
- neural cell adhesion molecule (N-CAM), 225
-  neural crest, 203–204, 206f, 220–222, 251–252, 251f, 253–253.e1f, 253f, 304, 305–306
- head, 222
- mesenchyme, 304–305
- trunk, 222
- neural ectoderm, 218
- neural fold, 251
- neural groove, 203–204, 206f
- neural plate, 204, 206f
- neural tube, 203–204
 segmentation of, 254–259
- CNS/PNS transition zones, 258–259
- differentiating precursor cell
 populations, 255–258, 255f, 256f
- neuralgia, greater occipital nerve, 926
- neurenteric canal, 202
- neuroactive chemicals, 545
- neuroanatomy, triad of clinical ataxiology
 in relation to, 527
- neuroblasts, 300
 early development of, 256–257
- neurocranium, 324–328, 603
- neuroectodermal cells, 255
- neuroendocrine cells, small intestine, 1263–1264
- neuroendocrine system, dispersed, 69–70, 70f
- neuroepithelial receptor, 70
- neuroepithelium, embryo, 217
- neurogenesis, adult, 56
- neurogenic ectodermal placodes, 252–253
- neurohormones, 54–55
- neurohypophysis, 444, 540, 540f, 540t
- neuromeres, 304–305
- neuromodulators, 55
- neuromuscular junctions, 74–76
 autonomic, 75–76

- neuromuscular junctions (*Continued*)
 skeletal muscle, 74–75, 75f
 smooth muscle and, 138
 neuromuscular spindles, 73–74, 73f, 74f
 neuron(s), 464
 cell groups, 465
 neuronal receptor, 70
 neuronal types, in cerebral cortex, 552–552.e6, 553f
 neurone(s)
 of cerebellar nuclei, 508–509
 cholinergic, of cerebellar nuclei, 508–509
 dentate, 508
 neuropeptides, 56
 in mossy fibres, 514
 neuropore, rostral, 205f
 neurotransmission, autonomic, 436
 neurotransmitter(s)
 climbing fibres, 514
 molecules, 55–56
 neurovascular sheath, axillary, 956–956.e1
 neurulation, 249–250.e1
 failure, 250–250.e1
 primary, 203–204, 205f, 249, 249f, 250f
 secondary, 250–250.e1
 neutrophils, 79, 79f, 86f
 wound healing and, 170
 nipple, 1083–1084
 congenital inversion of, 1088–1088.e1
 nitric oxide (NO), 56
 NK cells, 82
 nodes of Ranvier, 59, 59f, 65
 nodule(s), of aortic valve leaflets, 1160
 non-keratinised epithelium, 34
 non-lymphocytic thymic cells, 1130
 noradrenaline (norepinephrine), 55, 555
 nose, 741, 742f
 soft tissue areas of, 741
 alar soft tissue area, 741
 caudal lobular notch, 741
 lateral soft tissue area, 741
 paraseptal soft tissue area, 741
 notochord, 201–202, 202f, 218
 caudal, 201
 development, 201, 203–204
 origin, 201
 removal (experimental), 201–202
 notochordal plate, 201, 202f, 206f
 notochordal process, 201
 nuchal ligament, 908
 nucleolus, 20
 nucleus, of cells, 17–20
 chromatin, 18–19, 18f
 chromosome karyotyping, 19–19.e1, 19f
 chromosomes, 19–19.e1
 envelop, 17–18, 17f
 telomeres, 19–19.e1
 nucleus accumbens, 544–545
 nucleus ambiguus, 489
 nucleus of Onuf, 468
 nucleus pulposus, 901–902
 nutrient artery
 fibular artery, 1517
 of humerus, 988
 of tibia, 1516
- O**
 obesity, in children, 418
 oblique arytenoid muscle, 784
 oblique cord, 1007
 oblique muscle, 834
 oblique vein, of left atrium, 1170
 obliquus inferior capitis muscle, 912
 obliquus superior capitis muscle, 912
- obstructive sleep apnoea, 768–768.e1
 obturator artery, 1334
 obturator externus muscle, 1469–1470, 1470f
 obturator fascia, 1330
 obturator foramen, 1444
 obturator internus muscle, 1328, 1469
 nerve to, 1484
 obturator membrane, 1443–1444, 1444f
 obturator nerve, 1229, 1429, 1482
 nerve lesions to, 1482
 obturator vein, 1336
 occipital artery, 641, 684, 807
 occipital bone, 879–882, 881f
 basilar part of, 881f, 882
 lateral (condylar) parts of, 882
 muscle attachments to, 882
 ossification of, 882, 882f
 squamous part of, 881–882
 occipital lobe
 of brain, 571–572
 internal structure and connectivity, 571–572
 occipital sinus, 625
 occipital triangle, of neck, 631
 occipital vein, 685
 occipitocervical junction, 334–336.e1, 336f, 337f
 occipitofrontalis muscle, 675–676
 oculomotor nerve, 840–841, 841f
 oculomotor nuclear complex, 499
 oesophageal branches, descending
 thoracic aorta, 1178
 oesophageal hiatus, 1114
 oesophageal plexus, 1063–1063.e1
 oesophageal surgery, injury, 1126–1126.e1
 oesophagus, 364, 661, 1131–1136, 1132f
 abdominal part of, 1242–1243
 innervation, 1243
 vascular supply and lymphatic drainage, 1242–1243
 arteries, 1132, 1133f
 barium studies, 1135–1135.e1
 at birth, 364
 cervical part of, 1131
 development, 1136
 diverticula, 1135
 dysmotility, 1136
 glands, 1134
 innervation, 1133
 lymphatic drainage, 1133
 microstructure, 1133–1135, 1134f
 rupture, 1135–1135.e1
 sphincteric mechanisms, 1136
 thoracic part, 1131–1132
 varices, 1132–1133
 vascular supply, 1132–1133
 veins, 1132–1133
 olecranon fossa, 999
 olfactory bulb, of brain, 557–558
 olfactory ensheathing cells (OECs), 68, 748
 olfactory ensheathing glia, 68
 olfactory glands, 748–749
 olfactory mucosa, 747–749.e1, 748–748.e1f
 olfactory nerves, 750, 752f
 development, 268–270
 olfactory receptor neurons, 747–748
 turnover of, 749–749.e1
 oligodendrocyte precursor cells (OPCs), 58–59, 258
 oligodendrocytes, 59, 59f, 552
 olivary complex, medulla oblongata, 486–487.e1
 olivocerebellar projection, 514, 515f
 olivocochlear bundle, 300
 omental bursa, 1239–1240
- omental foramen, 1234, 1240
 omental vestibule, 1239
 omohyoid, 636
 oocytes, secondary, 181
 ophthalmic artery, 838–840
 facial branches of, 684
 meningeal branch of, 840
 muscular branches of, 838
 ophthalmic nerve, 686, 842–843, 842f
 opponens digiti minimi muscle, 1045
 opponens pollicis muscle, 1044
 optic canal, 828
 optic chiasm, 456
 optic cup, endothelial channels surrounding, 293–294, 294f
 optic disc, 871
 optic nerve, 841–842
 formation of, 294–296
 head, 871–872, 871f
 optic primordium, establishment of, 292–294.e1
 anomalies of, 294–294.e1
 early vascular networks, formation of, 292–294
 optic and lens vesicles, formation of, 292, 293f
 optic radiation, 456
 optic tract, 456
 optic vesicles
 endothelial channels surrounding, 293–294, 294f
 formation of, 292, 293f
 optokinetic response, 837
 oral cavity, 691f, 693f
 oral mucosa, 692
 gingivae, 692
 innervation, 692
 lining mucosa, 692
 masticatory mucosa, 692
 vascular supply and lymphatic drainage, 692
 oral (presulcal) part, 695–698, 695f
 oral vestibule, 691
 orbicularis oculi muscle, 676–679
 orbicularis oris muscle, 680–681
 orbit, 828–849
 arteries of, 838–840, 839f
 bones of, 828–829, 829f
 connective tissue of, 829–832, 831–831.e1f
 pulleys, 831–832
 fat of, 829–832, 831–831.e1f, 832f
 floor of, 828
 foramina, 828–829.e1
 innervation of, 840–843, 841f, 842f
 lateral wall of, 828, 831f
 lymphatic drainage of, 838–840
 medial wall of, 828, 830f
 muscles of, minor, 834
 roof of, 828, 830f
 vascular supply of, 838–840
 veins of, 840, 840f
 walls of, 297
 orbital fat, 829–832, 831–831.e1f, 832f
 orbital fissures, 828–829.e1
 orbital foramen, 828–829.e1
 orbitomeningeal (cranio-orbital) foramina, 829–829.e1
 organ of Corti, 300, 816–819, 818f
 organogenesis, 216–222, 216f, 218f
 body axes specification in, 216–217
 embryonic cell populations at, 217–222
 organoids, 214
 oropharyngeal lymphoid tissue, 314–315
 oropharynx, 761–763
 anatomical landmarks in, 771–772
 base of tongue, 772
- oropharynx (*Continued*)
 lateral wall, 771
 parapharyngeal space, 771–772
 lingual tonsil, 763
 palatine tonsil, 761–763.e1, 762f
 innervation, 763
 microstructure, 763
 tonsillectomy, 763–763.e1
 vascular supply and lymphatic drainage, 762–763
 soft palate, 761, 763f
 innervation, 761
 palatine aponeurosis, 761
 palatoglossal and palatopharyngeal arches, 761
 vascular supply, 761
 os goniale, 301
 osseous cochlear canal, 812
 ossicular ligaments, 806
 ossification
 of clavicle, 957–958.e1
 ethmoid bone, 670
 of humerus, 964, 965f
 sternum, 1070, 1070f
 osteoblasts, 97–98, 97f
 osteoclasts, 98–99, 99f
 osteocytes, 98, 98f
 osteons, 99, 101f
 osteotendinous junction, 127
 ostiomeatal complex, 755, 755f
 otic capsule, 301
 otic ganglion, 594, 736–737
 otic neurogenic placodes, 253–254
 otitis media, 803
 otosclerosis, 806–807
 outflow tract, septation of, 232–233.e1, 233f, 234f
 ovarian follicles, 1408–1409
 antral, 1409, 1409f
 preovulatory, 1409
 primary, 1408, 1408f
 primordial, 1408, 1408f
 secondary, 1409
 ovarian medulla, 1409
 ovaries, 1406–1410, 1407f
 arteries of, 1407
 cortex of, 1407–1409
 descent of, 399, 399f, 400f
 development of, 396
 innervation of, 1407
 lymphatic drainage of, 1407
 microstructure of, 1407–1410
 supports for, peritoneal and ligamentous, 1407
 vascular supply of, 1407
 veins of, 1407
- P**
 p450c17 enzyme, 396
 Pacinian corpuscles, 72, 72f
 pain
 radicular, 931
 referred, 931
 spinal, anatomical basis of, 931
 palate, 694–695
 palatine aponeurosis, 761
 palatine artery, ascending, 641
 palatine bone, 674–675, 674f
 horizontal plate, 674
 orbital process, 674–675
 ossification, 675
 perpendicular plate, 674
 pyramidal process, 674
 sphenoidal process, 675
 palatine nerves, 738

-  palatine tonsil, 761–763.e1, 762f
 innervation, 763
 microstructure, 763
 tonsillectomy, 763–763.e1
 vascular supply and lymphatic drainage, 762–763
 palatoglossal arch, 761
 palatoglossus muscle, 697, 764
 palatopharyngeal arch, 761
 palatopharyngeus muscle, 765–766
 paleocortex, of brain, 557–561, 557f, 558f
 amygdala, 559–561, 560f
 olfactory bulb, 557–558
 olfactory tubercle, 559
 periamygdaloid cortex, 559
 prepiriform area, 559
 retrobulbar area, 558–559
 pallidotomy
 for dystonia, 549
 paradox, 549
 palmar fascial complex, 1025, 1026–1026.e1f
 palmar interphalangeal ligament, 1038–1039
 palmar metacarpophalangeal ligament, 1037
 palmaris brevis muscle, 1045
 palmaris longus muscle, 1010
 palpebral glands, 845–846, 845f
 palpebral muscle group, 676–679
 pampiniform plexus, 1377f, 1379–1379.e1
 pancreas, 365f, 366f, 367–368, 368f, 1199, 1305–1313, 1305f, 1306f
 arterial segmentation of, 1310–1310.e1
 arteries, 1308–1310, 1309f
 at birth, 368
 body of, 1306
 cellular development of, 367–368
 endocrine, 1312–1313
 exocrine, 1311–1312
 head of, 1305
 innervation, 1310–1311
 lymphatic drainage, 1310
 microstructure, 1311–1313, 1311f, 1312f
 neck of, 1305–1306, 1307f
 tail of, 1306
 vascular supply, 1308–1310
 veins, 1310, 1310f
 pancreatic ducts, 1306–1308.e2, 1308–1308.e1f
 pancreatic transplantation, 1313
 pancreatic tumours, 1313–1313.e1
 Paneth cells, 1263
 papillary layer, of dermis, 160
 papillary ridges, 168, 168f
 para-aortic bodies, 1192, 1229
 para-aortic paraganglia, 1176–1177
 paracolic gutters, 1240
 paraganglia, 438–439, 439f
 para-aortic, 1176–1177
 paraglottic space, 782
 paramesonephric (Müllerian) duct
 atrophy, 394
 development of, 391–393
 fusion of, 402
 male, 392f
 paranasal sinuses, 751–756, 753–753.e1f
 development of, 751–751.e1
 ethmoidal sinuses, 754–755
 frontal sinus, 751–752, 753f
 imaging of, 755–756
 maxillary sinus, 755
 sphenoidal sinus, 753–754, 754f
 spread of infection from, 756
 paranodal area, 1162
 paranodes, 65
 pararenal spaces
 anterior, 1219
 posterior, 1219
 paraseptal soft tissue area, 741
 parasympathetic cardiac innervation, 1170–1171
 parasympathetic ganglia, 281–282
 parasympathetic nerves, 593–594, 595f
 parasympathetic nervous system, 437
 parathyroid glands, 315–316, 659–660, 660–660.e1f, 660f
 innervation, 660
 lymphatic drainage, 660
 microstructure, 660, 661f
 vascular supply, 660
 paratracheal nodes, 649
 paraventricular nucleus, 537–537.e1
 paraxial mesenchyme, 220, 305–306
 segmentation, 329
 parietal bone, 604f, 663, 665–666
 ossification, 666
 parietal (posterior) branch, of superficial temporal artery, 684
 parietal lobe
 of brain, 570–571
 internal structure and connectivity, 570–571
 parietal pelvic fascia, 1330–1331
 parietal pleura, 1092–1092.e1f, 1092–1093
 costal part, 1092
 diaphragmatic part, 1092
 mediastinal part, 1093
 vertebral part, 1092
 Parkinson disease, 543, 548–549, 549f
 parotid fascia, 665
 parotid gland, 599, 599f, 688–690, 689f, 690f, 712
 capsule, 689
 duct, 689–690
 innervation, 690
 lymphatic drainage, 690
 structures within, 689
 vascular supply, 690
 parotid-masseteric fascia, 664
 parturition, 1411–1415
 Passavant's muscle (palatopharyngeal sphincter), 765–766
 patella, 1493–1495, 1493f, 1494f
 articulating surfaces, 1494
 fibrous layer of the articular capsule, 1495
 ligaments, 1495, 1495f
 muscle attachments, 1493
 ossification, 1494
 structure, 1493
 surface anatomy of, 1434, 1435f
 vascular supply, 1493–1494
 patellar ligament sheath, 1495
 patellofemoral articulation, 1503
 PAX2 gene, 402
 Pax7 gene, 123
 pectineus muscle, 1476
 branch of femoral nerve to, 1481
 pectoral fascia, 955–956
 pectoral girdle, 346–347
 acute ischaemia, 940–940.e2
 arteries, 950–951
 bones, 935, 936f
 compartment syndromes, 940–940.e2
 dermatomes, 952, 952f
 fascia, 935–936
 innervation, 940–946
 brachial plexus, 940–946, 940f, 941f
 dorsal scapular nerve, 940
 long thoracic nerve, 940
 spinal accessory nerve, 940
 pectoral girdle (*Continued*)
 subclavian nerve, 940
 suprascapular nerve, 940
 joints, 935, 936f
 lymph nodes, 951
 lymphatic drainage, 937–940
 muscles, 936–937
 musculotendinous landmarks, 948–950
 myotomes, 952
 nerve blocks, 952
 nerves, 950–952, 951t
 pulses, 950–952
 reflexes, 952
 skeletal landmarks, 947–948, 947f
 skin, 935–936
 surface anatomy, 935–952
 thoracic outlet syndromes, 947–947.e3
 vascular supply, 937–940
 arteries, 937–937.e2f, 937–938
 veins, 938–938.e1f, 938–939.e1
 veins, 951
 vessels, 950–952
 pectoralis major muscle, 978–979.e1, 979f
 pectoralis minor muscle, 976
 pedunculoopontine nucleus, 503
 in basal ganglia, 548
 pedunculoopontine tegmental nucleus.
 see pedunculoopontine nucleus, in basal ganglia
 pelvic fasciae, 1330–1331, 1330f
 obturator, 1330
 over levator ani, 1330
 over piriformis, 1330
 parietal, 1330–1331
 presacral, 1330–1331
 tendinous arch of, 1330
 visceral, 1331
 pelvic floor, 401
 pelvic girdle, 348–348.e1, 1423–1441, 1440b, 1442–1485
 bones, 1423, 1423–1423.e2f, 1444–1456
 bony pelvis, 1449–1451.e1, 1450–1450.e1f
 coccyx, 1449
 femur, 1451–1456, 1452f
 innervation, 1481–1484
 joints, 1423, 1456–1465
 hip, 1457–1461, 1458–1458.e1f
 pubic symphysis, 1456
 sacro-iliac, 1456–1457
 muscles, 1465–1477
 of gluteal region, 1466–1471
 of iliac region, 1465–1466
 of thigh, 1471–1477
 skin, 1442
 cutaneous vascular supply and lymphatic drainage, 1442
 innervation, 1442
 soft tissues, 1442–1444
 fasciae of muscles, 1442–1444
 subcutaneous tissue, 1442
 vascular supply and lymphatic drainage, 1477–1481
 arteries, 1477–1480
 veins, 1480–1481
 pelvic muscles, 1328–1330, 1328f
 levator ani, 1329–1330, 1329f
 obturator internus, 1328
 piriformis, 1328
 pelvic splanchnic nerves, 1189
 pelvis, 1200
 ligaments of, 1398–1403
 musculoskeletal framework, 1187, 1188f
 posterior, landmarks of, 917–918
 pelvis (*Continued*)
 surface anatomy of, 1196–1200, 1200b, 1433, 1434f
 abdominal planes and regions, 1196–1198
 intra-abdominal viscera and diaphragm, 1198–1199
 retroperitoneal structures, 1199–1200
 pelvis-lower limb interface, 1187
 penis, 1384–1389, 1385f, 1386f, 1387f
 arteries of, 1387, 1389f, 1390f
 body of, 1385, 1388f
 dorsal nerve of, 1343
 ejaculation of, 1389–1389.e1
 erection of, 1389–1389.e1
 innervation of, 1388–1389, 1391f
 lymphatic drainage of, 1388
 microstructure of, 1389
 root of, 1385
 skin of, 1385
 vascular supply of, 1387–1388
 veins of, 1387–1388
 perforating arteries, 456
 perforating branches
 anterior tibial artery, 1516
 fibular artery, 1517
 posterior tibial artery, 1516
 perforating cutaneous nerve, 1484
 perforating femoral arteries, 1479
 perforator flaps
 in ankle and foot region, 1553, 1553f
 in hip and thigh, 1480
 in knee and leg, 1517
 periamygdaloid cortex, 559
 periarthrocortex, of brain, 557f, 561–565, 562f, 563f
 entorhinal cortex, 564–565
 hippocampal formation, 562f, 563–564.e1, 563f
 limbic system, 561–565
 retrosplenial region, 564–564.e1
 septum, 565
 pericardiophrenic arteries, 1115
 pericardial branches, descending
 thoracic aorta, 1178
 pericardial cavity, 205, 206f, 1141, 1142f
 pericardial fluid, 1141
 pericardiocentesis, 1083–1083.e1
 pericardium, 1141–1144.e1
 development, 203
 pericolic spaces, 1219
 pericytes, 143, 148, 148f
 periderm, early development of, 286–288, 287f
 perifollicular zone, 1319
 perihypoglossal nuclei, 489–489.e1
 perilymph, 812
 perinatal period, 404–406, 406f
 reflexes present in, 284–285
 perineal artery, 1342
 perineal membrane, 1339–1340
 perineal nerve, 1343
 perineum, 1328–1343
 anal region, 1338–1342, 1339f
 innervation of, 1343
 lymphatic drainage, 1342–1343
 urogenital region, 1338–1340, 1339f
 vascular supply, 1342–1343
 arteries, 1342
 veins, 1343
 perineural invasion, 1311
 perineurium, 64
 periodontal ligament, 709–710, 709f
 arterial supply of, 711
 periosteal collar, 103
 periosteum, 100

- peripaleocortex, of brain, 557–561, 557f, 558f
- amygdala, 559–561
- olfactory bulb, 557–558
- olfactory tubercle, 559
- periamygdaloid cortex, 559
- prepiriform area, 559
- retrobulbar area, 558–559
- peripancratic spaces, 1219
- peripatellar plexus, 1487
- peripheral arterial puncture, 247–248
- peripheral auditory system, 824–825, 825f
- peripheral blood cells, 77–82, 77t
- peripheral myelin, 66–67
- peripheral nerves, 63–69, 63f
- blood supply of, 65
- fibers, classification of, 63–64
- peripheral nervous system (PNS), 249, 433–435
- autonomic nervous system, 281–282
- development of, 279–283
- enteric nervous system, 282–283
- somatic nerves, 279–281
- perirenal space, 1218
- perisynaptic glia, 67
- peritoneal cavity, 205, 375–381, 1230–1241, 1240b
- at birth, 381
- development of, 363–382
- general arrangement of, 1239–1240.e1
- inframesocolic region, 1240
- recesses of, 1240–1240.e1
- supramesocolic region, 1239–1240.e1
- peritoneal connections, 1237–1239
- peritoneal folds, 1398–1402
- peritoneum, 375–381, 1236–1237, 1240b
- folds of, 1398–1402
- general organisation of, 1236–1237, 1236f
- general properties of, 1237
- innervation of, 1238–1239
- vascular and lymphatic drainage of, 1238
- peri-urethral glands, 1384
- perivascular fibrous capsules, 1292
- periventricular zone, hypothalamus, 537–538
- permissive interactions, embryonic tissue, 211–212
- peroxisomes, 9–10
- perpendicular plate, of ethmoid bone, 668
- pes cavus, 1545–1546
- pes planus, 1545–1546
- petrosal sinus
- inferior, 621–622, 647
- superior, 621
- Peyronie disease, 1389–1389.e1
- phagocytes, 88–90
- phagocytosis, 88–89, 89f
- phalangeal cells, 818
- phalanx (phalanges)
- of foot, 1534–1535
- of hand, 1030–1031.e1, 1031f
- ossification of, 1031–1031.e1
- pharyngeal arches, 305–311, 305f, 306t
- arterial supply, 309–310, 309f, 310f
- innervation, 309
- muscles, 307–309, 308f
- skeletal elements, 307, 307f
- vascular supply, 309–311
- venous drainage, 311, 311f
- pharyngeal artery, 640, 738
- ascending, 640
- meningeal branches, 640
- pharyngeal branches, 645
- glossopharyngeal nerve, 653
- pharyngeal clefts, 305–306
- pharyngeal constrictors, 757
- pharyngeal derivatives, 311–316, 313f
- bilateral, 314f, 315f
- caudal pharyngeal complex, 316
- laryngeal vestibular diverticulum, 312–313, 313f
- midline, 311–313
- parathyroid glands, 315–316
- pituitary gland, 311–312
- respiratory diverticulum, 313
- salivary glands and oropharyngeal lymphoid tissue, 314–315
- thymus, 316
- thyroid gland, 312, 312f, 313f
- pharyngeal nerve, 738
- pharyngeal plexus, 768
- pharyngeal pouches, 305–306
- pharyngeal tonsil, 758, 759–760.e1
- adenoidectomy, 760–760.e1
- functions, 760
- lymphatic drainage, 759–760
- microstructure, 760
- vascular supply, 759–760
- pharyngeal veins, 648, 757
- pharyngobasilar fasciae, 757
- pharynx, 697f, 757–772, 757f, 758–758.e1f
- floor of, 306
- inside-out surgical anatomy of, 771–772
- laryngopharynx, 763–768.e1
- laryngeal inlet, 763–764
- obstructive sleep apnoea and snoring, 768–768.e1
- pharyngeal plexus, 768
- piriform fossa, 763
- nasopharynx, 758–761, 759f
- innervation, 759
- non-tonsillar, 759
- pharyngeal tonsil, 759–760.e1, 760f
- oropharynx, 761–763
- lingual tonsil, 763
- palatine tonsil, 761–763.e1, 762f
- relations, 759
- phonation
- increased pitch in, 787, 787f, 788f
- laryngeal muscle tension patterns during, 787–789, 788f
- normal vocal fold closure in, 787, 787f
- vectors of force around the cricoarytenoid joint during, 786–789, 786f
- photoageing, of skin, 169
- phrenic ganglia, 1117
- phrenic nerves
- accessory, 1118
- cervical plexus of neck, 651, 651f
- diaphragm, 1116–1118, 1118f, 1119f
- lesions, 1117
- transvenous stimulation, 1117–1118
- phrenic plexus, 1190
- phrenic veins, 1116–1116.e1
- phrenicocolic ligament, 1315
- Phrygian cap, 1299
- pia mater, 446f, 447–448, 627, 923–923.e1, 923f
- pillar cells, 816
- pilosebaceous unit, 160–164, 162f, 289–290
- pineal gland, 542.e1f, 542
- pinocytosis, 8
- piriform fossa, 763
- piriformis muscle, 1328, 1469
- nerve to, 1484
- pisiform bone, 1029
- pit(s), primitive, 200
- pitch, increased, 787, 787f, 788f
- pituitary gland, 254–254.e1, 311–312
- pituitary hormones, 540t
- pivot joints, 112
- placenta
- after delivery, 1413–1415, 1415f
- development of, 190–195, 191f, 192f, 1413, 1414f
- basal plate, 191–192.e1, 192f
- chorionic plate, 191–193.e1, 193f
- intervillous space, 193–195, 193f
- placental villus, 194–195, 194f
- variations of, 1415
- placental tissues, 190
- placental villus, 194–195, 194f
- structure of, 194–195, 194f
- transport across, 195
- placode, ectodermal, 204, 252–254.e1, 253f, 254f
- plane joints, 112
- planes, 595–597, 596f
- plantar aponeurosis, 1522–1523.e1, 1524f
- plantar arch, 1552, 1552f
- plantar calcaneocuboid ligament, 1541
- plantar calcaneonavicular (spring) ligament, 1540
- plantar interossei muscle, 1550, 1550–1550.e1f
- plantar ligaments, 1542, 1543
- plantar muscles, of foot
- first layer, 1547–1548, 1547f, 1548f
- fourth layer, 1550, 1550–1550.e1f
- second layer, 1548–1549
- third layer, 1549, 1549f
- plantar reflex, 1432
- plantaris muscle, 1511, 1547
- plasma, 77, 236
- plasma membrane
- molecular organisation of, 5–6, 5f
- plasticity, cardiac, 153
- platelets, 82
- agglutination, 82
- cell lineages of, 88
- role in haemostasis, 82
- structure, 82
- platysma muscle, 634, 681
- pleura, 1091–1095, 1091f
- cervical, 1092–1092.e1f, 1092–1093
- innervation, 1094–1095
- lymphatic drainage, 1094–1095
- margin of, 1066
- microstructure, 1095
- parietal, 1092–1092.e1f, 1092–1093
- costal part, 1092
- diaphragmatic part, 1092
- mediastinal part, 1093
- vertebral part, 1092
- pneumothorax, 1095–1095.e1
- pulmonary ligament, 1093–1094
- recesses, 1094
- reflection of, 1066
- surface anatomy of, 1065–1066
- vascular supply, 1094–1095
- visceral, 1093
- pleural cavities, 1061
- pleural cavity development, 353, 353f
- pleural recesses, 1094
- pneumocytes, 1108
- pneumomediastinum, 1175–1175.e3, 1177f
- pneumothorax, pleura, 1095–1095.e1
- Poland syndrome, 979–979.e1
- polycythaemia, 78
- polymorphonuclear leukocytes, 40
- polyorchidism, 1381–1381.e2
- polyribosomes, 7
- pons, 429, 491–496
- central tegmental tract, 493
- cranial nerve nuclei and related tracts, 493–496
- external features, 491
- internal organisation, 491–492
- pathways and nuclei of, 492–496
- pons nuclei, 493
- pons reflexes, 496
- posterior longitudinal fasciculus, 493
- superior cerebellar peduncle, 496
- transverse section through
- level of principal sensory and motor nuclei of the trigeminal nerve, 491–492, 492–492.e1f
- level of the facial colliculus, 491, 492–492.e1f, 492f
- pons nuclei, 493
- pons reflexes, 496
- popliteal artery, 1435f, 1438, 1514–1515
- pulse of, 1438
- popliteal fossa, 1487–1487.e1f, 1487–1488, 1487f, 1488f
- popliteal nodes, 1518
- popliteal vein, 1517
- popliteus muscle, 1506–1507, 1512
- porta hepatis, 1291–1292, 1291f, 1292f
- portal vein, 240–241
- porto-systemic shunts, 1293
- post lactation, breast, 1089
- postcardinal veins, 239
- posterior abdominal wall, 1217–1229, 1229b
- bones, 1219
- boundaries, 1217
- contents, 1217
- definitions, 1217
- muscles, 1219–1220, 1219f
- skin, 1217–1219
- soft tissues, 1217–1219
- vascular supply and lymphatic drainage, 1220–1226
- posterior abdominal wall hernias, 1220
- posterior antebrachial cutaneous nerve, 1021
- posterior artery, pulse of, 1438
- posterior atlanto-occipital membrane, 904–904.e2f, 905, 905f
- posterior auricular artery, 641, 684, 798
- stylomastoid branch of, 807
- posterior auricular vein, 685
- posterior brachial cutaneous nerve, 993
- posterior cerebral artery, 455–456
- posterior cingulate cortex, of brain, 566
- posterior circumflex humeral artery, 988
- posterior commissure, hypophysis, 542
- posterior compartment, 1476–1477
- posterior cranial fossa, 616–617
- posterior cricoarytenoid muscle, 784
- posterior cruciate ligament, 1501
- posterior cutaneous nerve, of forearm, 993
- posterior division, of femoral nerve, 1482
- posterior ethmoidal artery, 840
- posterior ethmoidal nerve, 842
- posterior ethmoidal sinuses, 754–755
- posterior femoral cutaneous nerve, 1484
- posterior fossa, of brain, 460–461
- posterior funiculus, 469–470, 470f
- posterior gastric artery, 1246–1247, 1248f
- posterior intercostal artery, 1123, 1178, 1205–1206, 1205f
- thoracic wall, 1080
- posterior intercostal vein, 1123
- posterior interosseous artery, 1017–1018
- posterior limiting lamina, 853f, 854
- posterior longitudinal fasciculus, 493

- posterior longitudinal ligament, 899, 900f
 posterior (dorsal) nucleus, of vagus nerve, 489
-  posterior root ganglia, 925–925.e1
 posterior sacro-iliac ligament, 1456–1457
 posterior sternoclavicular ligament, 964
 posterior superior alveolar artery, 737
 posterior superior alveolar nerve, 738
 posterior superior nasal nerve, 738
 posterior superior pancreaticoduodenal artery, 1308
 posterior surface
 of liver, 1287f, 1288
 of pancreas, 1306
 of stomach, 1244
 posterior talocalcaneal ligament, 1539
 posterior thigh, anastomoses in the, 1480
 posterior tibial artery, 1435f, 1436f, 1438, 1516, 1552–1553
 posterior tibial recurrent artery, 1516
 posterior tibial tendon dysfunction, 1537–1538.e3
 posterior tibial veins, 1517
 posterior tibiofibular ligament, 1538
 posterior triangle, of neck, 601, 631
 posterior ulnar recurrent artery, 1017, 1017f
 posterior vertebral muscle, 638
 posterolateral corner, of knee, 1499f
 postganglionic fibres, 69
 postganglionic nerves, 435
 postganglionic parasympathetic neurons, 1310
 postlaminar zone, of optic nerve head, 871
 postmenopausal females, breast of, 1089
 postnatal brain maturation, 285
 postpharyngeal foregut, 363–369, 363f, 364f, 365f
-  duodenum, 367–367.e1
 mucosa, 366–367
 muscularis, 367
 oesophagus, 364
 at birth, 364
 serosa, 367
 special glands of, 367–369
 liver, 366f, 368–369
 pancreas, 365f, 366f, 367–368, 368f
 stomach, 364–367, 365f, 366f
 posture, 915–916
 anatomy of, 820–822
 power grip, 1035–1036
 PPRM. *see* premature rupture of membranes
 prechordal plate, 201
 precostal venous line, 240
 precursor cell populations,
 differentiating, 249
 early development of glioblasts, 257–258
 early development of neuroblasts, 256–257
 radial glia, 256
 pre-epiglottic space, 782, 783f
 preganglionic nerves, 435
 preganglionic vagal efferents, 1310
 pregnancy, 1411–1415
 breast, 1089
 cervix in, 1412
 period of, 404
 uterus in, 1411–1413, 1411f, 1412f
 pelvic changes in, 1413
 relations of, 1413
 preimplantation development, 183–186
 blastocyst, 184–185, 185f
 cleavage, 183–184, 185f
 ectopic implantation, 186
- preimplantation development (*Continued*)
 extraembryonic tissues, formation of,  186–188
 amniotic cavity, 187, 187f
 epiblast, 187, 187f
 extraembryonic mesoblast, 187–188
 hypoblast, 187
 yolk sac, 187
 fertilisation, 181–183, 185f
 in vitro, 182–183
 staging of embryos, 181, 182f, 183f, 184f
 twinning, 186, 186f
 uterine wall, attachment to, 185–186
 prelaminar zone, of optic nerve head, 871
 prelaryngeal nodes, infrahyoid, 649
 premaseteric artery, 683
 premature rupture of membranes (PPROM), 197
 premotor cortex, of frontal lobe, 568–569
 prepipriform area, of brain, 559
 prepuberty, breast, 1088
 prepuce, of penis, development of, 403
 presacral fascia, 1330–1331
 presplenic fold, 1315
 pretectal nuclei, 499
 preterm birth syndrome, 412
 pretracheal nodes, 649
 prevertebral space, 633–634
-  priapism, 1389–1389.e1
 prickle cell layer, of epidermis, 157, 157f
 primary afferent neurons, 438
 primary excretory duct, 383
-  primary intestinal (midgut) loop, 372–372.e1
 primary restraints, 1506, 1507f
 primary vestibulocerebellar mossy fibres, 518, 519f
 primitive circulation, 205–206
 primitive groove, 201
-  primitive hindgut, 373–375.e1
 anal canal, 374–375
 blood supply to gut, 375
 maturation of large intestine, 374
 primitive node, 200–203
 primitive streak, 200–203, 200f, 201f, 208, 216
 caudal portion, 200–201
 epithelial-to-mesenchyme transition, 208
 formation, 200
 ingression, 201, 216
 rostral portion, 200–201
 primordial germ cells, 200f, 203
 development of, 394, 395f
 gonad development of, 391
 migration of, 391
 procerus muscle, 742
 proisocortex, of brain, 557f
 projection fibres, 579–581
 internal capsule, 268–269
 promontory, 803
 pronator quadratus muscle, 1011
 pronator teres muscle, 1008, 1009f, 1010f
 pronephros, 383, 383f
 proper ovarian ligament, 1407
 proprioceptors, 71
 prosencephalon (forebrain), 204, 429–430
 development, 266–273
-  cerebral cortex, cellular
 development of, 270–273, 271f, 272–272.e1f, 273f
 diencephalon, 267, 267f
 telencephalon, 267–273
-  prostate, 1372–1376, 1373–1373.e1f, 1374f, 1375f
 age changes in, 1376
- prostate (*Continued*)
 development of, 401–402.e1
 innervation in, 1374–1375
 lymphatic drainage, 1374
 microstructure of, 1375–1376, 1376f
 vascular supply, 1374
 arteries, 1374
 veins, 1374
 zonal anatomy of, 1373–1374, 1375f
 prostatic urethra, 1367–1368, 1369f
 protein synthesis, 7
 proteoglycans, 42
 protoplasmic astrocytes, 58
-  proximal airways, 354–354.e1
 anomalies, 354–354.e1
 proximal radio-ulnar joint, 1005–1007, 1006f, 1007f
 pseudoglandular phase, respiratory system development, 355
 pseudostratified epithelium, 32
 psoas fascia, 1217
 psoas major muscle, 1220, 1465–1466, 1465f
 psoas minor muscle, 1220, 1466
 pterygoid arteries, 735
 pterygoid processes, 721–722
 pterygoid venous plexus, 735, 807
 pterygomandibular raphe, 680, 757
 pterygopalatine fossa, 606, 737–740, 740b
 pterygopalatine ganglion, 594, 739–740, 760
 orbital branches of, 843
 pterygospinous ligament, 733
 puberty, 418
 breast, 1088–1089, 1088f
 reproductive organs maturation, 403
 pubic symphysis, 1456
 articulating surface, 1456
 factors maintaining stability, 1456
 innervation, 1456
 ligaments, 1456
 movements, 1456
 relations, 1456
 vascular supply, 1456
 pubic vein, 1336
 pubis, 1446–1447
 body, 1446–1447
 inferior pubic ramus, 1447
 innervation, 1447
 muscle attachments, 1447
 ossification, 1447
 pecten pubis, 1447
 pubic tubercle, 1447
 superior pubic ramus, 1447
 vascular supply, 1447
 pubo-analis muscle, 1329
 pubocervical ligaments, 1403
 pubococcygeus muscle, 1329
 pubofemoral ligament, 1458–1460
 pudendal nerve, 1484
 in pelvis, 1337
 in perineum, 1343
 pulmonary arteries, 1123
-  pulmonary defensive mechanisms,
 lungs, 1106–1106.e2
 pulmonary plexus, 1063–1063.e1
 pulmonary sequestration, 1106–1106.e1
 pulmonary trunk, 1174–1175
 pulmonary valve, 234–235.e1, 1153, 1153f, 1155f
 diastole, 1153
 pulmonary veins, 1123
 pulses, 599
 arterial, 1426
 of subclavian artery, 938
 of upper limb, 950–952
- pulvinar, thalamus, 534
 pupillary light reflex, 859
 Purkinje cell layer, 509–510, 512f
 pyloric glands, 1252
-  pyloric orifice, 1245–1245.e1
 pyramidal eminence, 803
 pyramidalis muscle, 1209–1210, 1210f
- ## Q
- quadrangular membrane, 778
 quadrangular space, 985
 quadrate ligaments, 1007
 quadrate lobe, of liver, 1288
 quadratus femoris muscle, 1470–1471
 nerve to, 1484
 quadratus lumborum muscle, 1219–1220
 quadratus plantae, 1548, 1549f
 quadriceps femoris muscle, 1472–1473
 actions of, 1473
 innervation of, 1473
- ## R
- radial artery
 in forearm, 1016
 in wrist, 1048, 1049f
 radial body, 999
 radial collateral ligament complex, 1004
 radial fossa, 999
 radial glia, 256
 radial nerve, 992–993
 compression, 1021–1021.e1
 deep, 1021
 in forearm, 1020–1021.e1
 of upper limb, 942, 943f
 at wrist, 1052
 radial recurrent artery, 1016
 radiate ligaments, 1075
 radiate sternochondral (sternocostal) ligaments, 1076
 radicular canal, nerves in, 923
-  radiocarpal joints, 1031, 1032–1032.e1f, 1033–1033.e1f
 force transmission of, 1035, 1035f, 1036f
 loading of, 1034–1036.e1
 movements of, 1034–1036.e1
 radioscaphocapitate ligament, 1033–1034
 radio-ulnar syndesmoses, 1007
 radius, 999–1001, 999f, 1000f
 articular attachments of, 999–1001
 body of, 999
 distal, 999, 1000f
 ligamentous attachments of, 999–1001
 muscular attachments of, 999–1001
 ossification of, 1001
 proximal, 999
 vascular supply of, 1001, 1001f
 rami communicantes (communicans), to ciliary ganglion, 842–843
 ramus (rami), of spinal nerves, 926–928
 intermedius, 925
 RANKL, 97
-  ranula, 713–713.e1
 rapidly adapting receptors (RAR), 1106–1106.e2
 Raynaud phenomenon, 149–149.e1
 receptor-mediated endocytosis, 8–9.e1, 8–9.e2f
 rectal venous plexus, 1279
 rectovaginal folds, 1399, 1402f
 rectum, 380–381, 1276
 rectus abdominis muscle, 1198, 1207–1209, 1207f
 divarication of, 1209

- rectus anterior capitis, 637
rectus femoris muscle, 1472–1473
rectus lateralis capitis, 637
rectus muscle, 833–834, 833f
rectus posterior major capitis muscle, 912
rectus posterior minor capitis muscle, 912
rectus sheath, 1208–1208.e1f, 1208–1209, 1209f, 1210f
recurrent interosseous artery, 1018
recurrent laryngeal nerve, 790–791, 791f
red marrow, 85, 85f
red nucleus, 500–500.e1, 500f
red pulp, 1318–1319
reference lines, 595–597, 596f
referred pain, 1296
diaphragmatic, 1117–1118
pancreas, 1311
stomach, 1249
reflection(s), serous pericardium, 1141–1141.e1, 1142f
reflex(es), 593
accommodation, 857, 859f
autonomic, 439
crossed extensor, 478, 479f
flexor, 478, 478f, 479f
lower limbs, 1432
muscle stretch, 478, 478f
pupillary light, 859
sensitivity, gamma effects on, 478
visual, 822, 822f
reflux, gastro-oesophageal, 1115, 1136, 1245–1245.e1, 1245f
refraction (ocular), 862–863
disorders of, 863
regional anaesthesia, in thorax, 1062–1062.e2
regulatory (Treg) T cells, 82
Reinke's oedema, 781–781.e1
relaxed skin tension (RSTLs), 169
Remak Schwann cells, 64
remodelling, of bone, 106, 106f
renal arteries, 1200, 1221, 1349–1352, 1351f
renal corpuscle, 1354, 1354f
renal cortex, 1349
renal fascia, 1346, 1347f
renal pelvis, 1349–1350.e1, 1350f
renal tubule, 1355–1356, 1356f
renal veins, 1224, 1352, 1354f
renal vessels, 1356
reproductive ducts, development of, 391–393
female, 393, 393t
male, 394
reproductive system, 391–403
antenatal ultrasound of, 403
magnetic resonance imaging of, 403
male, 1377–1391, 1391b
resident cells, 38–39
resources, maternal, 'parental conflict,' 418–419
respiratory diverticulum, 313
respiratory surfaces (alveoli)
alveolar area, 1107
alveolar structure, 1107–1109
microstructure, 1107–1109
pulmonary surfactant, 1107f, 1108f, 1109
respiratory system development, 353–357.e1, 353f, 354f
alveolar phase, 355–356
canalicular phase, 355
distal airways, 354–356
congenital anomalies, 357–357.e1
embryonic phase, 355
future, 354, 354f
respiratory system development
(Continued)
intrapulmonary vasculature
development, 356
intrauterine maturation, 356–357.e1
lymphatics development, 356
proximal airways, 354–354.e1
anomalies, 354–354.e1
pseudoglandular phase, 355
saccular/alveolar phase, 355
restiform body, medulla oblongata, 486–487.e1
restriction, cells, 210
reticular fibres, 42f
reticular lamina, 37
reticular layer, of dermis, 160
reticular nuclei
lateral column of, 502–503.e1
medial column of, 502
median column of, 501–502, 502f
thalamus, 535
reticulated epithelium, 763
reticulocerebellar mossy fibre
afferents, 518
reticulospinal tracts, 476–477, 476f
reticulotegmental nucleus, 518
retina, 863–872, 864f
cells of, 865–870
central, 869–870, 869f
differentiation of, 294–295
formation of, 294–296
innervation of, retinopetal, 871
microstructure of, 864–870, 864f, 865f
vascular supply of, 870–872, 870f, 871f
retinacula, 1489
retinal-blood barrier formation, 295
retrobulbar area, of brain, 558–559
retrocaval ureter, 1361
retroperitoneum, 1217–1229, 1229b
bones, 1219, 1219f
boundaries, 1217
contents, 1217
definitions, 1217
muscles, 1219–1220
vascular supply and lymphatic
drainage, 1220–1226
retropharyngeal nodes, 649
retropharyngeal space, 757–758, 759
retrotrubal nucleus, 546
retrosplenic region, of brain, 564–564.e1
rhombencephalic alar plate (dorsolateral lamina), cell columns of, 262, 263f
rhombencephalic basal plate
(ventrolateral lamina), cell columns of, 261–262
rhombencephalon (hindbrain), 261–266, 262f, 263f, 429
cell columns of rhombencephalic
alar plate (dorsolateral lamina), 262, 263f
cell columns of rhombencephalic
basal plate (ventrolateral
lamina), 261–262
metencephalon, 263–266, 264f
myelencephalon, 262–263
rhomboid major muscle, 977–978
rhomboid minor muscle, 977
rhombomeres, 304–305
ribosomes, 7
ribs, 337, 1070–1074.e1, 1071f
accessory, 1073–1073.e1
costal cartilages, 1074
eleventh, 1073–1074
first, 1073
fractures, 1074–1074.e1
second, 1073
ribs (Continued)
tenth, 1073–1074
twelfth, 1073–1074, 1073f
typical, 1071–1073, 1072f
variant, 1073–1073.e1
right atrium, 1147–1150, 1148f, 1149f, 1151f
right common carotid artery, 1178
right common iliac artery, 1331
right coronary artery, 1163–1166, 1165f, 1166f, 1167f
right coronary plexus, 1172
right gastric artery, 1247
right gastro-omental artery, 1247–1248
right hepatic duct, 1299–1300
right hepatic vein, 1294–1295
right lobe, of liver, 1288
right phrenic nerve, 1116
right portal fissure, 1288
right suprarenal gland, 1322, 1323f
right surface
of heart, 1147
of liver, 1287, 1287f
right ventricle, 1150–1153
external features of, 1150
internal features of, 1150–1153, 1151f
papillary muscles of, 1153
rima glottidis, 781, 781f
risorius muscle, 681
rod(s), of retina, 866–867, 866f, 867f
root
of lungs, 1104
of neck, 600–601, 652f, 661–662
of teeth, dentine, 707
rosettes, mossy fibres, 513, 514f
rostral somites, 305–306
rostral spinocerebellar tract, 518
rotation, axial, 113
rotator cuff disease, 983–983.e1
rotatores muscle, 910, 910f
rough endoplasmic reticulum, 7, 7f
endocytic pathway, 8, 8–9.e2f
exocytic (secretory) pathway, 8
Golgi apparatus (Golgi complex), 7–8, 8–9.e2f
polyribosomes, 7
protein synthesis, 7
ribosomes, 7
round ligament
of liver, 1290
of uterus, 1402–1403
Rouvière's sulcus, 1289
rubrospinal tracts, 475
Ruffini endings, 72–73
sacral plexus (Continued)
superior gluteal nerve, 1484
visceral and pelvic muscular branches
of sacral plexus, 1484
sacral posterior spinal rami, 927–928
sacral sympathetic system, 1189
sacral visceral branches, 1337
sacrococcygeal joints, 917
sacrococcygeal junction, 907
innervation of, 907
ligaments of, 907, 907f
vascular supply of, 907
sacro-iliac joint, 1456–1457
auricular surfaces, 1456
factors maintaining stability, 1457
fibrous layer of the articular capsule, 1456
innervation, 1457
ligaments, 1456–1457
movements, 1457
relations, 1457
sciatic foramen, 1457
variants, 1457
vascular supply and lymphatic
drainage, 1457
sacrospinous ligament, 1456–1457
sacrospinous ligament, 1456–1457
sacrum, 337–338, 895–898, 896f, 897–897.e1f, 1449
apex of, 897
base of, 895–897, 896f
canal of, 898
muscle attachments to, 898
ossification of, 898, 898f
surfaces of
lateral, 897, 897–897.e1f
pelvic, 896f, 897
posterior, 896f, 897
variants of, 898
saddle joints, 112
sagittal band injury, 1043–1043.e1
sagittal sinus
inferior, 620
superior, 620, 622f
salivary glands, 314–315, 712–716, 713–713.e1f
age changes in, 716
basal cells, 715–716
control of, 716
ducts, 715
lymph nodes, 716
microstructure of, 714–716, 714f, 715f
minor, 713–714
myoepithelial cells, 715
parotid gland, 712
sublingual gland, 713–713.e1
submandibular duct, 713, 714f
submandibular gland, 712–713
salivary nuclei, 496
salpingopharyngeal fold, 758–759
salpingopharyngeus muscle, 760, 766
saphenous hiatus, 1443, 1443f
saphenous nerve, 1482, 1518
infrapatellar branch of, 1487
sarcomere(s), 115–116, 116f, 117f, 118f, 119f
sarcoplasmic reticulum, 117, 119f
cardiac muscle and, 151
sartorius muscle, 1471–1472
branch of femoral nerve to, 1482
satellite cells, 67–68, 67f, 68f, 123–124, 123f
satellite glial cells (SGCs), 67, 69, 258
scalenus anterior muscle, 637–638, 637f
scalenus medius muscle, 638
scalenus posterior muscle, 638

- scalp, 590, 663–690
 fascia of, 664
 skin of, 663–664.e1
 scaphoid bone, 1028–1028.e1
 scapula, 958–962.e1, 959f, 960f, 961f
 acromion, 960
 angles, 959
 coracoid process in, 960–961
 costal surface, 958
 landmarks of, 917
 lateral border, 958
 ligaments, 961–962.e1
 medial border, 958–959
 movements of, 961
 ossification of, 961–961.e1
 posterior surface, 958
 spine of, 959–960
 superior border, 958
 scapular artery, dorsal, 646
 scapulothoracic joint, movements of, 967–969
 depression, 967–968
 elevation, 967–968
 lateral rotation, 969
 medial rotation, 969
 protraction, 968–969
 retraction, 968–969
 scar(s)
 excessive, formation of, 171
 skin, 169–171
 Scarpa's ganglion, 820
 Schmidt-Lanterman incisures, 59, 65
 Schwann cells, 64–65
 precursors, 258
 sciatic nerve, 1200, 1429, 1482–1483, 1483f
 sclera, 850–853, 851f, 852f
 sclerotomy(s), 208
 sclerotomy, cell populations, 332–338.e1, 333f, 334f, 335f
 intervertebral disc development, 333–338
 vertebrate development, 332–333, 335f
 Scribble protein, 207
 scrotum, 1389–1391
 development of, 403
 anomalies of, 1390
 lymphatic drainage of, 1391
 vascular supply of, 1390–1391
 sebaceous glands, 163, 163f
 second metatarsal bone, 1534
 secondary restraints, 1506, 1507f
 secondary vestibulocerebellar mossy fibres, 518, 519f
 segment I, of liver, 1289
 segment II, of liver, 1289
 segment III, of liver, 1289
 segment IV, of liver, 1289
 segment V, of liver, 1290
 segment VI, of liver, 1290
 segment VII, of liver, 1290
 segment VIII, of liver, 1290
 segmental arteries, of kidney, 1349–1350, 1352–1352.e1f
 segmental innervation, of lower limb, 1432–1434.e1
 segmental nerves, 1206–1207.e1
 segmental radiculomedullary feeder arteries, 929
 segmentation
 of neural tube and early brain regions, 254–259
 CNS/PNS transition zones, 258–259
 differentiating precursor cell populations, 255–258, 255f, 256f
 segmentation (*Continued*)
 occipitocervical junction, 334–336.e1, 336f, 337f
 paraxial mesenchyme, 329
 selectins, 27
 semicircular canals, 300, 811, 811f
 head movements of, 821, 821f
 semicircular ducts, 814, 814f
 semilunar line, 1198
 semimembranosus muscle, 1476–1477
 seminal glands, 1383–1384, 1384f
 innervation of, 1384
 lymphatic drainage of, 1384
 microstructure of, 1384, 1384f
 vascular supply of, 1384
 seminal vesicles, development of, 394
 seminiferous epithelium, 35
 semispinalis muscle, 910–911, 911f
 semitendinosus muscle, 1476
 sensory epithelia, 32
 sensory ganglia, 67f, 68–69
 sensory pathway, ascending, 430–431, 432f
 sensory receptors
 functional classes of, 70–71
 general features of, 70, 71f
 septum (septa)
 of brain, 565
 interalveolar, 1107–1108
 orbital, 830
 septum transversum, 220
 seromucous (submucosal) glands, 1107–1107.e1
 serosa, 45, 367, 1195, 1265, 1404
 of gallbladder, 1303
 of large intestine, 374, 1284–1285
 of peritoneum, 1253
 of small intestine, 373
 serotonin, 555
 serous membrane, 45
 serous pericardium, 1141, 1143–1144f
 serratus anterior muscle, 978
 serratus posterior inferior muscle, 978, 1078
 serratus posterior superior muscle, 978, 1078
 Sertoli cells, 1381
 sesamoid bones, 1535–1536
 sex determination, in embryo, 396–397
 sexual differences, in pelvis, 1451–1451.e1
 sheath(s)
 of eyeball, fascial, 830–832, 832–832.e1f
 fibrous, of flexor tendons, 1040, 1041f
 of hair, 162
 synovial
 of carpal flexor tendons, 1040–1041, 1042f
 of digits, 1038
 of dorsal carpal tendon, 1042–1042.e1, 1043f
 shock absorption, 129, 129f
 short gastric arteries, 1246, 1316
 short radiolunate ligament, 1034
 short stature, 416, 419
 shoulder, instability of, 1053, 1054f
 shoulder girdle, 954–996
 bones, 956–964, 957f, 958f, 959f, 960f, 961f, 962f
 injuries to, 991–991.e1
 joints, 964–975.e1, 965f, 967f, 968f, 969f, 970–970.e1f, 970f, 971f, 972f, 973f
 lymphatic drainage, 985–990
 muscles, 975–985, 975t
 concavity compression, 982–983.e1
 shoulder girdle (*Continued*)
 coordinate shoulder and elbow motion, 983–985, 984–984.e1f, 984f
 scapular motion, 977–978
 scapular suspension, 975–976, 975f, 977f
 thoracohumeral motion, 978–982, 979f, 981f
 skin, 954, 954–956.e1, 955f, 956f
 soft tissues, 954–956.e1, 954–956.e1
 vascular anastomoses around, 988–988.e1
 vascular supply, 985–990
 shunts
 arteriovenous, 144
 vascular, 144
 Sibson's fascia, 633
 sigmoid arteries, 1277–1278
 sigmoid colon, 380, 1275–1276, 1276f
 sigmoid mesocolon, 1236
 peritoneal relationships of, 1238
 sigmoid sinus, 621, 622f, 623f
 sigmoid volvulus, 1276f
 simple epithelia, 31–32, 33f
 sinu-atrial junction, 228–228.e1
 sinu-atrial node, 1162
 sinus of Morgagni, 759
 sinus tympani, 803
 sinusoid(s), 143, 143f, 1297
 sinusoidal endothelial cells, 1298
 sinuvaginal bulb, 393, 402
 sixth pharyngeal arch, 306
 skeletal landmarks
 of head, 595–598
 of neck, 600, 600f
 skeletal muscle, 74–75, 115–120
 action of, 126
 connective tissues of, 117
 contraction of, 120–121
 development of, 121–124
 force of, 125–126
 form and function of, 124–126
 growth of, 121–124
 innervation of, 120
 lymphatic drainage of, 117–120
 mass regulation of, 124
 microstructure of, 115–117, 115f, 116f
 power of, 125–126
 repair for, 123–124
 strength of, 125–126
 vascular supply of, 117–120, 119f
 skeletal tissues. *see also* bone
 materials of, properties of, 130, 130t
 Skier's thumb, 1039–1039.e1
 skin, 154–176, 1202–1207.e1
 appendages of, 154–167
 of arm, 954, 954–956.e1, 955f, 956f
 of back, 878, 878f
 innervation of, 878
 lymphatic drainage of, 878, 879f
 vascular supply of, 878, 879f
 classification of, 154, 155f, 156f
 development, 286–291, 286f, 291b
 adnexae, 289–290
 basement membrane zone, 287–288
 epidermis, non-keratinocyte populations, 288
 maturation of the dermis, early
 blood vessels and innervation, 288–289
 dorsal, 1022
 eccrine sweat glands, 290
 embryonic populations contributing, 286–291
 fetal, 290
 skin (*Continued*)
 of forearm, 997, 998f
 functions of, 154–154.e1
 of hand, 1022–1023
 dorsal vs. palmar, 1022
 innervation of, 1023, 1023f, 1024f
 vascular supply of, 1022–1022.e2, 1023f
 head, 590
 immunological anatomy of, 154
 innervation of, 167
 layers of, 155
 lines of, 154, 167–169, 167f, 1022, 1022f
 after manipulation or incision, 168–169
 of lower limbs, 1423–1425
 lymphatic drainage of, 166–167, 1206
 microstructure of, 154–167
 nails, 290
 of neck, 590, 628–629
 cutaneous innervation, 628–629, 628f
 cutaneous vascular supply, 628, 628f
 lymphatic drainage, 628, 628f
 neonatal, 290–291
 palmar, 1022
 of pectoral girdle, 935–936
 regional variations in, 154–154.e1
 segmental nerves, 1206–1207.e1
 of shoulder girdle, 954, 954–956.e1, 955f, 956f
 stem cells of, 171–173
 thorax, 1067–1068
 types of, 154–154.e1
 of upper limb, 935–936
 vascular supply and lymphatic drainage, 1203–1203.e1f, 1203–1206
 vascular supply of, 166–167, 166f, 167f
 skull, 322–328, 322f, 590, 603–612, 604f, 605f
 antenatal ultrasound and MR imaging of the head and neck, 328
 anterior view, 603–605, 604f
 calvaria, 327–328
 inferior view, 606–610
 lateral view, 606, 607f
 meninges and venous sinuses, 324–325, 324f
 neurocranium, 324–328
 posterior view (occipital view), 605, 605f
 skull base, 325–327, 326f
 superior view, 605–606, 605f
 viscerocranium, 322–324, 323f
 skull base, 325–327, 326f
 slowly adapting receptors (SAR), 1106–1106.e2
 small cardiac vein, 1170
 small intensely fluorescent (SIF) cells, 69
 small intestine, 380, 1254–1265, 1265b
 at birth, 373
 duodenum, 1254–1257
 ileum, 1258–1261, 1259f
 jejunum, 1257–1258.e1, 1257f, 1258f
 maturation of, 373
 mesentery and, 1199
 microstructure, 1262–1265
 circular folds, 1262, 1262f
 epithelium, 1263–1264
 interstitial cells of Cajal, 1265
 intestinal villi, 1262, 1263f, 1264f
 mucosa, 1263–1265
 muscularis externa, 1265
 serosa, 1265
 submucosa, 1265

- small intestine (*Continued*)
peritoneal relationships of the mesentery of, 1238
- small saphenous vein, 1517
- smooth endoplasmic reticulum, 7, 7f
- smooth muscle, 136–153
calcium regulation of, 139
contraction of, structural basis of, 139
excitation-contraction coupling in, 139
innervation of, 138, 138f
media, 147
microstructure of, 136–138.e1, 136f, 137f, 138f
neurovascular supply of, 138
origin of, 139–140
remodelling, in disease, 140–140.e1
vascular supply of, 138
- snoring, 768–768.e1
- soft palate, 694, 761, 763f
innervation, 761
muscles of, 764–768
dilator tubae, 764
hypopharyngeal diverticula, 767–768
inferior pharyngeal constrictor, 767
levator veli palatini, 764, 764f, 765f, 766f
middle pharyngeal constrictor, 767
musculus uvulae, 766
palatoglossus, 764
palatopharyngeus, 765–766
salpingopharyngeus, 760, 766
stylopharyngeus, 766
superior pharyngeal constrictor, 767
tensor veli palatini, 764
palatine aponeurosis, 761
palatoglossal and palatopharyngeal arches, 761
vascular supply, 761
- soft tissue, 664–665, 1202–1207.e1
of arm, 954–956.e1, 954–956.e1
of breast, 1084
of head, 598–600
lymphatic drainage of, 1206
of neck, 600–601, 600f
- segmental nerves, 1206–1207.e1
of shoulder girdle, 954–956.e1, 954–956.e1
subcutaneous tissue, 1202
vascular supply and lymphatic drainage, 1203–1203.e1f, 1203–1206
- of wrist, 1024–1026.e2
- soleus muscle, 1511–1512
- solitariospinal tract, 477
- solitary nucleus, 489–490
- somatic arteries, 237–238, 238f
- somatic nerves, development, 279–281
cranial nerves, 279–281, 280f
spinal nerves, 281
- somatic veins, later development of, 240
- somatic venous complexes, 238–240, 239f
- somatopleure, 216
- somatopleuric coelomic epithelium, 204–205
- somatopleuric mesenchyme, 222
- somatostatin (ST), 56
- somites, 220
development, 329–332, 329f, 330f, 331f, 332f
epithelial, 203–204, 205f, 208
somitogenesis, 329
sound, in fetus, 303
- space(s)
digital, of hand, 1026–1026.e2
epidural, 922–923, 922f
- space(s) (*Continued*)
palmar, 1026–1026.e2
subarachnoid, 922f
subdural, 923
of thorax, 1061–1061.e1
specialised intercellular junctions, 28–29
specialised junctions, 28–29
spectrin, 78
speech, anatomy of, 792
spermatic cord, 1382–1383.e1, 1383f
spermatids, 1380–1381
spermatoceles, 1381–1381.e2
spermatocytes, primary and secondary, 1380
spermatogonia, 1380
spermatozoa, 181, 1381
maturation of, 1381
motility of, 1381
sphenoid bone, 604f, 719–722.e1, 720f
body, 719–721
greater wings, 721
lesser wings, 721
ossification, 722–722.e1
pterygoid processes, 721–722
superior orbital fissure, 721
sphenoidal conchae, 722
sphenoidal sinus, 753–754, 754f
sphenomandibular ligament, 726–727
sphenopalatine artery, 738–738.e1
sphenopalatine foramen, 747
sphenoparietal sinus, 624–625
sphincter pupillae muscle, 858
Spigelian hernia, 1216
spinal accessory nerve, of upper limb, 940
spinal arteries, 928–929, 928f
spinal cord, 259–261, 259f, 429, 430f, 464–482, 920–922, 921f, 922f
clinical procedures of, 931–932
external features, 464, 464f
gross anatomy of, 920–932, 932b
injury of, 930–931
internal organisation, 464–477
ischaemia, 929
lesions, 478–479, 480–482f
maturation of, 260–261
relations, 464, 464f
spinal reflexes, 477–479.e1
syndromes of, 931–931.e1
vascular supply of, 928–930
veins of, 929–930, 930f
spinal cord injury without radiological abnormality (SCIWORA), 931
spinal cord ischaemia, 929
spinal ganglia, 925–925.e1
lesions of, 931
spinal grey matter, 260, 464–469, 465f
anterior (ventral) horn, 468–469, 468f
lateral horn, 467–468
neuronal cell groups of, 465, 466f
posterior horn (dorsal horn), 465–467
spinal meninges, 922–923
spinal nerves, 433, 593, 595f, 924–930, 924f
development, 281
functional components of, 926
gross anatomy of, 920–932, 932b
lesions of, 931
proper, 925–926
rami of, 926–928
somatic components of, 926
thoracic, 1062–1063.e1
variations of, 926
vascular supply of, 928–930
visceral components of, 926
- spinal roots, 925–925.e1
anterior, 920–922, 925
- spinal roots (*Continued*)
appearance of, 925
coverings of, 923, 924f
orientation of, 925
posterior, 920–922, 925
relations of, 923
variations of, 926
vascular supply of, 928–930
- spinal trigeminal nucleus, 490–491.e1
- spinal white matter, 259–260, 469–477, 469f
- ascending pathways, 469–472.e1
descending tracts, 472–477
propriospinal pathways, 477
- spinalis muscle, 909
- spinocerebellar tracts, 470–471, 471f
- spinocervicothalamic pathway, 472
- spinoreticular pathway, 472
- spinoreticular tracts, 488
- spinothalamic tracts, 471–472.e1, 471f, 488
- spiny stellate cells, expressing glutamate, 552
- spiral organ, 816–819, 818f
- splanchnopleure, extraembryonic, 200
- splanchnopleuric coelomic epithelium, 204–205
- splanchnopleuric mesenchyme, 222
- spleen, 381–382, 1199, 1314–1321
arteries, 1316, 1317–1317.e1f, 1318f
fibrous framework, 1318
function, 1314f
gross anatomy, 1314, 1314f
imaging, 1320, 1320f
innervation, 1317–1318
ligaments, 1315–1315.e1
lymphatic drainage, 1316–1317, 1319f
microcirculation, 1319–1320
microstructure, 1318–1320, 1319f
peritoneal and mesenteric relationships of, 1238
red pulp, 1318–1319
relations, 1314–1315, 1315f, 1316f
vascular supply, 1316–1317
veins, 1316
white pulp, 1318, 1320f
splenectomy, 1320–1321
splenic artery, 1310, 1316, 1317–1317.e1f
splenic trauma, 1320–1320.e1
splenic vein, 1316
splenius capitis muscle, 908, 908f
splenius colli muscle, 908, 908f
splenogonadal fusion, 1381–1381.e1
splenomegaly, 1320–1320.e1
spleno-omental fold, 1315
spontaneous twinning, 186
squamous epithelium, 31
SRY gene, 397
stapedectomy, 806–807
stapedial footplate, 301
stapedial reflex, 807
stapedius muscle, 302, 807
stapedius reflexes, 496
stapedotomy, 806–807
stapes, 301, 805–806
fixation, 806–807
ossification, 806
stellate cells, 1312
of cerebellar cortex, 509
stellate macrophages (Kupffer cells), 1298
- stem cells
epidermal, 157
skin, 171–173
small intestine, 1263
- sternalis muscles, 1078–1079.e1
- sternochondral joints, 1076, 1076f
movements, 1076
- sternochondral (sternocostal) ligaments, radiate, 1076
- sternoclavicular joint, 964–966
articular disc, 964–966
articulating surfaces, 964, 965f
fibrous layer of articular capsule, 964
innervation of, 966
ligaments, 964
movements of, 966
stability of, 966
vascular supply, 966
- sternocleidomastoid artery, 640
- sternocleidomastoid muscles, 634–635, 635f
- sternocostal joints, 1076, 1076f
- sternocostal triangles, 1111
- sternohyoid muscle, 636
- sternothyroid muscle, 636
- sternotomy, 1083–1083.e1
- sternum, 1069–1070.e1, 1069f
body of, 1069–1070
development, 360
- steroid, production, fetal adrenal glands, 391
- stiffness (biomechanics), 128
- stillbirth, 411
- stomach, 364–367, 365f, 366f, 1199, 1243–1253, 1253b
arterial anastomoses of, 1248, 1248f
arterial supply of, 1246f
at birth, 367
cardiac orifice, 1244–1245.e1
curvatures, 1243–1243.e1
form and internal appearances of, 1245–1245.e2
gastro-oesophageal junction, 1244–1245.e1
innervation, 1249
lymphatic drainage, 1249, 1250f
microstructure
epithelium, 1251–1253, 1251f, 1252f
mucosa, 1251
muscularis externa, 1253
submucosa, 1253
orifices, 1244–1245.e1
parasympathetic innervation, 1249, 1251f
parts of, 1243, 1243f
pyloric orifice, 1245–1245.e1
relations, 1243–1244
rotation of, consequences of, 376
surfaces, 1243–1244
sympathetic innervation, 1249
vascular supply and lymphatic drainage, 1245–1249
- straight sinus, 620
- stratified columnar epithelia, 34, 34f
- stratified cuboidal epithelia, 34, 34f
- stratified epithelia, 32–35
- stratified squamous epithelia, 32–34
- stress relaxation, 129–130
- stria medullaris thalami, hypophysis, 541–542
- striatal connections, in basal ganglia, 545–547, 546f, 547f
- striatopallidal axons, 547
- striatum, 543–547
- striosomes, 545
- stroma
of bone marrow, 85
of choroid, 855, 856f
ciliary, 857, 859f
of cornea, 853–854, 854f
of iris, 858
- styloglossus muscle, 697

- stylohyoid, of anterior triangles of neck, 636
- stylohyoid ligament, 697
- styloid process, 606
- stylomandibular ligament, 727
- stylo mastoid artery, 807
- stylopharyngeus muscle, 766
-  subarachnoid cisterns, 445–447, 446–446.e1f, 446f
- subarachnoid haemorrhage, 458
- subarachnoid space, 445–447, 446f
- subcardinal veins, 239
- subcentral veins, 240
- subclavian arteries, 592, 601, 1178
- left, 1178
- right, 1178
- subclavian nerve, of upper limb, 940
- subclavian vein, 601, 648, 989–990
-  catheterisation, 648–648.e1
- subclavius muscle, 976, 977f
- subcostal artery, 1115, 1178, 1205–1206, 1205f
- subcostals, 1078
- subcutaneous fibroadipose tissue, 664
- subcutaneous tissue, 161f, 1202
- subdural hematoma, 618
- subglottic space, 782
-  subglottic stenosis, 775–775.e1
- subhepatic space, right, 1239
- sublingual artery, 641, 698
-  sublingual gland, 713–713.e1
- submandibular duct, 713, 714f
- submandibular ganglion, 594, 713
- submandibular gland, 656, 712–713
- deep part of, 712–713
- superficial part of, 712
- submental artery, 641
- submental triangle, of neck, 631
- submucosa, oesophagus, 1134
- suboccipital muscle, 912, 913f
- suboccipital nerve, 926
- suboccipital triangle, 912, 913f
- subphrenic space
- left, 1240
- right, 1239
- subsartorial nerve plexus, 1482
- subscapular artery, 987–988
- subscapular fascia, 956
- subscapularis muscle, 983
- substance P (SP), 56
- substantia nigra, 500
- in basal ganglia, 548
- substantia propria, of cornea, 853–854, 854f
- subthalamic nucleus
- in basal ganglia, 543f, 544f, 548
- hypophysis, 541
- subthalamus, 541
-  subvesical duct(s), 1300–1300.e1
- sulci
- of cerebral hemisphere, 552
- formation of, 270
-  frontal lobe, 566–567.e1
-  insular lobe, 575–575.e1
-  occipital lobe, 571–571.e1
-  parietal lobe, 570–570.e1
-  temporal lobe, 572–572.e1
- superficial abdominal reflex, 1198
-  superficial arteries, of head and neck, 591–591.e1f
- superficial cervical artery, 645
- superficial cervical fascia, 631
- superficial circumflex iliac artery, 1478–1479
- superficial epigastric artery, 1478
- superficial external pudendal artery, 1479
- superficial fatty layer, subcutaneous tissue and, 1202
- superficial fibular nerve, 1519–1520, 1553
- superficial hepatic lymphatics, 1295
- superficial inguinal nodes, 1481
- superficial inguinal ring, 1213
-  superficial musculoaponeurotic system (SMAS), 664, 744–744.e1
- superficial reflexes, 1198
- superficial sural arteries, 1515
- superficial temporal artery, 683–684
- frontal (anterior) branch, 684
- parietal (posterior) branch, 684
- superficial temporal vein, 685
- superficial thoracic fascia, 1068
- superficial tissue, of upper limb, 939
- superficial transverse metacarpal ligament, 1025
- superficial transverse perineal muscles, 1340–1341
- superficial veins
- of elbow, 990
- of foot, 1553
- of knee, 990f, 1517–1518
- superior alveolar arteries, 710–711
- superior anorectal artery, 1278, 1278f
- superior anorectal vein, 1279
- superior border
- of pancreas, 1306
- of spleen, 1315
- superior cerebellar peduncle, 496, 508
- superior cervical ganglion, 655–656
-  superior colliculus, 498–498.e1
- superior concha, 747
- superior costotransverse ligament, 1075
- superior deep cervical nodes, 649
- superior epigastric veins, 1203, 1204f
- superior extensor retinaculum, of ankle, 1521, 1522f
- superior fibular retinaculum, 1522
- superior gemellus muscle, 1470, 1470f
- superior genicular arteries, 1515
- superior gluteal artery, 1332–1333
- superior gluteal nerve, 1484
- superior gluteal veins, 1335–1336
- superior hypogastric plexus, 1190–1191
- superior labial artery, 683
- superior laryngeal artery, 640, 789
- superior laryngeal nerve, 790
- superior laryngeal vein, 789
- superior longitudinal fasciculus, 576–577
- superior longitudinal lingual muscle, 697
- superior meatus, 747
-  superior mesenteric artery, 1221, 1258–1260, 1259f, 1261–1261.e1f
- superior mesenteric nodes, 1226
- superior mesenteric plexus, 1190
- superior mesenteric vein, 1260, 1262f
- superior muscular branches, popliteal artery, 1515
- superior oblique muscle, 834
- superior olivary complex, 493
- superior ophthalmic vein, 840
- superior orbital fissure, 721, 829
- superior pancreaticoduodenal artery, 1256–1257
- superior petrosal sinus, 621, 807
- superior pharyngeal constrictor muscle, 767
- superior phrenic arteries, 1116
- superior phrenic branches, descending thoracic aorta, 1178
- superior rectus muscle, 833
- superior sagittal sinus, 620, 622f
- superior (upper) subscapular nerve, 990
- superior suprarenal arteries, 1323
- superior surface, of liver, 1286, 1287f
- superior thoracic artery, 987
- superior thyroid artery, 640
- superior thyroid vein, 648
- superior tibiofibular joint, 1494
- articulating surfaces, 1494
- factors maintaining stability, 1494
- fibrous layer of the articular capsule, 1494
- innervation, 1494
- ligaments, 1494
- movements, 1494
- relations, 1494
- synovial membrane, 1494
- vascular supply and lymphatic drainage, 1494
- superior ulnar collateral artery, 988–989
- superior vena cava, 1179
- superior vesical artery, in urinary bladder, 1365
- supinator muscle, 1015–1016, 1015f, 1016f
- supplementary motor cortex, of frontal lobe, 569
- supracardinal veins, 239
- suprachiasmatic nucleus, hypothalamus, 536–537
- suprachoroid, 855
- supraciliary layer, 857
- supraclavicular artery, 986
-  supraclavicular brachial plexus, injuries of, 946–946.e10
- supraclavicular nerves, 629
- supraclavicular triangle, of neck, 631
- supragranular pyramidal cells, 554
- suprahyoid artery, 641
-  supra-optic nucleus, hypothalamus, 537–537.e1
- supraorbital artery, 684, 839
- supraorbital nerve, 686, 842
- supraorbital vein, 684–685
- suprapleural membrane, 633
- suprapubic catheterisation, 1200
- suprarenal artery, 1221
- suprarenal cortex, 1325–1326
-  suprarenal gland, 390–391.e1, 1322–1327, 1322f
-  anomalies of, 391–391.e1
- antenatal ultrasound of, 391
- arteries, 1323–1324, 1323f
- at birth, 391
- excision, 1326
- function, 1325–1326, 1325f, 1326f
- innervation, 1324–1325, 1324f
- left, 1322–1323
- lymphatic drainage, 1324
- magnetic resonance imaging of, 391
- microstructure, 1325–1326
-  neoplastic lesions of, 1326–1326.e2
- right, 1322, 1323f
- vascular supply, 1323–1324
- veins, 1324
- suprarenal medulla, 1326
- suprarenal plexus, 1324–1325
- suprarenal vein, 1224
-  suprascapular artery, 645, 986–986.e1, 986f
- suprascapular nerve, 990
- of upper limb, 940
- supraspinatus fascia, 956
- supraspinatus muscle, 982
- supraspinous ligament, 899f, 900
- supratrochlear artery, 684, 840
- supratrochlear nerve, 686, 842
- supreme intercostal artery, thoracic wall, 1080
- sural arteries, 1515
- sural nerve, 1518
- surface anatomy
- of cerebral hemisphere, 552
- of head, 590–602
- of neck, 590–602
- surface ectoderm, 217
- suspensory ligament, of ovary, 1407
- sustentacular cells, 300, 748
- suture(s), 107, 108f, 603
- swallowing (deglutition), anatomy of, 768–771, 1136
- dysphagia, 770
- oesophageal phase, 770
- oral phases when swallowing solids, 768–769
- oral preparatory phase, 768
- oral transit/transfer phase, 768
- pharyngeal phase, 769–770, 769f
- pharyngeal tissue spaces, 770–771
- spread of infection, 771
- supramedullary influence on, 770
- swallowing in the neonate, 770
- swallowing pattern generator, 770
-  swan neck deformity, 1039–1039.e1
- sweat glands, 164–165, 164f
- symmetrical opening, in temporomandibular joint, 729
- sympathetic cardiac innervation, 1170
- sympathetic ganglia, 282
- sympathetic nerves, 594–595
- sympathetic nervous system, 436–437, 436f, 437f
- sympathetic neurons, 69
- postganglionic, 436
- preganglionic, 436, 436f, 437f
- sympathetic system
- pelvic part of, 1337–1338, 1338f
- somatic and vascular branches, 1189
- sympathetic trunk, 436, 1063
- symplyphes, 108–109, 109f
- synapses, 52–56, 52f
- activity mechanisms, 54–55
- classification of, 52–55, 53f, 54f
- climbing fibres and cerebellar interneurons, 514
- development, 55
- plasticity, 55
- type I, 54
- type II, 54
- synchondroses, 108, 109f
- syncytiotrophoblast, 189
- syndesmosis, 108
- synovial fluid, 111
- of temporomandibular joint, 727
- synovial joints, 109–115, 110f
- classification of, 112–113, 112f
- innervation of, 111–112
- lymphatic drainage of, 111
- mechanical properties of, 131, 131f
- vascular supply of, 111
- synovial membrane, 110–111, 110f
- of ankle joint, 1538
- of talocalcaneal joint, 1539–1540
- synoviocytes, 111
- synthetic human entities with embryo-like features (SHEEFs), 215
- T**
- T lymphocytes (thymus-derived), 81–82
- cytotoxic, 81
- development, 87

- T lymphocytes (thymus-derived)
(Continued)
helper, 81–82
regulatory (Treg), 82
specialised, 82
tail folding, 204, 206f
talar fractures, 1530
talocalcaneal joint, 1539–1540, 1539f, 1540f
talocalcaneonavicular joint, 1540
talonavicular ligament, 1540
talus, 1525–1530, 1528–1530f, 1531f
tarsal arteries, 1552
tarsal coalition, 1533–1533.e1
tarsal (Meibomian) glands, 845–846, 845f
tarsal joints, 1539–1543
tarsal plates, 296–298, 845, 845f
tarsometatarsal joints, 1543
tarsus, 1525, 1526f, 1527f
taste, discrimination, 701
taste buds, 700–701
central connections, 701
innervation, 700–701
microstructure of, 700
tear film, preocular, 847, 848f
tectorial membrane, 819, 819f, 905
tectospinal tracts, 475
tectum, 497–498.e1
teeth (dentition), 321–322, 701–712.e1
chronology of, 693
deciduous (primary), 703, 703f
dental alignment and occlusion, 703
eruption of, 703, 704f, 705f
general arrangement of dental tissues, 705–710.e1, 706f
innervation of, 711, 711–712.e1
lymphatic drainage of, 711
morphology, 701–704.e2, 702f
pain sensation in, 712–712.e1
permanent (secondary), 702f
vascular supply and lymphatic drainage of the teeth and supporting structures, 710–711
venous drainage of, 711
tegumentum, 498–499
telencephalon, 429–430
development, 267–273
telomeres, 19–19.e1
temperature, body, skin involvement, 154
temporal bone, 604f, 793–796, 794f
external acoustic meatus, 795
ossification, 796, 796f
petrous part, 793–795
squamous part, 793
mandibular fossa, 793
zygomatic process, 793
styloid process, 795
tympanic part, 795
temporal fasciae, 665
temporal lobe, internal structure and connectivity, 572–574, 573f
temporalis muscle, 731–732, 732f
actions, 732
innervation, 732
relations, 732
vascular supply, 732–732.e1
temporomandibular joint, 726–737, 740b
articular disc, 727–729, 728f
articular surfaces, 727
chorda tympani nerve, 737
development of, 731, 731f
fibrous capsule of, 726, 726f
innervation, 735–737
ligaments of, 726–727
lymphatic drainage, 735
mandibular nerve, 735–736.e1
temporomandibular joint (Continued)
maxillary vein, 735
muscles, 731–733
otic ganglion, 736–737
spread of infection from the infratemporal fossa, 737
synovial membrane, 727
vascular supply and lymphatic drainage, 733–735
temporoparietal fasciae, 665
temporoparietalis muscle, 676
tenascin, 42–43
tendinous arch, of pelvic fascia, 1330
tendons, 126–127
attachments of, 127, 127f
biomechanics of, 130
extensor digitorum, 1043–1043.e1
function of, 126–127
structure of, 126–127, 126f
tensor fasciae latae, 1466
tensor tympani muscle, 302, 807
tensor tympani reflex, 496, 807
tensor veli palatini muscle, 764
tentorium cerebelli, 618–619, 618f
teres major muscle, 983
teres minor muscle, 983
terminal glia, 67
testicular artery, 1378
testicular torsion, 1381–1381.e1
testis, 1377–1381.e2, 1377f, 1378f
age-related changes of, 1381
arteries of, 1378–1379, 1379f
descent of, 397, 398f
inguinoscrotal phase, 398–399.e1
transabdominal phase, 397–398
development of, 394–396.e1
anomalies of, 396–396.e1
developmental anomalies of, 1381–1381.e2
innervation of, 1379
lymphatic drainage of, 1379
microstructure of, 1380–1381, 1380f
retractile, 1381–1381.e1
vascular supply of, 1378–1379
veins of, 1379–1379.e1
tethered cord syndrome, 931
thalamic radiations, 579–580
thalamocortical afferent fibres, 554
thalamotomy, for dystonia, 549
thalamus, 529–535, 529f, 529t, 530f, 531f, 532f, 532t
anterior nuclei, 530
intralaminar nuclei, 534
lateral dorsal nucleus, 534
lateral geniculate nucleus, 533–534, 533f
lateral nuclei, 530–534
lateral posterior nucleus, 534
medial geniculate nucleus, 533
medial nuclei, 530
midline nuclei, 534
nuclear masses, 532f
pulvinar, 534
reticular nucleus, 535
ventral anterior nucleus, 530–531
ventral lateral nucleus, 531
ventral posterior nucleus, 531–532
thermoregulation, sweat glands and, 164
thigh
perforator flaps in, 1480
skin of, 1442
surface anatomy of, 1434f, 1435f, 1437
third metatarsal bone, 1534
third to seven cervical vertebrae, 336
third ventricle, of brain, 442, 442f, 443f
thoracic aorta, 1175–1176.e2
coarctation of, 1175–1176.e2
descending, 1177–1178
thoracic artery, internal, 645
thoracic cavity, 1061–1061.e1
fascia and spaces, 1061–1061.e1
thoracic duct, 1125f
tributaries, 1125–1126
thoracic posterior spinal rami, 927
thoracic splanchnic nerve
greater, 1187–1188
least, 1188
lesser, 1188
thoracic sympathetic trunk, 1126–1127.e1
thoracic vertebrae, 337, 893–894, 893f
eleventh, 893–894, 893f
first, 893–894, 893f
general features of, 893–894
muscle attachments to, 894
ninth, 893–894, 893f
ossification of, 894
tenth, 893–894, 893f
twelfth, 893–894, 893f
thoracic viscera, interventional access, 1083–1083.e1
thoracic wall, 1067–1090
antenatal imaging, 360
anterior intercostal branches, 1079–1080
anterior rami, thoracic spinal nerves, 1081–1083, 1082f
arteries, 1079–1080.e1
bone, 1068–1074.e1
cartilage, 1068–1074.e1
development, 357–362
innervation, 1081–1083
intercostal nodes, 1081
joints, 1074–1077
costotransverse, 1075–1076
costovertebral, 1074–1077
interchondral, 1074–1077
manubriosternal, 1074
rib head, 1074–1075, 1074f, 1075–1075.e1f
sternochondral, 1074–1077, 1076f
sternoclavicular, 1074
sternocostal, 1074–1077, 1076f
xiphisternal, 1074
lymphatic drainage, 1079–1081
of deeper tissues, 1081
muscles, 1077–1079, 1077f
intrinsic, 1077–1079
musculophrenic artery, 1080
parasternal (internal thoracic) nodes, 1081
perforating branches, 1080
posterior intercostal arteries, 1080
posterior rami, thoracic spinal nerves, 1083
sternal branches, 1079
superior diaphragmatic (phrenic) nodes, 1081
supreme intercostal artery, 1080
vascular supply, 1079–1081
veins, 1080–1081
internal, 1080
left superior intercostal, 1080
posterior intercostal, 1081
thoracoabdominal interface, 1187
thoraco-acromial artery, 987
thoracocentesis (pleural aspiration), 1083–1083.e1
thoracodorsal artery, 988
thoracodorsal nerve, 991
thoracolumbar fascia, 1217, 1218f
thoracoscopic access, 1083–1083.e1
thoracostomy tube (chest drain)
insertion, 1083–1083.e1
thoracotomy incisions, 1083–1083.e1
thorax, 1060–1066, 1060f
arteries of, 1061, 1062–1062.e1f
bones of, 1060, 1060f, 1068–1074.e1
cartilage, 1068–1074.e1
development, 353
fascia, 1068
innervation of, 1062–1063.e1
autonomic, 1063
joints of, 1060, 1060f
lymphatic drainage of, 1062
muscles of, 1060–1061
musculoskeletal framework of, 1060–1061
neonatal, 362
perinatal period, 360–362
skeleton movement mechanism, 1079
skin, 1067–1068
surface anatomy of, 1063–1066
musculotendinous landmarks, 1064
paediatric, 1066
skeletal landmarks, 1063–1064, 1063f, 1064f
viscera, 1064–1066, 1065t
vascular supply of, 1061–1062
veins of, 1062, 1062f
Thornwaldt cyst, 759
thrombocytes, 82
thumb
joints of, movements of, 1038
movements of, 1047–1047.e3
thymectomy, 1131–1131.e1
thymocytes, 1130, 1130f
thymoma, 1131–1131.e1
thymus, 316, 1128–1131.e1, 1128f
arteries, 1129
changes during postnatal life, 1131
congenital anomalies of, 1131
cortex, 1130
development, 1131
epithelial framework, 1129, 1130f
general architecture, 1129
innervation, 1129–1129.e1
lymphatic drainage, 1129
microcirculation, 1130–1131
microstructure, 1129–1131
relations, 1128–1129
vascular supply, 1129
thyroarytenoid muscle, 786
thyrocervical trunk, 645
thyroepiglottic ligaments, 777
thyrohyoid membrane, 777
thyrohyoid muscle, 636
thyroid cartilage, 775
thyroid gland, 312, 312f, 313f, 656–659
arteries, 657
C cells, 659
follicular cells, 659
imaging, 657–659, 658f
innervation, 657
lymphatic drainage, 657
lymphatics, 657
microstructure, 659, 659f
surfaces and relations, 657
vascular supply, 657
veins, 657
thyroid vein, middle, 648
tibia, 1489–1492, 1490f
body, 1490–1491
distal end, 1491
innervation, 1491
medial malleolus, 1491
muscle attachments, 1491
ossification, 1491–1492, 1492f

- tibia (*Continued*)
 proximal end, 1489–1490
 tibial tuberosity, 1490, 1490f
 vascular supply, 1491
 tibial nerve, 1429–1430, 1518–1519, 1553–1554
 tibialis anterior muscle, 1507–1508, 1509f
 tibialis posterior muscle, 1514, 1547
 tibiofemoral articulation, 1503
 articulating surfaces, 1495–1496
 bursae, 1502
 discoid lateral meniscus, 1497
 femoral surface, 1496
 intercondylar area, 1496
 intra-articular ligaments, 1500–1501
 lateral meniscus, 1497
 medial meniscus, 1497
 menisci, 1496–1498
 meniscomfemoral ligaments, 1498
 relations and 'at risk' structures, 1502
 soft tissues, 1498–1500, 1498f, 1499f
 synovial membrane, plicae and fat pads, 1501, 1501–1501.e1f, 1501f, 1502f
 tibial plateau, 1495–1496, 1496f
 transverse ligament of the knee, 1498
 tight junctions, 28
 tissue(s)
 conduction, 1161–1163.e1
 integrating cells into, 31–45
 limb development, 343–346
 mucoid, 43–44
 regular, 43, 43f
 supporting, 38–44
 tissue interactions, embryonic, 209–213
 induction, 209–213, 210f, 211f
 instructive, 211–212
 permissive, 211–212
 tissue spaces, 725
 toilet training, for full-term neonates, 390
 tongue, 320–321, 320f, 321f, 695–701, 697f
 innervation, 699–701
 autonomic, 701
 lingual artery, 698, 698f
 lingual papillae, 695–696
 lingual veins, 698–699
 lymphatic drainage, 699
 muscles, 696–698
 oral (presulcal) part, 695–698, 695f
 vascular supply and lymphatic drainage, 698–699
 tonsillar artery, 641
 tonsillar lymphoid tissue, 763
 tooth buds, 217–218
 torques, 128, 128f
 trabecular bone, 99–100, 101f
 trabecular cardiac myocytes, 229
 trachea, 661–662, 1097–1098
 cartilages, 1101
 cervical part, 1097
 epithelium, 1106–1107.e1
 respiratory system development, 354–354.e1
 surface anatomy of, 1065–1066
 thoracic part, 1097–1098, 1098f
 vascular supply, lymphatic drainage and innervation, 1101–1104.e1
 tracheobronchial tree, 1103f
 tracheo-oesophageal fistula, 1136
 tract of Lissauer, 477
 transcription factors
 EBF1, 385
 GATA3, 385
 transdifferentiation, 44
 transitional epithelium, 34f
 translation, joint movement, 113, 114f
 transmedian mass, cardiogenic mesoblast, 203
 transoesophageal ultrasound, 1135–1135.e1
 transtentorial coning, 619
 transversalis fascia, 1202
 transverse acetabular ligament, 1458–1460
 transverse aortic arch, elongated, 1176–1176.e2
 transverse arch, 1545
 transverse arytenoid muscle, 784
 transverse cervical cutaneous nerve, 629
 transverse colon, 380
 transverse facial artery, 683–684
 transverse fibre
 of palmar aponeurosis, 1025
 of palmar fascial complex, 1025
 transverse humeral ligament, 974
 transverse intermuscular septum, of leg, 1488
 transverse sinus, 620–621
 transversospinal muscle, 910–912, 910t
 transversus abdominis muscle, 1212, 1212f
 transversus linguae muscle, 697
 transversus thoracis muscle, 1078
 trapezium bone, 1029
 trapezius muscle, 975–976, 975f
 trapezoid bone, 1029
 triangles, of neck, 600–601
 triangular fibrocartilage complex, 1007, 1031–1032
 triangular ligament, 1290–1291
 triangular space, 985
 triceps jerk, 952
 triceps muscle, 985
 triceps surae muscle, 1512
 trigeminal motor nucleus, 495–496
 trigeminal nerve, 686–687, 686f
 trigeminal sensory nuclei, 495, 495f
 trigeminocerebellar mossy fibres, 517–518, 517f
 trigger finger, 1041–1042
 trigone, of urinary bladder, 1364
 trilaminar disc, 203, 205f
 triquetrum bone, 1029
 triticeal cartilages, 775
 trochanteric anastomosis, 1480
 trochlea, 997–998
 trochlear nerve, 841, 841f
 trochlear nucleus, 498–499
 trophoblast, 200
 tropism, lumbar articular, 904
 tubal tonsil, 758–759
 tunica albuginea, 1377, 1379f
 tunica intima, 141
 tunica media, 147
 collagen and elastin, 147–147.e1
 hyaluronic acid, 147
 smooth muscle, 147
 tunica vaginalis, 1377–1378
 tunica vasculosa, 1377
 twinning, 186, 186f
 spontaneous, 186
 two plate-like diverticula, 300
 tympanic artery, inferior, 640
 tympanic cavity, boundaries of, 802–805
 anterior wall, 805
 auditory tube blockage in children, 805
 floor, 802
 lateral wall, 802
 medial wall, 803, 804f
 posterior wall, 803–805
 roof, 802
 tympanic membrane, 802–803, 802f
 tympanic membrane, 302–303, 802–803, 802f
 innervation, 803
 microstructure, 802–803
 myringoplasty, 803
 otitis media, 803
 tympanic mucosa, 808–809
 tympanic nerve, 653
 tympanic plexus, 760, 807–808, 808f
 tympanic ring, 300, 302, 796
 typical rib, 1071–1073, 1072f
- UK, growth charts, 416, 417f
 ulna, 1001–1003, 1002f
 articular attachments of, 1003
 body of, 1002
 distal, 1002–1003
 ligamentous attachments of, 1003
 muscular attachments of, 1003
 ossification of, 1003, 1003f
 proximal, 1001–1002
 vascular supply of, 1003
 ulnar artery
 deep palmar branch, 1049
 dorsal carpal branch, 1048–1049
 dorsal cutaneous branch, 1048
 in forearm, 1017–1018, 1017f
 palmar carpal branch, 1048
 superficial palmar arch, 1049–1050.e1
 at wrist, 1048–1049
 ulnar body, 1002
 ulnar canal, 1024
 ulnar collateral ligament complex, 1004
 ulnar nerve, 992
 compression, 1020–1020.e1, 1052–1052.e1
 division, 1052–1052.e2
 in forearm, 1019–1020.e1
 of upper limb, 944, 944f
 at wrist, 1052–1052.e2
 ulnocapitate ligaments, 1034
 ulnolunate ligaments, 1034
 ulnotriquetral ligaments, 1034
 ultrasound
 antenatal, 406–408.e1
 of back, 338
 first trimester, 406–407
 of lower limb, 351, 351f
 of reproductive system, 403
 second trimester, 407–408.e1, 408f
 of suprarenal gland, 391
 of upper limb, 348
 of urinary system, 390
 diaphragm, 1114, 1114f
 transoesophageal, 1135–1135.e1
 of uterus, 1411
 umbilical arterial catheterisation, 247, 247f
 umbilical artery, 246, 1333–1334
 early, 238
 umbilical cord, 198–199, 372–373.e1
 umbilical fissure, 1289
 umbilical veins, 240–241, 246
 catheterisation, 247
 early, 240
 later, 240–241, 242f
 umbilicus muscle, 1198, 1209
 uncinat fasciculus, 577–578
 uncinat process, 755, 1305
 unilaminar epithelia, 31–32, 33f
 unipolar brush cell, 513
 unmyelinated axons, 64
 upper abdomen, peritoneum of, 1237–1238
 upper genital tract, 1398–1410
 upper joint compartments, 727–727.e1
- upper limb, 347–348
 acute ischaemia, 940–940.e2
 arteries, 347, 348f, 937–937.e2f, 937–938, 950–951
 bones, 935, 936f
 compartment syndromes, 940–940.e2
 dermatomes, 952, 952f
 fascia, 935–936
 focal nerve lesions in, 946–946.e10
 innervation, 940–946
 brachial plexus, 940–946, 940f, 941f
 dorsal scapular nerve, 940
 long thoracic nerve, 940
 spinal accessory nerve, 940
 subclavian nerve, 940
 suprascapular nerve, 940
 joints, 935, 936f
 lymph nodes, 951
 lymphatic drainage, 937–940
 muscles, 936–937
 musculotendinous landmarks, 948–950
 myotomes, 952
 neonatal, 348–348.e1
 nerves, 347–348, 950–952, 951t
 blocks, 952
 at risk from musculoskeletal injury, 946–946.e14
 pulses, 950–952
 reflexes, 952
 segmental innervation of, 945–946, 945f
 skeletal landmarks, 947–948, 947f
 skin, 935–936
 surface anatomy, 935–952, 947f, 949f
 thoracic outlet syndromes, 947–947.e3
 vascular supply, 937–940
 veins, 347, 938–938.e1f, 938–939.e1, 951
 vessels, 347, 950–952
 ureter, 1199, 1356–1361, 1357f
 development of, 387
 developmental anomalies of, 1360–1361, 1360f
 ectopic, 1360–1361
 innervation in, 1359–1360, 1359f
 lymphatic drainage, 1358
 microstructure of, 1360
 relations of, 1344f, 1356–1358, 1358f
 retrocaval, 1361
 vascular supply, 1358
 arteries, 1358, 1358f
 veins, 1358
 ureteric orifices, 1364–1365
 ureteric peristalsis, 1360
 urethroceles, 1361
 urethra, 1397
 development of, 401–401.e1
 anomalies of, 401–401.e1
 female, 1370
 innervation in, 1370
 lymphatic drainage, 1370
 microstructure of, 1370
 vascular supply, 1370
 male, 1367–1370, 1368f
 anterior, 1369
 congenital anomalies of, 1369–1369.e1
 innervation in, 1369
 intramural part of, 1367
 lymphatic drainage, 1369
 membranous, 1368
 microstructure of, 1369–1370
 posterior, 1367–1368
 prostatic, 1367–1368, 1369f
 traumatic injury to, 1369–1369.e1
 vascular supply, 1369
 sphincter, 401

- urethral artery
in female urethra, 1370
in male urethra, 1369
- urethral sphincter, 401
-  mechanism, 1340–1340.e1
- urinary bladder, 1362–1367
anterior aspect of, 1362
apex of, 1364
development of, 387–390, 388f, 389f
innervation in, 1365–1367, 1366f
interior, 1364–1365
distal ureter, 1364–1365
internal urethral orifice, 1365
mucosa, 1364
trigone, 1364
ureteric orifices, 1364–1365
- ligaments of, 1364, 1364f
lymphatic drainage, 1365
microstructure of, 1367, 1367f
neck of, 1365
in females, 1365
in males, 1365
-  outflow obstruction, 1365
-  relations of, 1362–1362.e1f, 1362–1364.e1, 1363f
- vascular supply, 1365
arteries, 1365
veins, 1365
- urinary continence, 1370–1372, 1371f
in female, 1372
in male, 1371–1372, 1372f
- urinary epithelium, 34f
- urinary system, 383–390
-  anomalies of, 390–390.e1
-  antenatal ultrasound of, 390
-  at birth, 390–390.e1
- magnetic resonance imaging of, 390
- postnatal maturation of, 390
-  urine, production of, 1356–1356.e2
- urogenital region
deep perineal fascia of, 1340
-  deep perineal space, 1339–1340.e1
- perineal body, 1340
- perineal muscles, 1340–1342
- of perineum, 1338–1340, 1339f
- subcutaneous perineal space in, 1340
- superficial perineal fascia of, 1340
- superficial perineal space in, 1340, 1341f
-  urethral sphincter, mechanism, 1340–1340.e1
- urogenital sinus, 384, 385f
- urogenital system
development of, 383–403, 383f, 403b
- male/female homologues of, 393t
- urothelium, 34–35, 34f
- uterine artery, 1334
- uterine tubes, 1405–1406, 1405f, 1406f
arteries of, 1406
development of, 393
innervation of, 1406
lymphatic drainage of, 1406
microstructure of, 1406, 1406f
vascular supply of, 1406
veins of, 1406
- uterine wall, attachment, 185–186
- uterosacral ligaments, 1403
- uterus, 1398–1405, 1399f, 1400f
arteries of, 1403
body of, 1398, 1400f, 1401f, 1404
cervix of, 1398
microstructure of, 1404–1405, 1404f
development of, 393
developmental anomalies, 1398–1398.e2
-  innervation of, 1404
- uterus (*Continued*)
lymphatic drainage of, 1403–1404
microstructure of, 1403–1404
in pregnancy, 1411–1413, 1411f, 1412f
pelvic changes in, 1413
relations of, 1413
prolapse of, development of, 1417, 1417f
-  retroversion, 1398–1398.e2
- vascular supply of, 1403–1404
- veins of, 1403
- utricle, of ear, 813–814, 813f
- utrículosaccular chamber, 299–300
central part of, 300
- uvea, 855–860
- V**
vagal neural crest cells, 304–305
-  vagina, 1393–1398.e2, 1396f, 1397f
arteries of, 1398
development of, 393
-  developmental anomalies, 1398–1398.e2
- innervation of, 1398
- lymphatic drainage of, 1398
- prolapse of, development of, 1417, 1417f
- vascular supply of, 1398
- veins of, 1398
- vestibule of, 1397
- vaginal artery, 1334
- vagus nerves, 653–654
auricular branch, 653–654
branches of, 653–654
carotid body branch, 654
inferior (nodose) ganglion, 653
of mediastinum, 1128
meningeal branches, 653
pharyngeal branch, 654
posterior (dorsal) nucleus of, 489
recurrent laryngeal nerve, 654
superior (jugular) ganglion, 653
superior laryngeal nerve, 654–655
in thorax, 1063
- vallate papillae, 696, 696f
- valve of coronary sinus (Thebesian), 1169
- vas deferens. *see* deferens ductus
- vasa recta, 148–149
- vasa vasorum, 141f, 147–148
- vascular plexuses, 1195
- vascular supply
cutaneous, of arm, 954
diaphragm, 1115–1116
of head, 590–592
of neck, 590–592
of pectoral girdle, 937–940
pleura, 1094–1095
thoracic skin, 1067
of upper limb, 937–940
- vasculature
cerebral, 148
cutaneous, 149–149.e1
-  diseases of, 149–149.e3
-  pulmonary, 148
-  regional adaptations of, 148–149.e1
- renal, 148–149
- vasoactive intestinal polypeptide (VIP), 56
- vasoconstriction, 143
pulmonary, 148
- vastus intermedius muscle, 1473
- vastus lateralis muscle, 1473
- vastus medialis muscle, 1473
- veins, 143–144, 144f, 592
-  of anal canal, 1283–1283.e1
- of arm, 989–990
- of brain, 458f, 459–463, 459f
- veins (*Continued*)
cerebral hemisphere, 460–461f, 461–462, 462f
posterior fossa, 460–461
-  of diaphragm, 1116–1116.e1
- of duodenum, 1257
- of female urethra, 1370
- of forearm, 1018
deep, 1018
superficial, 1018
- of hand, 1050
deep, 1050
superficial, 1050
- of ileum, 1260
- of internal ear, 819
- of large intestine, 1278–1279
- of lesser pelvis, 1334–1336, 1335f
- limb development, 345
- of lower limbs, 350, 1426–1427, 1428f, 1438
-  of lungs, 1106–1106.e1
- of male urethra, 1369
- of orbit, 840, 840f
- of ovaries, 1407
- of penis, 1387–1388
- of spinal cord, 929–930, 930f
- stomach, 1248–1249
superficial, 592f
-  of testis, 1379–1379.e1
- of thoracic skin, 1067, 1069f
- of thorax, 1062, 1062f
-  of upper limb, 347, 938–938.e1f, 938–939.e1, 951
- of ureter, 1358
- of urinary bladder, 1365
- of uterine tubes, 1406
- of uterus, 1403
- of vagina, 1398
- of vertebral column, 885, 886f
- of vulva, 1393
- venepuncture, of veins, 951
- venous sclerae (canal of Schlemm), 852
-  venous access, central, 648–648.e1
- venous fissure, 1289
- venous muscle pumps, of lower limb, 1427
- venous sinusoids, 1318
- ventral anterior nucleus, thalamus, 530–531
- ventral lateral nucleus, thalamus, 531
- ventral posterior nucleus, thalamus, 531–532
- ventral splanchnic arteries, 238
- ventral striatum, 547
- ventricle(s)
of brain
fourth, 443–444, 443f, 444f
lateral, 440–442, 441f, 442f
third, 442, 442f, 443f
- of heart, 229–230
left, 1155–1159
right, 1150–1153
-  septation of, 232–232.e1, 233f
- ventricular wall, formation, 229–230, 229f, 230f
- of larynx, 780
- ventricular system, 440–448, 440f, 448b, 617–627
development of, 273–276, 274f
relations to, 440–445
topography of, 440–445
- ventricular wall, formation, 229–230, 229f, 230f
- ventricular zone (germinal matrix), vessels of, 278–279
- ventrolateral prefrontal cortex, of frontal lobe, 569–570
- ventrolateral (anterolateral) trunk muscles, development, 338
- ventromedial nucleus, hypothalamus, 538
- venule(s), 143–144
- vermiform appendix, 1199
-  vertebra(e), general features of, 886–889, 886f, 887–887.e1f, 888f
- vertebra prominens, 892, 892f
muscle attachments to, 892
- ossification of, 892
- vertebral artery, 454–455, 454f, 455f, 644–645, 644f, 645f
cervical branches of, 645
muscular branches, 645
spinal branches, 645
- vertebral bodies, joints between, 901–903
- vertebral canal, 887–888
- vertebral canal stenosis, 888
-  cervical, 892–892.e1
- vertebral column, 882–886, 883f, 884f
anterior aspect of, 883
-  arteries of, 885, 886–886.e1f
- curvatures of, 884
- in elderly, 884–885
- injury of, 930–931
- innervation of, 886
- joints of, 901–907, 901f
- landmarks of, 916–917
- lateral aspect of, 883–884
- ligaments of, 899–901
- lymphatic drainage of, 885–886
- movements of, 913–915
- posterior aspect of, 884
- stability in, factors involved in, 914–915
- structural defects of, 884
- veins of, 885, 886f
- vertebral muscle
anterior, 637, 637f
lateral, 637–638
posterior, 638
- vertebral vein, 648
- vertebrate, development, 332–333, 335f
- vertical fibre, 1025
- vertical gaze, premotor neurons for, 499
- vertical lines and planes, abdomen, 1196, 1197f
- verticalis linguae, 697–698
- vesico-uterine folds, 1399, 1402f
- vessels
limb development, 344–345, 345f
lower limb, 349–350
lymphatic, 149, 149f
upper limb, 347, 950–952
walls, features of, 141, 141f
- vestibular folds, 779–780
- vestibular (Scarpa's) ganglion, 820
- vestibular labyrinth, 813–815
- vestibular ligaments, 779–780
- vestibular nerve, 820, 820f
-  vestibular nuclear complex, 494–494.e1
-  vestibular system, microstructure of, 814–815.e1
- vestibular window, 803
- vestibule(s)
bulbs of, 1397
-  posterior part of, 1398–1398.e1
- of vagina, 1397
- vestibulocochlear ganglia, of eighth cranial nerve, 299–300
- vestibulocochlear nerve, 819–824, 820f
- vestibulospinal tracts, 475–476, 476f
- villous cytotrophoblast cells, 190–191
- villus core, small intestine, 1264–1265
- vincula tendina, of fingers, 1041–1042, 1042f

- viscera
 of head, 598–600
 of neck, 600–601, 600f
 spinal levels of, 917, 917t
- visceral afferent neurons, 438
- visceral afferent pathways, 438
- visceral afferents, 1311
- visceral arteries, unpaired, 1200
- visceral efferent pathways, 436, 436f
- visceral fasciae, 1217–1219
- visceral hypoblast, 203
- visceral hypoblast cells, 187
- visceral ligaments, of pelvis, 1402–1403
- visceral pelvic fascia, 1331
- visceral peritoneum, 1253
- visceral pleura, 1093
- visceral space, 633
- visceral surface, of spleen, 1314–1315
- visceral venous complexes, 240–241
- viscerocranium, 322–324, 323f, 603
- viscoelasticity, 129–130, 129f
- visual field defects, 873–874
- visual pathway, 872–874, 872f
- visual reflexes, 822, 822f
- vitamin A, deficiency of, 105
- vitamin C, deficiency of, 105
- vitamin D
 deficiency of, 105
 synthesis of, 154
- vitelline arteries, early, 238
- vitelline veins, 240–241
 early, 240
 later, 240–241, 241f
- vitreous body, differentiation of, 295, 296f
- vitreous humour, 863
-  vocal fold nodules, 781–781.e1
-  vocal folds, 780–781.e1, 780f
-  vocal ligaments, 780–781.e1
- vocalis muscle, 786
- vomer, 604f, 671
 ossification, 671
- vomiting, 1136
-  von Willebrand factor, 146–146.e1
- vulva, 1392–1393, 1392f
 arteries of, 1393, 1394–1395f, 1395f
 innervation of, 1393, 1396f
 lymphatic drainage of, 1393, 1394–1395f
 vascular supply of, 1393
 veins of, 1393
- ## W
- Wagner-Meissner corpuscles, 72
- Waldeyer's ring, 757
- watershed areas, 457–458, 458f
- weaning, 419
- weight, fetal, 410
 estimated (EFW), 410, 410f
 growth velocity calculation, 410–411
 sonographic estimated (SEFW), 411
- white matter, 508, 551–552
 of cerebral hemispheres, 575–581, 576f
- white pulp, 1318, 1320f
- Wiebel-Palade body, 146
- wound contraction, 171
- wound healing
 cutaneous, 169–171, 170f
 phases of
 haemostasis, 169
 inflammation, 169–170
 proliferation, 170
 re-epithelialisation, 170
 remodelling, 170–171
 scarless, 171
- woven bone, 99, 99f
- wrinkles, 168
- wrist, 1022–1056, 1052b
 arteries of, 1048–1050.e1, 1049f
 degloving injuries of, 1022–1022.e2
 joints of, 1031–1040
 force transmission of, 1035
 innervation of, 1040
 loading, kinetics, 1035
 movements of, 1034–1035
 vascular supply of, 1039–1040, 1040f
 soft tissues of, 1024–1026.e2
 surface anatomy of, 949f, 1052–1053
 of upper limb, 952
 vascular supply of, 1048–1050
- ## X
-  xiphichondral (costoxiphoid) ligaments, 1076
-  xiphoid process, sternum, 1070–1070.e1
- ## Y
- Y chromosome, 397
- yellow marrow, 85
- yolk sac, 187, 195–196, 196f, 200, 217
- ## Z
- zona fasciculata, 1325–1326
- zona glomerulosa, 1325–1326
- zona incerta, 541
- zona reticularis, 1325–1326
- zonula adherens, 28
- zygapophysial joints, 903–904
 articular capsule of, fibrous layer of, 904
 articulating surfaces of, 904
 'at risk' structures of, 904
 innervation of, 904
 intracapsular structures of, 904
 ligaments of, 904
 synovial membrane of, 904
 vascular supply of, 904
- zygomatic arch, 606
- zygomatic bone, 604f, 671–672, 672f
 ossification, 672
- zygomatic nerve, 738, 843
- zygomatic process, 793
- zygomaticofacial nerve, 687
- zygomatico-orbital artery, 684
- zygomaticotemporal nerve, 687
- zygomaticus major muscle, 679
- zygomaticus minor muscle, 679