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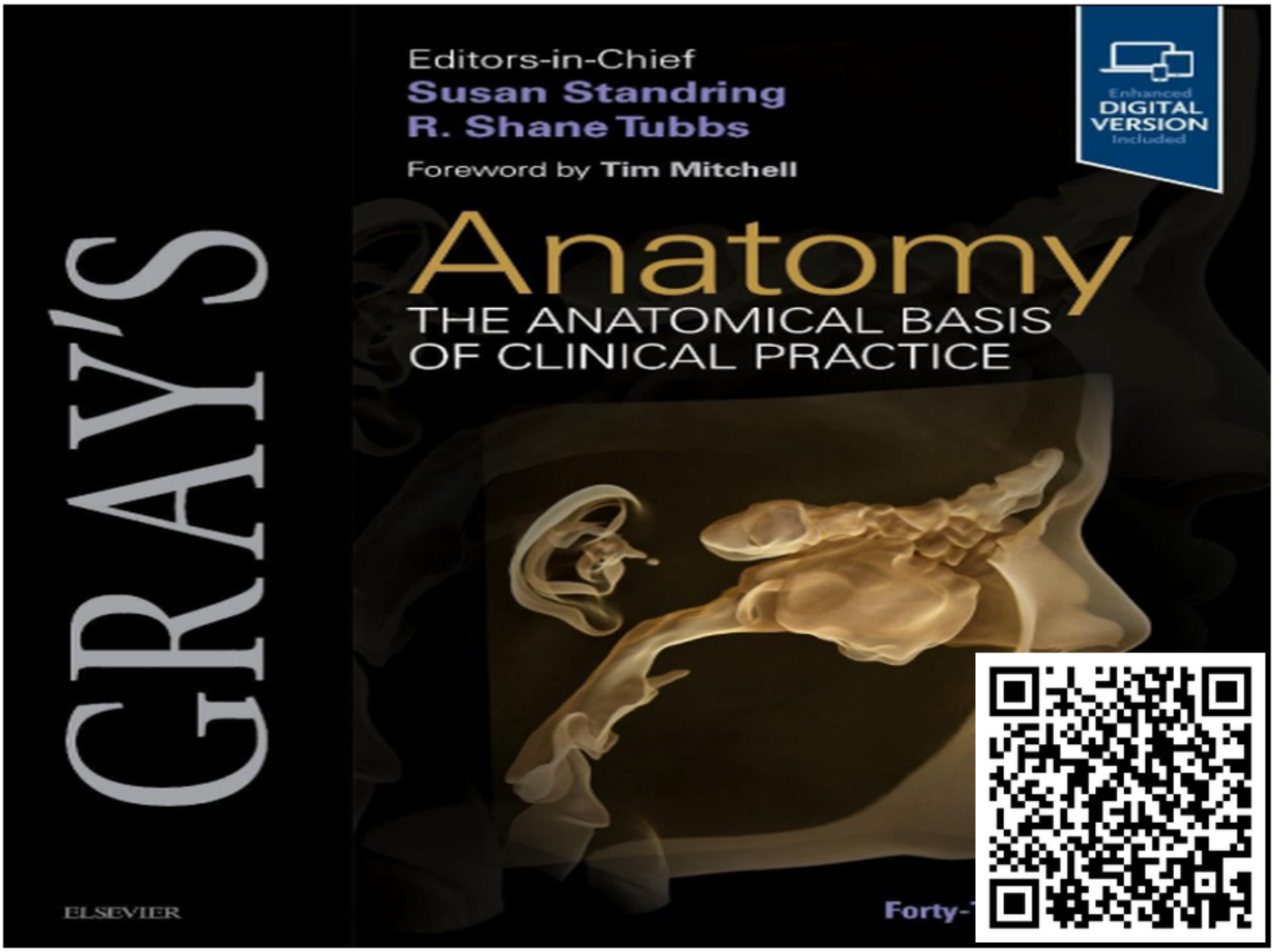

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Editors-in-Chief

Susan Standring

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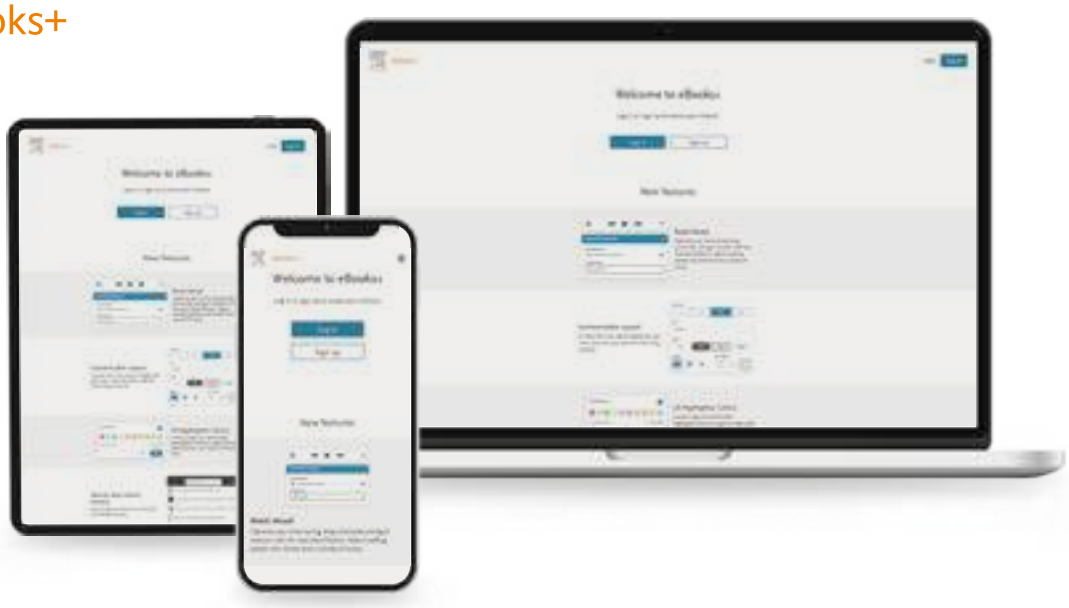

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Anatomy

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.

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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 defendable 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).

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.

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.

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, Ranee 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 Standring
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, 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.

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 Standring.)

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	JW Parker & Son	*Anatomy Descriptive and Surgical*
		The drawings by Henry Vandyke Carter. The dissections jointly by the author and Dr Carter		
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	Longman	
		Gray's preface removed		
14th	1897	TP Pick	Longman	
15th	1901	TP Pick & R Howden	Longman	
16th	1905	TP Pick & R Howden	Longman	
17th	1909	Robert Howden	Longman	*Anatomy Descriptive and Applied*
		Notes on applied anatomy by AJ Jex-Blake & W Fedde Fedden		
18th	1913	Robert Howden & Blake & Fedden	Longman	
19th	1916	Robert Howden & Blake & Fedden	Longman	
20th	1918	Robert Howden & Blake & Fedden	Longman	
		First edition to feature a photograph and obituary of Henry Gray		
21st	1920	Robert Howden	Longman	
		Notes on applied anatomy by AJ Jex-Blake & John Clay		
22nd	1923	Robert Howden	Longman	
		Notes on applied anatomy by John Clay & John D Lickley		
23rd	1926	Robert Howden	Longman	
24th	1930	TB Johnston	Longman	
25th	1932	TB Johnston	Longman	
26th	1935	TB Johnston	Longman	
27th	1938	TB Johnston & J Whillis	Longman	*Gray*'s Anatomy
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: *Functional Neuroanatomy of Man* – being the neurology section of *Gray*'s Anatomy, 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	*The Anatomical Basis of Clinical Practice*
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

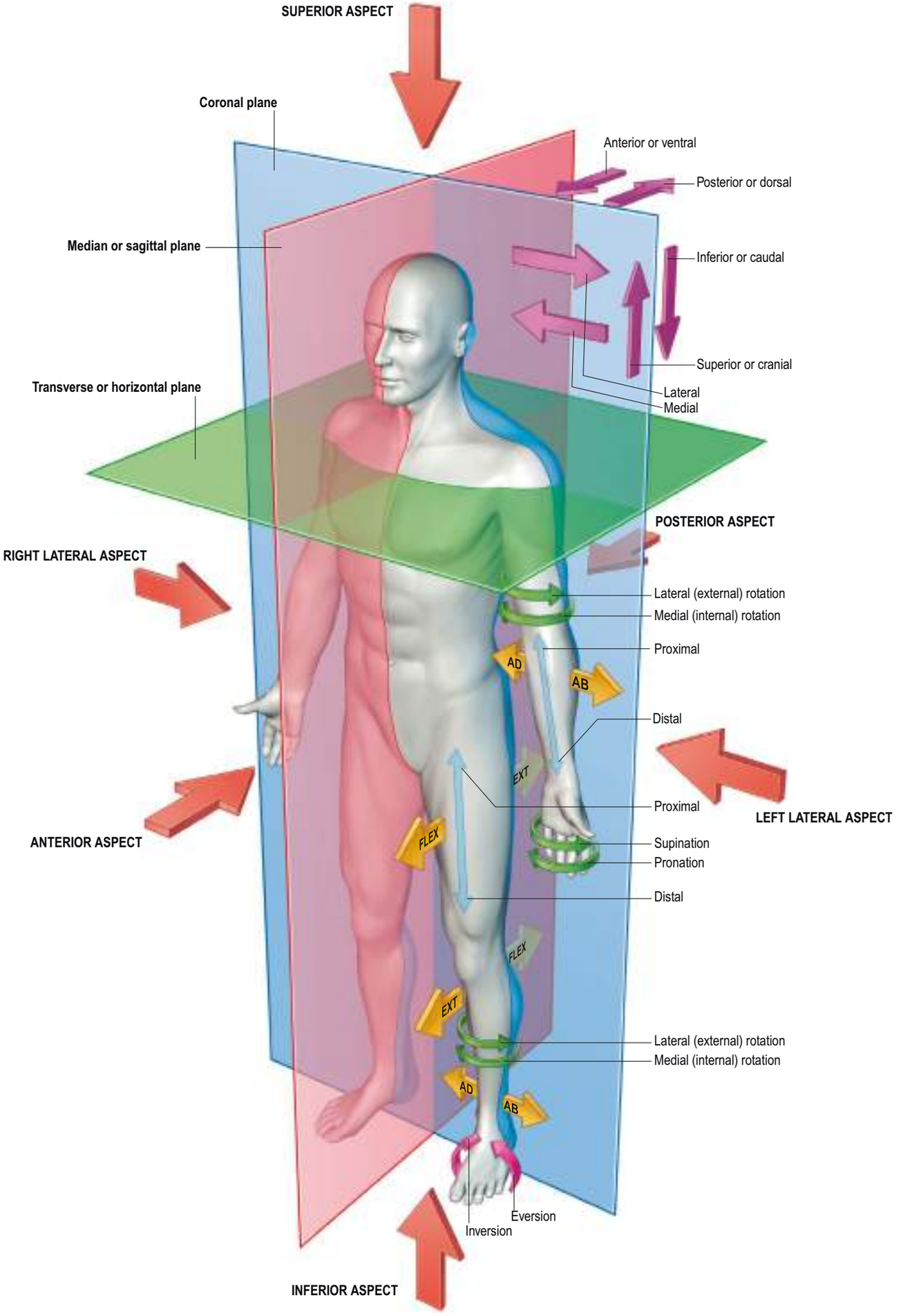

Fig. 1 The terminology widely used in descriptive anatomy. Abbreviations shown on arrows: AD, adduction; AB, abduction; FLEX, flexion (of the thigh at the hip joint); EXT, extension (of the leg at the knee joint).

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

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