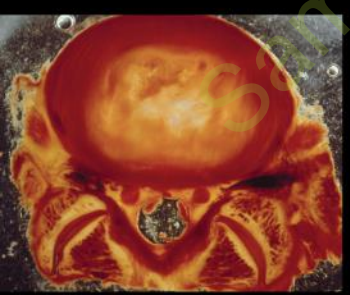
Endorsed by:

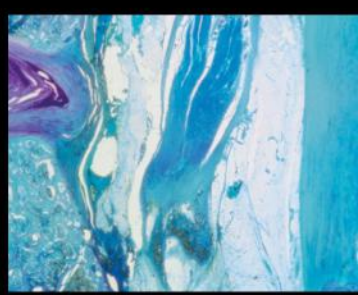
AUSTRALIAN PHYSIOTHERAPY ASSOCIATION

THE LUMBAR SPINE

An atlas of normal anatomy and the morbid anatomy of ageing and injuries

JAMES TAYLOR





ELSEVIER

THE LUMBAR SPINE

An atlas of normal anatomy and the morbid anatomy of ageing and injuries

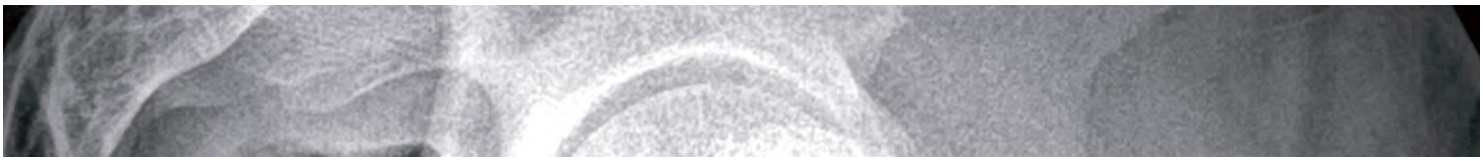
THE LUMBAR SPINE

An atlas of normal anatomy and the morbid anatomy of ageing and injuries

JAMES TAYLOR

ELSEVIER

CONTENTS



FOREWORD

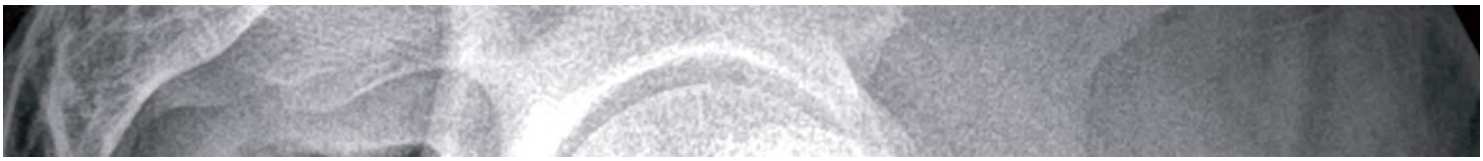
As an education and research-focused academic, I am frequently invited to review papers and book proposals. It is hard to express the excitement I felt when Professor Jim Taylor's *The Cervical Spine* draft came across my desk some years ago, followed a few years later by the draft of its companion, *The Lumbar Spine*. These atlases bring together the extensive, and arguably unmatched, research by Professor Taylor of the normal and morbid anatomy of the cervical and lumbar spine.

Professor James Taylor has a long and distinguished medical and academic career; his work on spinal anatomy is hard to match. Professor Taylor's work has informed and changed health professionals' understanding of anatomy and pathology of the spine. I first became aware of Professor Taylor's work in the mid-1990s when he published a series of articles on the cervical spine anatomy and morbidity. With each new publication, I, like many of my peers, paid attention.

As healthcare providers it is imperative that we understand both normal and pathological anatomy – it is often hard to find more than one example of pathology in a textbook. *The Lumbar Spine* provides unparalleled detail of normal, age-related changes and trauma-related injuries of the lumbar spine anatomy. All healthcare professionals with an interest in spinal health should be grateful that Professor Taylor has put these atlases together.

I have had the privilege of helping Professor Taylor to finalise both *The Cervical Spine* and *The Lumbar Spine* atlases. Working on these manuscripts was never a chore. Every clear and detailed image was a delight; every explanation provided me with further insights into the young, old and damaged human spine. As an undergraduate, I excelled at 'normal' anatomy. These books deepened my understanding of the normal, the ageing and the morbid human spine anatomy. I am honoured to have collaborated with Professor Taylor on this book and I commend it to all health professionals whose work involves the human spine.

Angie Fearon PhD, M (Phty), BAppSci (Phty), GCTE, FHEA, MAPA



PREFACE

This atlas presents pictures of normal, degenerate and injured lumbar spines, including bones, joints and muscles, garnered from studies of spinal autopsy specimens examined over a period of 33 years. They began with James Taylor's doctoral study at Edinburgh University, where he examined the developing spine (1967–74) and continued with studies of normal adult anatomy and age changes at the University of Western Australia (UWA), at Royal Perth Hospital (RPH) and in private practice (1976–2000).

Given careful observation, its 150 pictures and diagrams contain more information than many words could convey. Captions and labels have been kept to a minimum to avoid obscuring the images themselves. A short list of relevant literature is included in each section of the atlas.

THE MATERIAL STUDIED

Materials for study of the lumbar spine atlas have been collected since the 1960s. First, for the study of spinal development, and then for the study of normal anatomy, age changes and injuries, for which lumbar spine joints and whole lumbar spines were collected – both formalin-fixed material, and fresh, unfixed material. The latter were obtained both in the anatomy dissecting room and at autopsy in departments of pathology, to be examined at the request, or with the permission, of the pathologists.

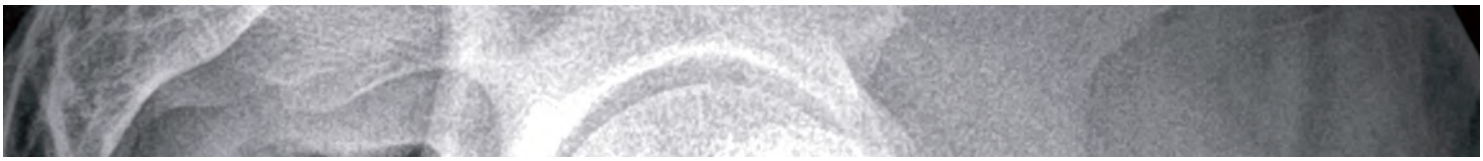
To begin with, lumbar intervertebral discs and facet joints were embedded in cellulose or low-viscosity nitrocellulose and sectioned on a microtome (see Chapter 1 for methodology).

In later studies, whole unfixed lumbar spines were used for movement studies and formalin-fixed spines were studied for their normal anatomy or pathological features (see References for details).

The three doctoral studies making important contributions to this atlas are Giles (1987), Taylor (1974) and Twomey (1981).

Numerous articles describing the work have also appeared in peer-reviewed journals, books and book chapters. See, for example, McFadden and Taylor (1990), Taylor (1975), Taylor and Twomey (1980, 1986), Taylor, Twomey and Levander (2000), Twomey and Taylor (1982).

Further references are cited as appropriate.



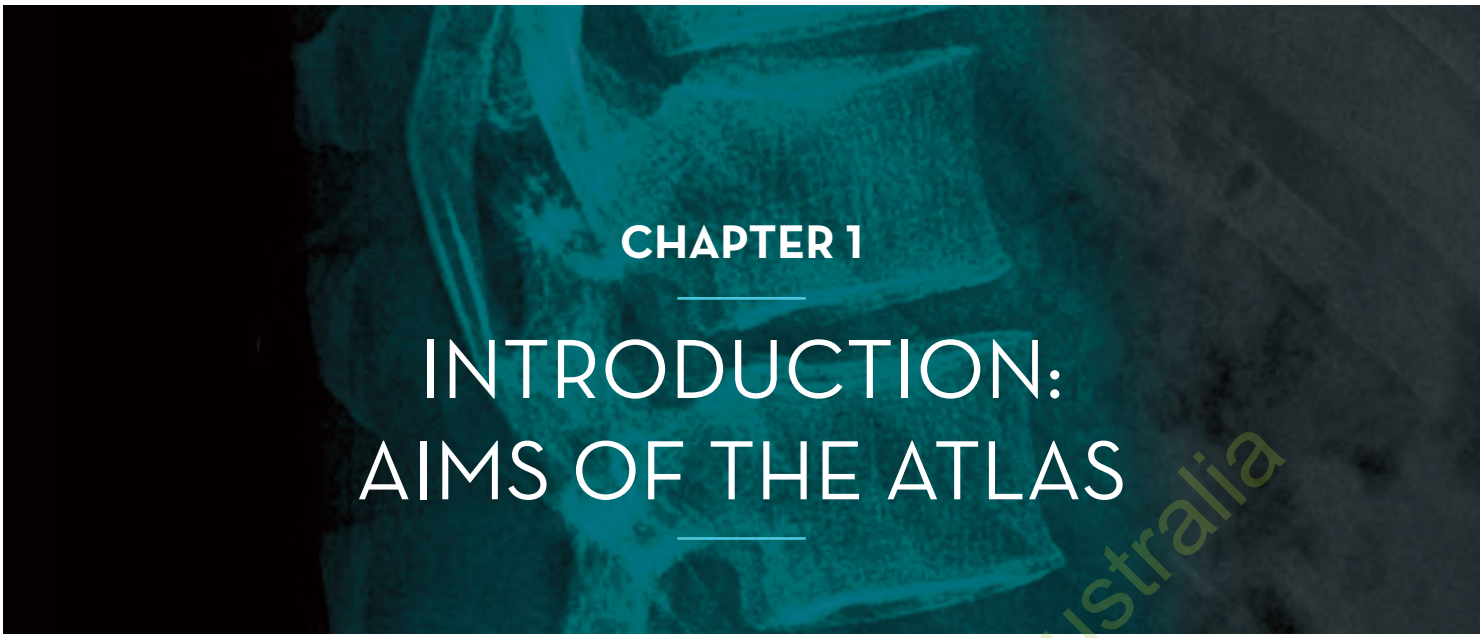
ABOUT THE AUTHOR

James Taylor graduated MBChB at Edinburgh Medical School in 1955. He served as a GP surgeon in Congo as co-director of a hospital and medical training school founded by the late Sir Clement Chesterman, a Gallipoli veteran. In 1964 he returned to Edinburgh University to teach anatomy to medical students and undertake research on growth and development of the human spine, graduating with a PhD in 1974. Emigration to Australia in 1975 opened new research possibilities, including an attachment to the Sir George Bedbrook Spinal Unit at Royal Perth Hospital (RPH). Dr Taylor and his research team developed two new methods of sectioning autopsy spines. These methods (see Study Methods, page 2) gave high-quality and detailed information on the nature of blunt trauma injuries. As a consequence, he was invited to continue his spinal research in the Pathology Department at RPH, working with the forensic pathologists reporting to the coroner on blunt trauma spinal injuries in autopsy spines. This work provided access to study hundreds of spines from subjects of all ages.

Eminent spinal surgeons, radiologists and medical researchers, including Dr Nils Shonstrom and Professor Bo Levander from Sweden and Professor Ken McFadden from Canada, visited Dr Taylor for periods of cooperative research in his laboratory. On study leave, Dr Taylor continued to expand the range of his intervertebral disc research with Professsor John Scott, a world authority on proteoglycans.

In his last nine years before retirement, Dr Taylor was invited to work with Dr Philip Finch in his pain clinic. This work led to cooperative research of a clinical nature, particularly in the area of pain of spinal origin. Dr Finch, currently the Medical Director of Perth Pain Management Centre, has specialised in the field of pain medicine since 1978. Dr Finch gave the author invaluable help in the early stages of this atlas, reviewing the topic of disc innervation and discogenic pain.

Dr Taylor published an atlas on the cervical spine in 2019, which won first prize in the clinical science section of the Medical Book of the Year competition run by the British Medical Association in the United Kingdom.



CHAPTER 1

INTRODUCTION: AIMS OF THE ATLAS

The aims of the atlas are to:

- illustrate the functional anatomy of the normal lumbar spine based on examination of serial transverse and sagittal sections
- describe and illustrate age changes in the lumbar spine, showing how degenerative changes alter function and may cause pain and disability
- describe and portray the nature and distribution of lumbosacral spinal injuries due to blunt trauma, based on autopsy examinations of injured spines from blunt trauma deaths
- demonstrate to clinicians the areas vulnerable to injury.

THE AUTOPSY STUDIES

We present images of normal anatomy and the morbid anatomy of age changes and injuries. Our first studies were of sectioned lumbar facet joints; the embedding, sectioning at 100-micron thickness and staining were done in the Department of Anatomy and Human Biology at the University of Western Australia (UWA) by Mary Taylor and Mary Lee (Taylor & Twomey, 1986).

Serial sections of whole lumbar spines were made at Royal Perth Hospital (RPH) in the period from 1989 to June 1996 by James Taylor and Mary Taylor. Since then, a new coronial Act has restricted the possibility of examining parts of spines removed from cadavers.

Complete lumbar spines were examined as described below; the examinations were part of the forensic autopsies done routinely in the Department of Pathology at RPH where James Taylor and Mary Taylor assisted the forensic pathologists who had the responsibility of determining the cause of death in coroners' cases. Many spines were from young individuals who died from the effects of blunt trauma. We examined a large number of vertebrae and intervertebral joints showing normal anatomy and we were also able to research the nature of degenerative changes and spinal injuries (Taylor, Twomey & Levander, 2000).

Study methods

Two methods of sectioning were used. In the earlier study in the Department of Anatomy and Human Biology at UWA, individual spinal motion segments were decalcified, dehydrated,

slowly embedded in low-viscosity nitrocellulose and sectioned at 100-micron thickness on a microtome. One in seven sections was stained with haematoxylin and light green colouring and mounted on a glass slide for microscopic examination. This method of preparation took about three months to complete. This method produced detailed histological information, but it was not capable of sectioning whole lumbar spines.

In the later study conducted in the Department of Pathology at RPH, whole lumbar spines of all ages were examined, from early childhood up to individuals over 80 years of age. The whole lumbar spine was expertly removed from the cadaver by a laboratory technician and fixed by immersion in formalin for 7 to 10 days, then embedded in 6.5% warm gelatin solution in a suitable container and deep frozen on dry ice at –70°C for 24–48 hours. The gelatin-enclosed frozen block was sectioned in 2.5 mm thick serial slices in the sagittal plane on a specially adapted band saw with a precision-adjustable guide and a fine-toothed blade (see Figure 1.1). The enclosure in gelatin before freezing allowed sectioning without damage to the surface of the spinal tissues as the blade passed smoothly from the frozen gelatin into the frozen spinal tissues. Cold burns while handling the block were avoided by wearing two pairs of rubber gloves.

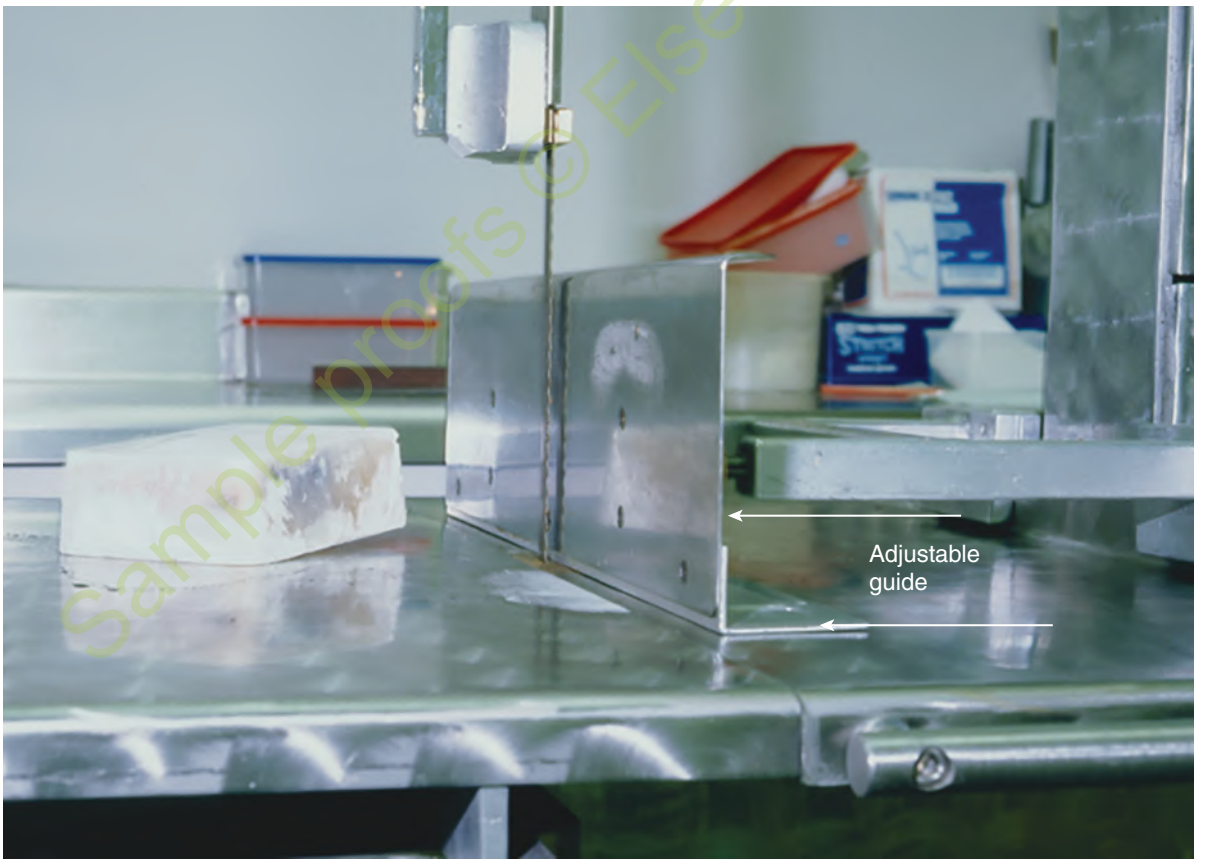


FIGURE 1.1 The modified band saw for sectioning spines

The saw table was fitted with a large, adjustable, precision guide (to regulate section thickness); a frozen block lies on the table, ready to be sectioned.

Each numbered slice was carefully washed and cleared of saw-cut debris and placed underwater in a large Petri dish to be photographed using a Pentax camera with a macro lens. Each slice was then examined under an M3 Leitz dissecting microscope at low magnification and closer pictures were taken of injuries or other structures of interest. Photography with the section underwater was necessary to avoid distortion by reflection of light from the surface of the section.

About 0.6 mm of tissue was lost as debris between successive sections. Sections were stored between numbered sheets of paper in 70% alcohol until the whole forensic examination of the case was complete. A written report on the nature and extent of injuries or other findings of interest was prepared for the forensic pathologist. This was included in the pathologist's report to the coroner to establish the cause of death (Taylor & Twomey, 1986).

FUNCTIONS OF THE LUMBAR SPINE

As a vital part of the axial skeleton, the lumbar spine's main functions are:

- stability in load-bearing
- movement
- protection of neural elements.

The human spine is uniquely adapted for erect posture, load-bearing and movement. It bears and transmits loads from the torso and upper limbs to the pelvis in an erect posture and in forward bending. The lumbar spine combines with hip joints and the thoracic spine to provide for movements required for bending, turning and reaching. The load-bearing function increases in a cranial to caudal direction, which is reflected in the progressive increase in area of the vertebral endplates from C3 to L3 or L4. The lumbar spine contains the lower end or conus of the spinal cord (at T12 to L1) with the central nervous centres for control of bowel and bladder function and lower limb reflexes. Below the cord, the lumbosacral spinal canal contains the cauda equina – the spinal nerves – which will supply the lower limbs.

The mechanical forces bearing on the lumbosacral spine throughout life may hasten the development of degenerative changes appearing in the bones (osteopenia and osteoporosis) and the joints (spondylosis), commencing in the intervertebral discs and then involving the facet joints.

This atlas will deal first with normal functional anatomy, then consider degenerative changes and the nature and consequences of injuries in the development of low back pain.

References

Taylor, JR & Twomey, LT 1986 Age changes in lumbar zygapophyseal joints. Observations on structure and function. *Spine*, 11(7), pp. 739–745.

Taylor, JL, Twomey, LT & Levander, B 2000 Contrasts between cervical and lumbar motion segments. *Critical Reviews in Physical and Rehabilitation Medicine*, 12(4), pp. 345–371.