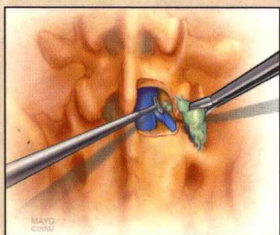
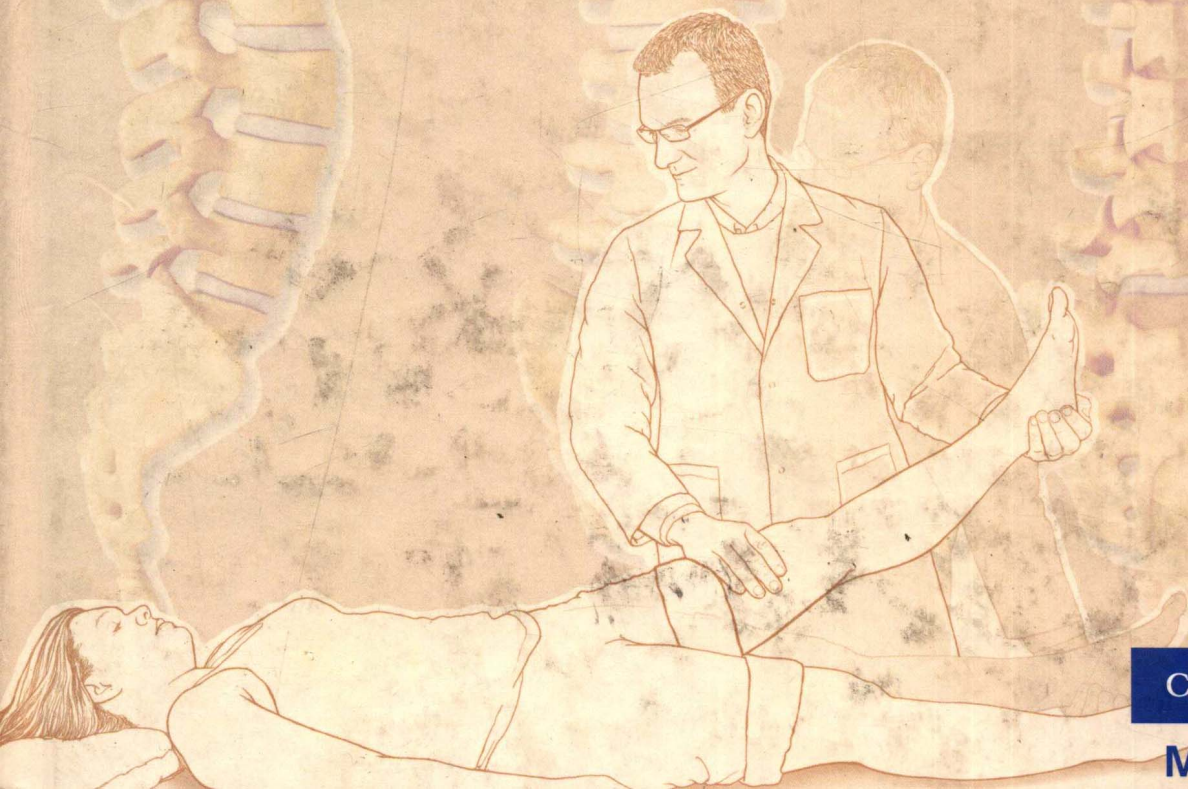


J. D. Bartleson • H. Gordon Deen



Spine Disorders

Medical and Surgical Management



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Medicine

Spine Disorders

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J. D. Bartleson, M. D.

Mayo Clinic

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Spine Disorders

To my wife Ruth, for her steadfast love and support. To my children Joseph and Ruthie, who continually inspire me to look at the world in new ways.

H. Gordon Deen, M. D.

To past, present, and future patients with spine disorders.

J. D. Bartleson, M. D.

Preface

It is fair to ask why another spine textbook is needed, especially one authored by a neurologist and a neurosurgeon. There are several reasons.

First, spine disorders are very common, cause considerable morbidity, and have a tremendous economic impact.

Second, the evaluation of a patient with back and limb pain can be challenging. While a clear-cut diagnosis is often possible, in many cases the diagnosis is uncertain. Even if a diagnosis can be established, there are typically multiple treatment options available. Experts disagree about the best course of treatment for an individual patient, and many therapies are only partially helpful. The uncertainties and frustrations associated with the diagnosis and treatment of spine conditions are felt by providers, patients, their families, employers, and payers.

Third, many healthcare providers have limited training in spine disorders. As a result, many providers are ill prepared to manage spine patients who often comprise a significant segment of their practice.

Fourth, we believe that the optimal management of the patient with spine pain, limb pain, or both involves a multidisciplinary approach. Neurologists and neurosurgeons have a long tradition of working together as a team in the evaluation and treatment of many neurologic conditions including tumors, cerebrovascular disease, and spine disorders. A neurologic

and neurosurgical perspective is important because most of the spine problems that require surgery involve compression of nervous tissue (the spinal cord, individual nerve roots, or the cauda equina). Fifth, while most spine textbooks now available are written by and for surgeons, the bulk of spine care is provided by non-surgeons. We believe a concise book targeted at the full range of providers who care for spine patients is needed.

This book grew out of a course that we have given for several years at the Annual Meeting of the American Academy of Neurology. The book describes the anatomy, physiology, and pathophysiology of the spine. It describes how to evaluate clinically and with laboratory and imaging studies the patient with disease affecting the cervical, thoracic, and lumbar levels of the spine. We describe available medical and surgical treatment options for the patient with various spine disorders. The book can be read from cover to cover or piecemeal as one encounters specific spine symptoms or considers potential surgical procedures. The goal of the book is not to teach the nonsurgeon how to do spine surgery but to inform the reader when surgery should be considered, what surgical interventions can be offered, and the risks and benefits that are involved. We hope and believe that this book will benefit all healthcare providers who see patients with spine disorders.

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J. D. B.

I am deeply indebted to my neurosurgical mentors, David F. Dean, M. D., Thoralf M. Sundt Jr., M. D.,

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H. G. D.

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Spine-related disease is, both literally and figuratively, a painful proposition. Pain in the neck, mid back, and low back is one of the most common medical conditions in adults. Other conditions affecting the spine do not cause pain (e.g., myelopathy) but contribute to cost and disability. Low back pain alone is said to be the most common cause of disability for persons under the age of 45 in the United States; at any one time, 1% of the U.S. population is chronically disabled and another 1% temporarily disabled by their back pain. In any given 3-month period, about 25% of U.S. adults report low back pain, and nearly 15% report neck pain. About 2% of all physician office visits relate to low back pain alone. Low back problems are reported to be the second-most common cause for absenteeism from work (after upper respiratory tract infections) and the most common cause for office visits to orthopedic surgeons, neurosurgeons, and occupational medicine physicians. Low back operations are said to rank third among all surgical procedures in the United States. A recent study of estimated healthcare expenditure for spine problems among U.S. adults when adjusted for inflation showed a 65% increase from 1997 to 2005; the total expenditure in 2005 was about \$85 billion. The estimates do not include indirect costs such as lost wages, disability payments, or “suffering.” Despite the increase in expenditures, self-reported measures of mental health, physical functioning, and limitations at work, school, and in social situations were worse in 2005 than in 1997. It is discouraging that we are spending more on spine problems in the United States but helping people less over time.

Scope of the problem

The scope of spine-related problems is reflected by the great number of different kinds of healthcare providers who treat patients with cervical, thoracic, and lumbar spine conditions (see Table 1.1). In addition, there is a very long list of different treatments that

are given to patients for their spine conditions (see Table 1.2).

Why do so many different kinds of providers treat spine patients with so many different therapies? There are four chief reasons. The first is that spine-related conditions, especially those due to spondylosis and those associated with pain, are very common. The second reason is that there are many different causes for the same clinical presentation. Because of the many potential causes for the same complaint and the lack of accurate diagnostic tests for the different conditions, the third reason is that providers have great difficulty making an accurate diagnosis. For example, healthcare providers can accurately diagnose only about 15% of patients with acute low back pain. The fourth and last reason is that whether or not we can diagnose the patient's problem, we have great difficulty effectively treating their symptoms, in particular their pain, especially if it is chronic, and pain is often the spine patient's chief complaint. Our inability to provide an accurate diagnosis and specific, promptly effective treatment spawns confusion and a multitude of potential therapies. The natural history for many patients is one of gradual improvement or, at the least, stability with fluctuation. As a result, any and all treatments may seem to be effective. The spine patient is not certain if they need a chiropractic manipulation or an operation on their back, and providers have honest disagreements about which course of treatment has the best outcome. The commonness of spine problems and their chronicity attract large numbers of practitioners who typically favor one avenue of treatment which may be of substantial help to a minority of patients or very modest benefit to a large number of patients. Patients desperately want to get better and often look for an easy answer and quick treatment and sometimes benefit from a very genuine placebo effect. In truth, for many patients, the goal of treatment of their back condition is to keep their symptoms under control rather than to cure them. For many patients with chronic spine problems, especially those

Table 1.1. Healthcare providers who treat spine-related problems

Anesthesiologists
 Chiropractors
 Homeopaths
 Internal medicine specialists
 Massage therapists
 Naprapaths
 Neurologists
 Neurosurgeons
 Occupational medicine specialists
 Occupational therapists
 Orthopedic surgeons
 Pain medicine specialists
 Physical medicine and rehabilitation specialists
 Physical therapists
 Primary care providers (MDs, osteopaths, physician assistants, nurse practitioners)
 Radiologists
 Others

Table 1.2. Treatment options for back pain

Medications

Botulinum toxin injections
 Disk injections
 Epidural injections
 Facet blocks
 Herbal medicines
 Homeopathy

Medications, both prescription and over-the-counter given by various routes and including analgesics, muscle relaxants, local anesthetics, and centrally acting drugs such as tricyclic agents and serotonin-norepinephrine reuptake inhibitors

Nerve blocks
 Trigger point injections

Surgical

Anterior discectomy and fusion with instrumentation
 Anterior discectomy and fusion without instrumentation
 Anterior fusion without discectomy
 Anterior and posterior fusion
 Discectomy with placement of artificial disk
 Intrathecal pump placement for purposes of medication administration
 Laminectomy with discectomy
 Laminectomy without discectomy

Microdiscectomy

Posterior fusion with instrumentation
 Posterior fusion without instrumentation
 Radiofrequency lesioning of nerves especially the medial branches of dorsal rami
 Spinal cord stimulator placement

Physical treatments

Acupuncture
 Bed rest
 Connective tissue massage
 Corsets
 Crutches
 Electrotherapy
 Exercises
 Magnet therapy
 Massage
 Multimodal rehabilitation
 Stretching
 Traction and distraction
 Transcutaneous electrical nerve stimulation, high and low frequency
 Ultrasound

Cognitive and behavioral

Back school
 Behavioral therapy
 Biofeedback
 Holistic therapy
 Meditation
 Relaxation techniques

involving pain, a combination of different therapies is more likely to be helpful than searching for a single magic bullet.

Epidemiology

Accurate assessment of the incidence (the rate at which people develop a new symptom or disease over a specified time period) and prevalence (measure of the number of people in a population who have a symptom or disease at a particular time) for spine pain is difficult to ascertain because of different definitions, collection methods, and populations studied. The following discussion relates mostly to spine and limb pain due to spondylosis. By spondylosis we mean the degenerative wear and tear changes that

affect the intervertebral disks and facet joints and the associated pain arising from these structures and the adjacent bones, ligaments, and muscles of the spinal column.

Cervical level

Neck pain is less common than low back pain and less studied. The lifetime prevalence of significant neck pain is about two-thirds to three-fourths of all individuals, and about 20% of adults experience neck pain over a 1-year period. About 5% of patients report significant disability from their neck pain. Neck pain occurs in about 15%–30% of adolescents. The incidence and prevalence of neck pain increase from adolescence until around the age of 50 and are slightly more frequent in women than men. After the age of 70, neck pain is about two-thirds as common as low back pain. Although not as common as lumbar radiculopathy, the annual incidence of cervical radiculopathy is about 1 in 1000 per year. About 18% of the population visits a healthcare provider each year for neck pain. The frequency of neck pain decreases somewhat after the age of 50.

Risk factors for neck pain include certain occupations (e.g., dentists). Risk factors in the workplace include time pressure demands, low co-worker support, working in a seated position with the neck flexed, and working with arms above the shoulders. Degenerative joint and disk changes on cervical spine imaging are also probably associated with increased risk of neck pain and cervical radiculopathy.

One of the main risk factors for persisting neck pain is a whiplash-type injury. Lighter individuals may be more susceptible to acute neck injury than heavier people, and there is a positive correlation with height where taller individuals are more susceptible to neck injury. Age does not seem to be a significant factor in injury-provoked neck pain. Litigation and emotional issues may complicate neck pain following injury. Neck pain is relatively less common in children and adolescents.

Thoracic level

Thoracic spine disease is less common than cervical, which in turn is less common than lumbar spine disease. It is estimated that only 1% of all disk herniations affect the thoracic spine. While there are fewer data, it is likely that many of the risk factors that lead to neck and low back pain are also associated with mid back pain. Thoracic pain commonly follows trauma from sports, leisure activities, and accidents.

Thoracic pain is relatively common in childhood and fairly common in adolescence. Osteoporosis is a major risk factor for vertebral compression fracture in the thoracic and lumbar spine.

Lumbar level

Two-thirds to three-fourths of people will experience low back pain during their lifetime; half of Americans report at least 1 day of low back pain in the past year; and many international surveys report a point prevalence of low back pain of between 15% and 30% of the studied population. Sciatica is less common with a lifetime prevalence of 14%–40%, and lower yet for significant sciatica secondary to disk herniation (4%–5% lifetime prevalence, higher in men than women). Low back pain begins in adolescence as a rule and gradually increases in frequency, then levels off, and may decline in the very elderly, over the age of 85.

In children and adolescents, the following factors have been linked with a possible increase in the risk of low back pain: genetic predisposition, lower socioeconomic status, athletic activities, presence of scoliosis, rapid growth, and increased height.

Risk factors for low back pain in adults include a history of low back pain in adolescence, lower socioeconomic status, lower level of education, poor physical conditioning, certain physical activities usually experienced in work (heavy lifting, bending and twisting, static work positions such as prolonged sitting or standing, exposure to whole body vibration), certain psychological and psychosocial work factors (monotony at work, job dissatisfaction, and poor relations with co-workers), depression, obesity, cigarette smoking, some congenital spine abnormalities (scoliosis, transitional vertebra), and prior episodes of low back pain as an adult. Low back pain is very common even in people without any of these risk factors.

Spinal anatomy

The vertebral column

The vertebral column consists of seven cervical vertebrae, twelve thoracic vertebrae, five lumbar vertebrae, the sacrum which consists of five fused segments, and the coccyx which is a small triangular bone consisting of three to five fused, rudimentary vertebrae (see Figure 1.1). The mature vertebral column has several curves. The cervical spine from the first cervical through the second thoracic vertebra is convex forward, the thoracic curve from the second to the twelfth vertebra is convex backward, the lumbar

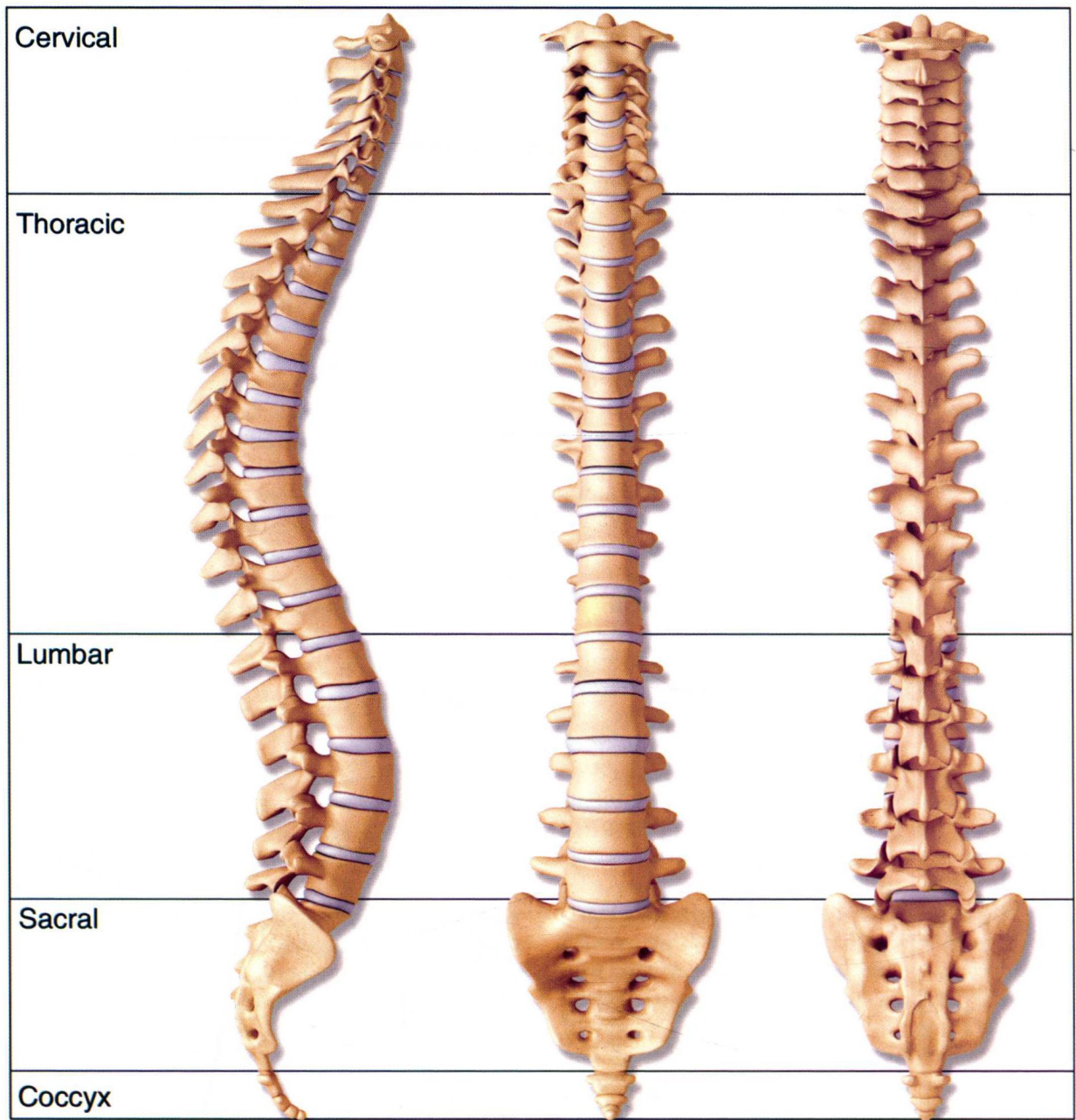


Figure 1.1. Anterior, posterior, and lateral views of the vertebral column showing the cervical, thoracic, and lumbar levels and the sacrum and coccyx.

curve from T12 to the lumbosacral junction is convex forward, and the sacrum and coccyx are concave forward (and convex backward) and help to form the posterior wall of the pelvis. The twelve paired ribs articulate with the thoracic vertebrae, and the sacrum is wedged between the ilium of the innominate bone on each side.

The typical vertebra consists of an anterior part, the vertebral body, and a posterior arch enclosing the vertebral (or spinal) foramen. The foramina of the individual vertebrae line up to form a vertebral (or spinal) canal which contains the spinal cord from the upper border of the atlas (the first cervical vertebra) usually to the lower end of the first lumbar vertebral

body in adults, and below that level, the vertebral canal contains the bundle of lumbosacral nerve roots termed the cauda equina (see Figure 1.2). In adults, the end of the spinal cord may be as high as the twelfth thoracic vertebra or as low as the interspace between the second and third lumbar vertebrae. In the newborn, the spinal cord ends at the level of the upper border of the third lumbar vertebra. As we grow, the spine grows more rapidly than the spinal cord and, as a result, the spinal cord is at a higher level within the spine in the adult compared to the infant and child. The usual vertebral body is roughly cylindrical but flattened posteriorly. The vertebral bodies change in shape and size at different levels. From the second cervical to the first sacral level, each vertebra is connected to the next by fibrocartilaginous complexes termed intervertebral disks between the vertebral bodies, synovial joints between the posterior arches, and various ligaments. The intervertebral disks lack synovium, are termed symphyses, and do permit limited motion.

The intervertebral disks are about the same size as the apposing vertebral bodies and vary in thickness at different spinal levels, being thicker at levels where the vertebral bodies are taller. The disks are thicker in the front than in the back in the cervical and lumbar regions and thus contribute to the spinal curvatures at these levels. Conversely, in the thoracic region, the intervertebral disks are fairly uniform in thickness, and the posterior convexity is due to the shape of the vertebral bodies, which are narrower in the front than in the back. When compared to their associated vertebral bodies, the cervical and lumbar disks are relatively thicker than the thoracic disks.

The intervertebral disks consist of an outer annulus fibrosus, which does receive some blood supply from adjacent vessels, and an inner nucleus pulposus which is avascular. The annulus fibrosus is outwardly convex and heavily laminated. Within each lamina, the majority of the collagenous fibers run in parallel, but fibers in adjacent laminae run in different directions such that overlapping fibers are at oblique angles to one another (see Figure 1.3). The disks are contained superiorly and inferiorly by cartilaginous plates which are firmly fixed to the bony end plates of the adjacent vertebral bodies.

The vertebral arch is composed of two short, round, rod-like bones called pedicles which project backward from the upper, dorsal surface of the vertebral body. Each pedicle meets a broad, vertical lamina. The two laminae are angled posteriorly and medially

and meet in the midline behind the vertebral foramen where they fuse with the posteriorly projecting spinous process. The spinous processes vary considerably in size, shape, and direction throughout the spine. In the cervical spine, the spinous processes are rather short and nearly horizontal, and usually have bifid tips. In the thoracic region, they are directed obliquely downward, and in the lumbar region are nearly horizontal. At the junctions of the pedicles and laminae, there are paired superior and inferior articular processes termed zygapophyses. The superior articular process projects upward, and the inferior process downward. Each process has a synovium-covered articular surface, and the superior process of one vertebra articulates with the inferior process of the vertebra above, forming a zygapophyseal or facet joint (see Figure 1.4). These paired facet joints permit a limited amount of movement while restricting excessive motion.

There are variably sized transverse processes which project laterally from the junction of each pedicle and lamina. They are rather diminutive in the cervical region and larger in the thoracolumbar spine. In the region of the transverse process of the cervical vertebrae is a foramen transversarium on each side through which passes a vertebral artery. In the thoracic spine, these transverse processes articulate with the ribs. The transverse processes and posteriorly projecting spinous processes serve as attachment sites for the strong paraspinal muscles.

Each pedicle has concave notches on its inferior and superior surfaces. The inferior notch is larger and deeper than the superior notch. The inferior notch of the pedicle of the vertebra above, the superior notch of the pedicle of the vertebra below, the intervertebral disk and vertebral body anteriorly, and the zygapophyseal joint posteriorly form the intervertebral foramen. The intervertebral foramina, also called neural foramina, are paired structures at each spinal level through which the spinal nerves and blood vessels travel (see Figure 1.4).

The anterior longitudinal ligament extends along the anterior surfaces of the vertebral bodies and intervertebral disks; the posterior longitudinal ligament is within the vertebral canal and runs along the posterior aspect of the vertebral bodies and intervertebral disks. Running along the posterior aspect of the vertebral canal and connecting the laminae of adjacent vertebrae are the ligamenta flava. The ligamentum nuchae in the neck, the supraspinous ligament in the thoracolumbar spine, and the interspinous

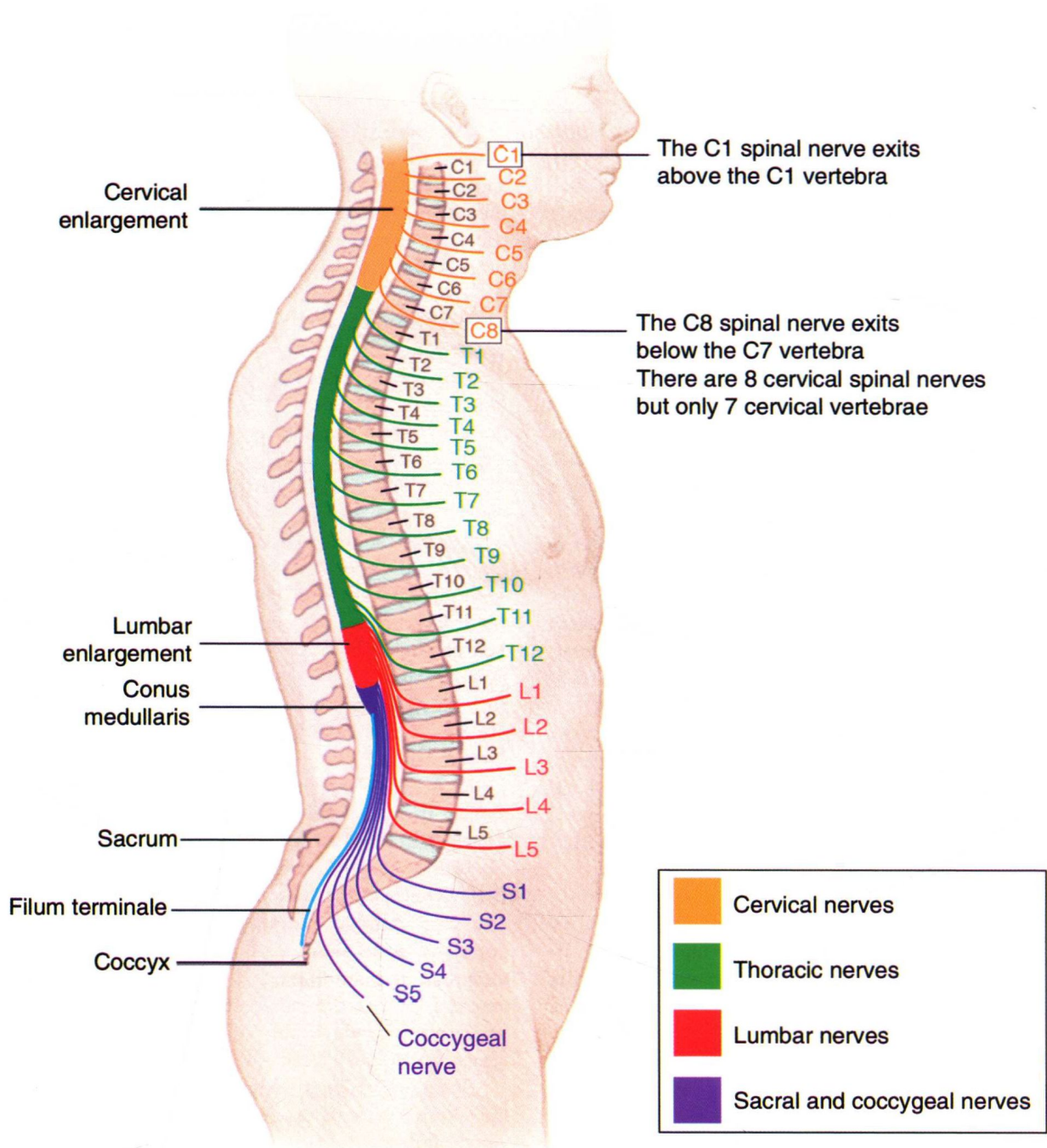


Figure 1.2. Sagittal view of the vertebral (spinal) canal showing the various segments of the spinal cord and spinal nerves which exit through the intervertebral foramina. The spinal cord ends at about the level of the L1 vertebral body, and below that is a bundle of nerve roots called the cauda equina which leave the vertebral canal in pairs at the appropriate level.

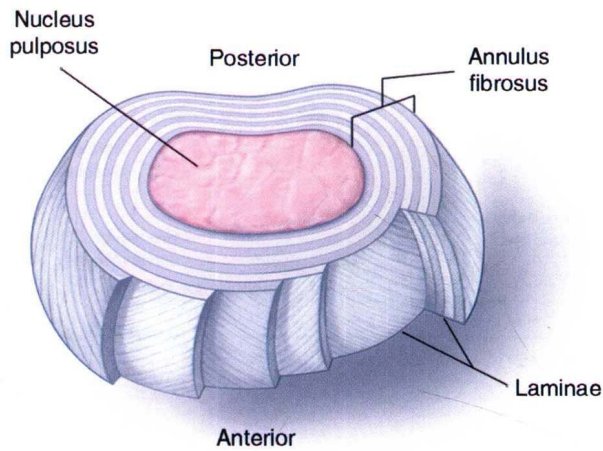


Figure 1.3. Diagram of intervertebral disk showing the outer annulus fibrosus and the inner nucleus pulposus. The annulus fibrosus has multiple layers or laminae. Within each lamina, the fibers run in parallel and usually at an oblique angle. Fibers in adjacent laminae run in different directions, helping to limit movement and strengthen the attachment between adjacent vertebrae. Individual laminae are much smaller than is shown in this diagram.

ligaments connect adjacent spinous processes. These ligaments also connect with deep paraspinal muscles.

The first and second cervical vertebrae, the atlas and axis respectively, merit special mention. The atlas lacks a typical vertebral body and consists of a ring-type structure. It supports the skull. Interlocking with the anterior aspect of the vertebral foramen at the level of the atlas is a small, hard cylindrical bony process, called the dens or odontoid process, which projects upward from the axis (the second cervical vertebra). The front of the dens forms a small joint with the back of the anterior arch of the atlas. The dens is kept in place by a transverse ligament. The atlas has two rather large lateral masses, and the upper aspect has a superior articular facet on each side which articulates with an occipital condyle on the bottom of the skull on each side. The articulations between the skull and atlas and between the atlas and axis facilitate rotational and nodding movements of the head and upper neck (see Figure 1.5). There is no intervertebral disk between the atlas and axis.

The lower five cervical vertebrae (C3–C7) have a unique lateral connection to the vertebra above. The upper surface of each of these vertebrae is concave from side to side, and this concavity is formed in large part by lateral uncinat processes on each side of the upper surface of C3–C7 (see Figure 1.6). The bony protuberance which extends upward along the lateral aspect of the upper surface of each of these vertebrae

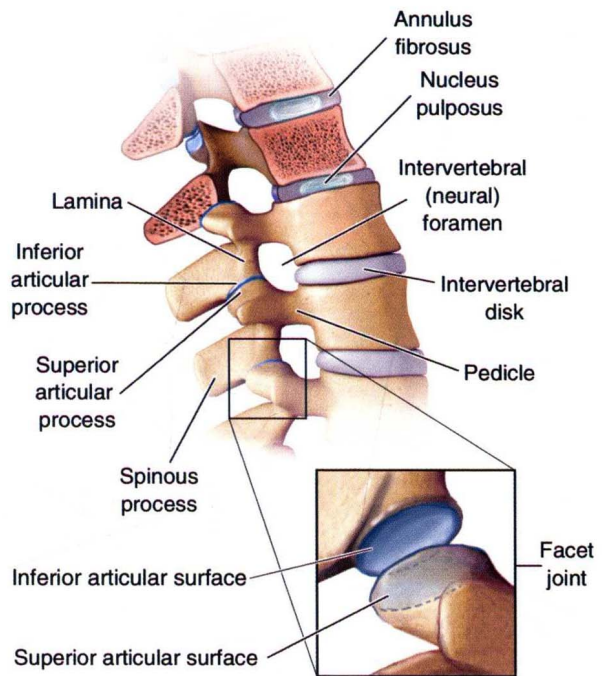
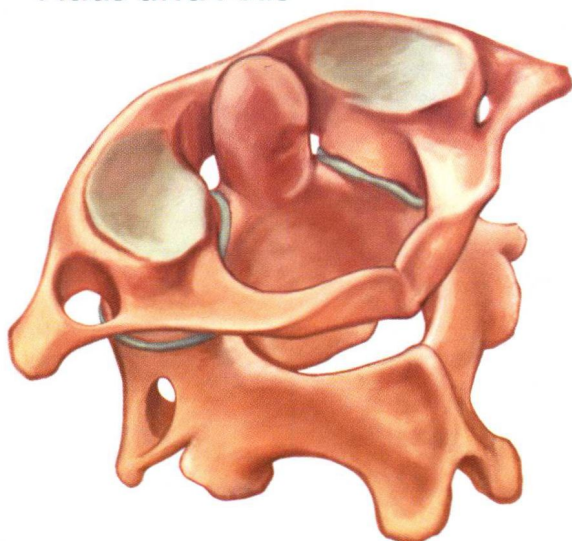


Figure 1.4. Lateral (lower) and mid sagittal (upper) views of the vertebral column show the component parts and relationships. The apposition of the synovium-covered articular surfaces of the inferior and superior articular processes form the paired facet (zygapophyseal) joints found at each spinal level. The intervertebral (neural) foramina through which the spinal nerves exit the vertebral foramen are formed by the undersurface of the pedicle above, the vertebra and intervertebral disk in front, the facet joint posteriorly, and the upper surface of the pedicle of the next lower vertebra below.

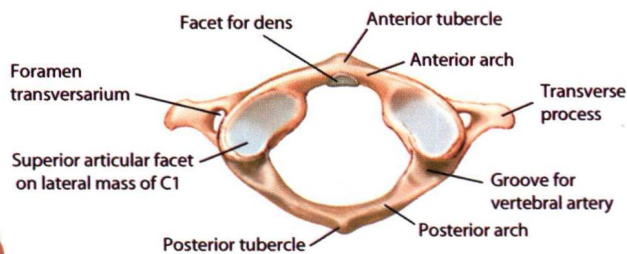
interfaces with a beveled edge of the cervical vertebra above and helps to prevent posterolateral disk protrusions. It is unclear whether this cleft is a fibrocartilaginous connection or a true synovial joint, but these articulations are termed uncovertebral joints or the joints of Luschka. Whether or not there is a true joint present, these “joints” can degenerate and hypertrophy and, given their posterolateral location, they are in a position to compress exiting cervical nerve roots (see Figure 1.6).

The combination of the intervertebral disk system, the ligaments which attach the vertebrae to one another, the facet joints, and the muscles which attach the vertebrae and adjacent structures permits a modest amount of movement between any two adjoining vertebrae. The intervertebral disks which bind the vertebrae together allow movement between adjoining vertebrae by virtue of their compressibility and slight ability to rotate. The summation of multiple small movements at multiple spinal levels gives

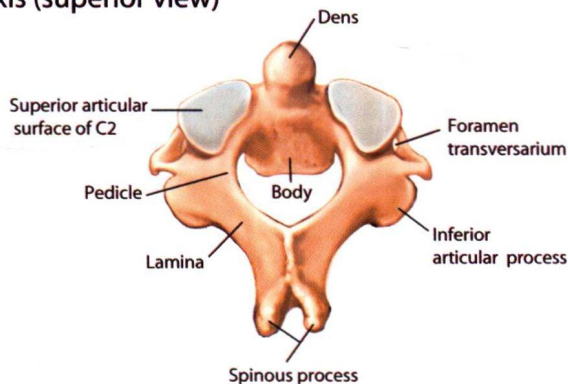
Atlas and Axis



Atlas (superior view)



Axis (superior view)



Axis (lateral view)

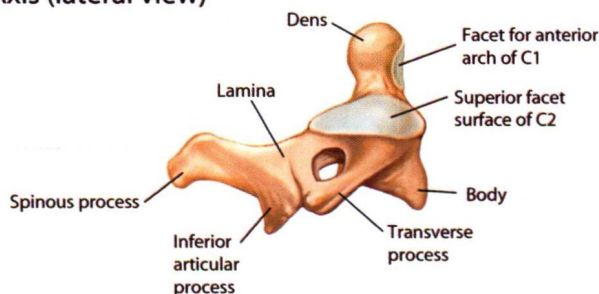


Figure 1.5. The image on the left shows the relationship between the atlas (the first cervical vertebra or C1) and the axis (the second cervical vertebra or C2) from above and behind. The three images on the right show separate views of the atlas and axis. The atlas articulates with the base of the skull above and with the axis below. The dens (odontoid process) is a peg which extends up from the axis and articulates with the back of the anterior arch of the atlas. A ligament behind the dens helps to keep it in place. There is no intervertebral disk between the atlas and axis.

rise to a fairly substantial range of motion for the vertebral column as a whole. Greater movement is possible in the cervical and lumbar regions because the disks are thicker at these levels.

The spinal cord is not round but oval, being wider than it is deep, more so in the cervical levels than elsewhere. The spinal cord and exiting nerve roots are covered by three membranes or meninges which are, from outside in, the dura mater, the arachnoid mater, and the pia mater (see Figure 1.7). The dura mater extends from the foramen magnum to the

second sacral vertebral level and has tubular prolongations along the nerve roots and spinal nerves as they pass through the intervertebral foramina to leave the spine. The space between the dura and the periosteum and ligaments within the vertebral canal contains a plexus of veins, loose fat, and areolar tissue. Local anesthetics, infection, and tumors can spread through this epidural space. Beneath the dura mater is the arachnoid, a delicate membrane that is loosely attached to the dura and envelops entering and exiting nerves and blood vessels. Between the dura

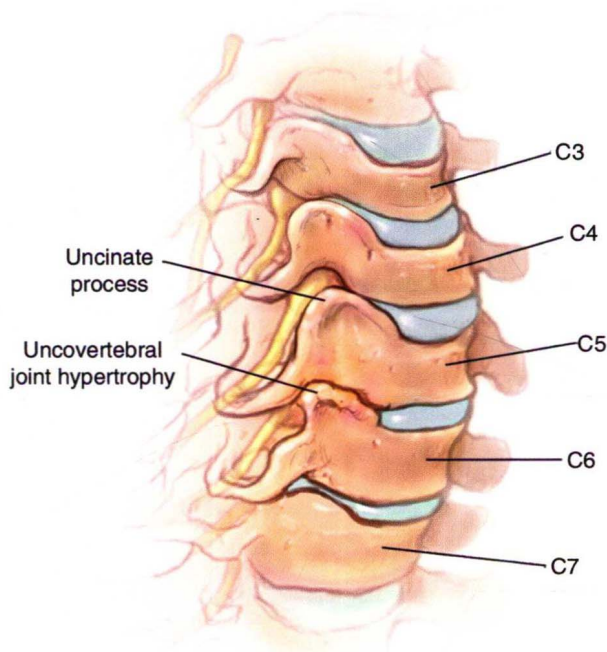


Figure 1.6. The C3–C7 vertebrae have uncinate processes which are upward projections of the lateral edges of the vertebral body on each side. Each uncinate process contacts the disk and beveled inferolateral surface of the vertebra immediately above. These so-called uncovertebral joints (joints of Luschka) can degenerate and hypertrophy. Such hypertrophy can cause cervical nerve root impingement, especially if it occurs posteriorly.

and the arachnoid mater is a potential subdural space which also ends at the second sacral level. The pia mater covers the spinal cord and also invests the nerve roots. Between the arachnoid and pia mater is the subarachnoid space which contains spinal fluid. The arachnoid and dura can expand such as when spinal fluid pressure is increased. The ability to expand can dampen transmitted spikes in spinal fluid pressure such as accompany the pulse-driven production of cerebrospinal fluid in the choroid plexus within the ventricles intracranially.

There are two areas of enlargement of the spinal cord: the cervical enlargement which extends from about the third cervical to the second thoracic spinal cord segment, and the somewhat smaller lumbar enlargement from the first lumbar to the third sacral spinal cord segment. The cervical and lumbar enlargements relate to the increased number of nerve cells and nerve fibers required for innervation of the

upper and lower limbs respectively. The cervical nerve roots travel downward only slightly before leaving the spinal canal and never more than one vertebral level from the corresponding spinal segment. Thus, the cervical spinal cord enlargement is only slightly higher than the corresponding vertebral levels. However, because the spinal cord typically ends at about the level of the first lumbar vertebral body, the lumbar enlargement lies at the ninth through twelfth thoracic vertebral levels, and, as a result, the lumbosacral nerve roots descend for some distance within the vertebral canal before exiting. As noted above, the spinal cord usually ends at the lower end of the first vertebral body but can be as high as the twelfth thoracic vertebra or as low as the disk below the second lumbar vertebra (see Figure 1.2).

The termination of the spinal cord is called the conus medullaris. Below the conus medullaris is a bundle of nerve roots termed the cauda equina (horse's tail) which descend within the lumbosacral spinal canal to exit in pairs through the appropriate intervertebral foramina. Within the cauda equina the sacral segments are located most medially and the first exiting, upper lumbar segments are located more laterally. From the bottom of the conus medullaris there is a connective tissue filament, the filum terminale, which extends all the way to the bottom of the vertebral canal into the sacrum and attaches to the coccyx.

Detailed spinal cord anatomy

Superimposing an H over an oval can separate a generic spinal cord level into the following sections (see Figure 1.8). The upper (posterior or dorsal) arms of the H surround paired funiculi or white columns which transmit ascending first-order sensory information dealing mostly with proprioception (vibration, joint precision sense, pressure, and touch). The ascending fibers in these columns are uncrossed and most have their cell bodies in the ipsilateral spinal (dorsal root) ganglia. Each of the paired dorsal funiculi is further divided into a lateral fasciculus cuneatus and a medial fasciculus gracilis. The fasciculus cuneatus carries fibers from the upper thoracic and cervical nerves, and the fasciculus gracilis carries nerve fibers from the lumbosacral and lower thoracic segments. Sacral level nerve fibers are medial to lumbar, which are medial to thoracic, which are medial to cervical level fibers. The ascending sensory nerves in the two fasciculi synapse in the nucleus cuneatus and the nucleus gracilis in the medulla oblongata after which the second-order neurons