This book is dedicated to
PATRICIA

Disorders of the Cervical Spine

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The ultimate in cervical collars– a Padang woman from Kayah State, Burma

Foreword

It gives me great pleasure to write this foreword to Mr Jeffreys' excellent monograph. In my opinion monographs are by far the best form of writing for postgraduate education. No one person can have both the breadth and the depth of experience to write a comprehensive postgraduate textbook of orthopaedics and the multi-author textbook inevitably has grave disadvantages.

In addition to having extensive experience of his chosen subject the author of a monograph must have wide background knowledge. Mr Jeffreys possesses both these qualities. For many years he has been studying the problems of the cervical spine and, through his appointment at the Robert Jones and Agnes Hunt Orthopaedic Hospital at Oswestry has had a unique opportunity to gain experience of this subject.

In addition he has a wide experience of orthopaedics and surgery in many parts of the world, having worked in Malaysia, Indonesia, Burma and Nigeria as well as making professional visits to North America and Scandinavia.

Mr Terence McSweeney, Consultant in Charge of the Spinal Injuries Unit at Oswestry contributes a valuable section on injuries to the neck. This is a complex and important subject and neck injuries are increasing in frequency: the fruits of his experience and thoughts make a noteworthy contribution to this monograph.

The neck is a fascinating subject for study – from many aspects – and I have read this book with great interest and pleasure. It is both lucid and comprehensive and I am sure it will receive the wide interest it deserves.

ROBERT ROAF
Emeritus Professor of Orthopaedic Surgery,
Liverpool University;
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Preface

'Behold, my desire is, that the Almighty would answer me and that mine adversary had written a book.'
Job, XXI, 35.

The cervical spine offers common ground for the orthopaedic surgeon, the neurologist, the neurosurgeon, the rheumatologist, the radiologist and the general physician. I have tried to write a brief survey of the area which I hope will be of some value to all these specialities. Inevitably the book has an orthopaedic accent, and I would like to think that orthopaedic residents in training will find it most useful. I have been selective in my material, and specialists in other fields will be well aware of deficiencies; but they may feel compensated by appreciating some of the orthopaedic problems of managing cervical injury and disease. I have also been selective in my bibliography, confining myself to those references which will lead the interested reader to other sources.

There is no orthopaedic consensus at Oswestry. We are a group of individual surgeons whose orthopaedic philosophies range from the reactionary to the revolutionary. The opinions expressed in this book therefore, are mine. Those opinions however have been moulded by my colleagues, who have criticized my views, rearranged my thoughts, influenced my surgical judgement and taught me. I am particularly grateful to those of my friends who have discussed the book with me and who have allowed me access to their patients; Arwyn Evans, Brian O'Connor, Gerry Slee and Donald Ward. The two surviving members of the active staff who taught me when I was a registrar, are Gordon Rose and John Rowland Hughes. They are still teaching me. Outside Oswestry, I have received advice and assistance from Marie Brookes, Edwin Bickerstaff, John Hopkins, Alan Lettin, Geoffrey Osborne and Peter Stiles.

Bill Park has guided me through the intricacies of radiology. At our weekly conference he teaches me radiographic interpretation in his inimitable way. He has read, criticized and greatly improved my manuscript of Chapter 2.

It would have been presumptuous of me to write on fractures and dislocations of the neck. My good friend, Terence McSweeney, has, by graciously agreeing to write Chapter 4, lent the book a lustre it would otherwise lack.

So many others have helped that I cannot count them; but some I must mention. The medical photography departments at Oswestry and Wrexham have kept up with my insatiable demands, usually at impossibly short notice. Christine Clutton and Elizabeth Lister have translated my illegible scrawl into typescript; Jacqueline Weston has drawn the illustrations with a clarity which the reader will appreciate; Jane Crocker has found hundreds of references for me; and Ceinwen Lloyd has stood by my side through more neck operations than either of us care to remember.

My publishers have been extremely helpful and very tolerant with a new author.

My family have endured the inevitable disruption of their lives with the love and loyalty they think I take for granted.

My interest in the spine was kindled by my old chief, Robert Roaf; and that someone of his distinction has agreed to write the Foreword is a source of immense personal satisfaction to me.

Finally, I wish to thank my two doctors, without whose combined wisdom and understanding, I would not have been able to write this book. They wish to remain anonymous, but when they read this I want them to realize that I know how much I owe to them.

TEJ
Wrexham
Oswestry

1 Applied anatomy

'Was common clay ta'en from the common earth
Moulded by God, and tempered with the tears
Of angels to the perfect shape of man.'
'To–', Tennyson, 1851.

INTRODUCTION

Man sees before he understands. The accuracy (but not the beauty) of Leonardo da Vinci's anatomical drawings, astonishing and unsurpassed after 400 years, disappears in his portrayal of structure whose function was not known to him. He knew what bones and muscles do, and could interpret their anatomy in architectural and engineering terms; and he drew them with a photographic regard for correct detail. He was the first biomechanic. He did not know what nerves do, and drew them as he thought they should look according to the metaphysics of Galen and Bacon*. We can not afford to smile at their naivety. We are as guilty of false extrapolation, and as restricted by orthodoxy as the medieval philosophers. Vesalius was four years old when Leonardo died. Within one generation the foundations of topographical anatomy, derived from dissection, had been laid so securely that all further details of anatomical knowledge have been mere additions to Vesalius' work.

This is not the place to discuss the importance of descriptive anatomy in the undergraduate curriculum; but its position in the clinician's approach to accurate diagnosis and management remains paramount and unchallenged. In recent years much attention has been paid to the detailed topographical structure of the neck. This chapter is unashamedly selective in concentrating on some of these aspects. It is not an attempt to teach anatomy to the orthopaedic surgeon; or to replace the cadaver and Gray as his primary source (even less is the word 'primary' a Freudian slip).

* Roger Bacon (1214–94) is not to be confused with his more famous seventeenth century namesake, Francis. Roger was the greater scholar. He was fluent in Latin, Greek, Hebrew and Aramaic. His works include theses on grammar, logic, mathematics, chemistry, alchemy and physic (*sic*). He invented spectacles.

The neck conveys vital structures from and to the head and trunk. It enables the head to be placed in a position to receive from the environment all information other than that provided by touch. We need to know as much as possible about these structures, about movement of the head relative to the neck and the neck relative to the trunk; disorders of the cervical spine will affect one or other of these things.

SURFACE ANATOMY

Many of the important structures of the neck can be seen and felt in the thin patient. Less is apparent in the obese, pyknic individual with a short neck, but certain landmarks can always be found.

The sternomastoid muscle, running from one corner to the other of a quadrilateral area, formed by the anterior midline, the clavicle, the leading edge of the trapezius and the mastoid–mandibular line, divides the side of the neck into anterior and posterior triangles (*Figure 1.1*).

The posterior triangle contains little which is visible on inspection. Palpation of the base of the triangle (which is really a pyramid) finds the first rib, crossed by the subclavian artery, the lower trunks of the brachial plexus and perhaps a cervical rib or its fibrous prolongation. Higher, the accessory nerve, running forwards to the sternomastoid, divides the triangle into an upper 'safe', and a lower 'dangerous' area (Grant, 1951). In this upper area the transverse processes of the cervical vertebrae can be deeply felt.

There is more to be seen, and felt, in the anterior triangle. The external jugular vein, and the platysma, cross the sternomastoid; and both stand out in the thin singer. The 'Adams' apple'* moves with swallowing, and the pulsation of the carotids is often visible. Below the body of the hyoid, the neurovascular bundle can be compressed against the carotid tubercle of the sixth vertebra; demonstrating how easily accessible is the spine through this area. In the apex of the triangle, the transverse process of the atlas is palpable immediately behind the internal carotid artery; and the finger tip can roll over the tip of the styloid process and the stylohyoid ligament. In the anterior midline can be usually seen, and always felt, the anterior arch of the hyoid, the notch of the thyroid cartilage, the cricoid and the upper rings of the trachea. With advancing age, the horizontal creases in the skin become more pronounced. Whenever possible, operative incisions should occupy one of these creases, in the interests of healing, if not beauty.

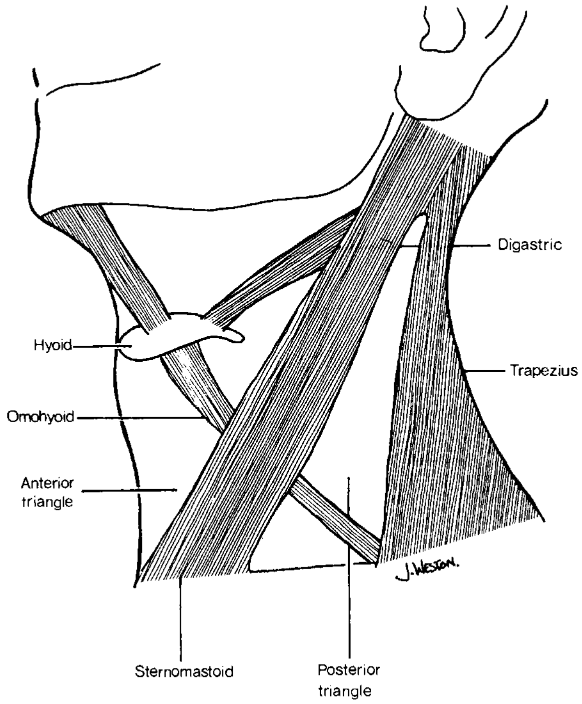

Figure 1.1 Muscular triangles of the neck

The currently fashionable long hair of both sexes makes inspection of the back of the neck difficult. Fortunately, fashion is fickle. The vertebra prominens, which may be the spinous process of the seventh cervical or the first thoracic vertebra, marks the lower end of the midline sulcus formed by the ligamentum nuchae in its leap to the occiput. The rounded ridge on either side of the sulcus is made by splenius capitis as the origin of trapezius is tendinous. The vertebra prominens is the top of the 'dowager hump' seen in patients with cervical spondylosis.

* So called because the forbidden fruit was supposed to have stuck in Adam's throat. There is no canonical authority for this legend. Indeed, Genesis clearly implies that he enjoyed it; and discovered sex.

THE CERVICAL VERTEBRAE

The atlas

The atlas has no body (*Figure 1.2*). The anterior arch is faceted to receive the tip of the odontoid process, and the medial aspect of each articular mass is indented by the attachment of the transverse band of the cruciate ligament. The spinal canal at this level is spacious. Its sagittal diameter may be divided into three; the anterior third being occupied by the arch of the atlas and the odontoid peg; the middle third by the cord; and the posterior third by the subarachnoid space. Cisternal puncture by the posterior or lateral route is therefore safe under normal conditions.

The oblique groove across the posterior arch of the atlas accommodates the vertebral artery after it has wound around the outside of the articular mass. The attachment of the posterior atlanto-occipital membrane is arched over the artery at this point, and this arch is sometimes outlined, completely or incompletely, by bone to form the arcuate foramen. The significance of this bony arch is commonly regarded as negligible; but it has been said that its presence renders the atheromatous vertebral artery more vulnerable to compression during rotation of the head (Klausberger and Samec, 1975).

The side-to-side width of the atlas is greater than that of any other cervical vertebra, to increase the leverage of the muscles inserted into the transverse process. This transverse process is the only one in the cervical spine which is not grooved to allow egress of a nerve root. The articular masses are broader and deeper than any other because they shoulder the weight of the skull, and also because the inferior articular facets lie directly below the superior, not behind them as do the inferior facets of the subjacent apophyseal joints.

The axis

The axis has stolen the body of the atlas (*Figure 1.3*) to form the odontoid peg which projects up from its centrum to lie behind the arch of the atlas. The tip of the odontoid is faceted in front to mate with its atlantic fellow, and behind to accommodate the synovial bursa which separates it from the transverse band of the cruciate ligament. On either side of the base of the odontoid, the centrum presents the inferior facets of the atlanto-axial joints. Below, the atlas begins to take on the characteristics of a typical cervical vertebra. Its laminae meet to project a bifid and massive spinous process whose depth and aquiline profile are very variable. The pedicles are thick and their upper margins continuous with that of the body, so that there is no U-shaped intervertebral foramen.

The inferior articular facet lies below and behind the superior, and subtends an angle of almost 90 degrees with the transverse process. This articulo-transverse angle is recessed at its apex to accommodate the tip of the pyramidal process of the third vertebra (Veleanu, 1975). Vertebrae three to six are so similar that it is not easy, or necessary, separately to identify an individual bone (*Figure 1.4*). In the articulated column they increase in size from above downwards. The margins of the bodies are sharply defined particularly around the superior rim where the posterolateral edge projects upwards to articulate with the body above. Gray does not give this

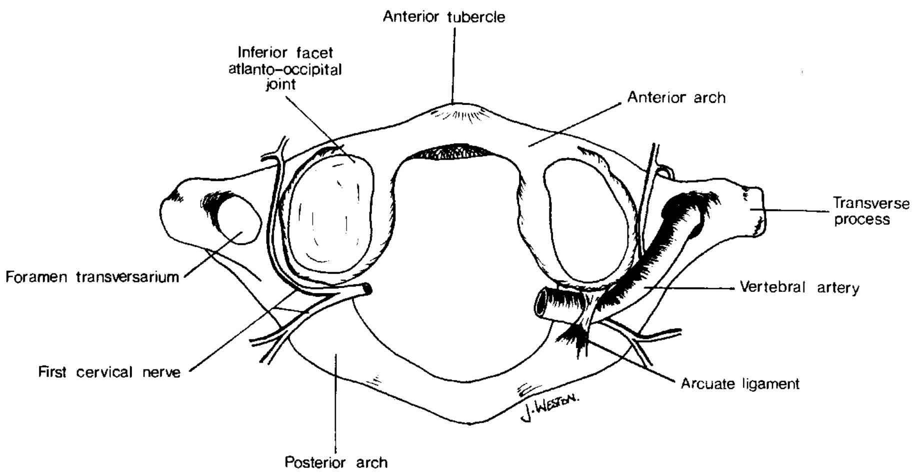

Figure 1.2 Atlas, superior aspect

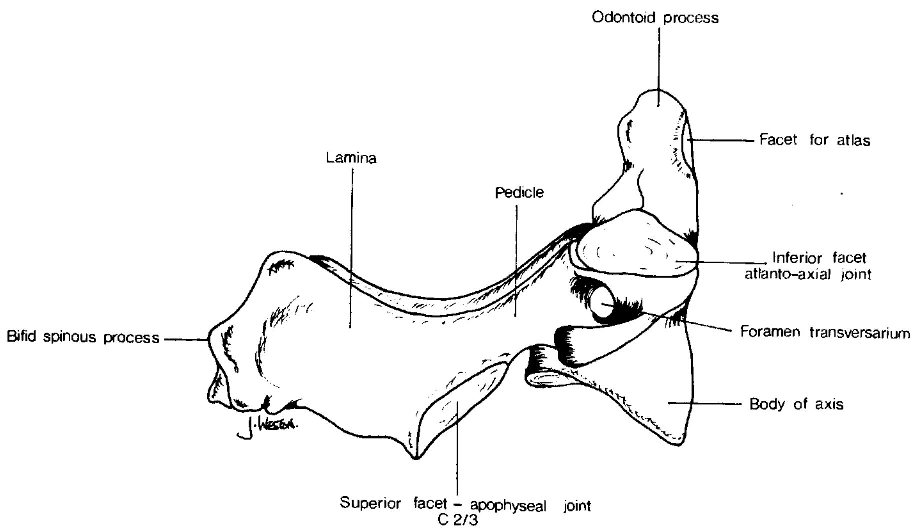

Figure 1.3 Axis, lateral view

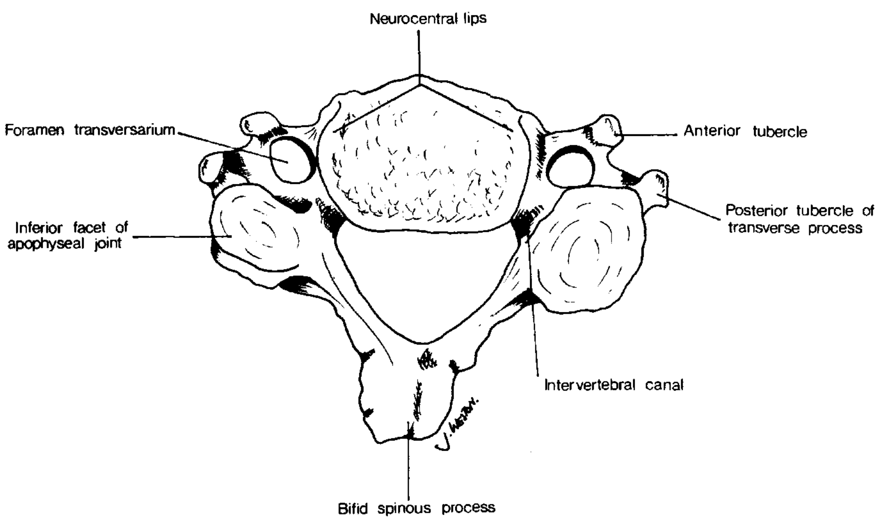

Figure 1.4 Typical cervical vertebra; superior view

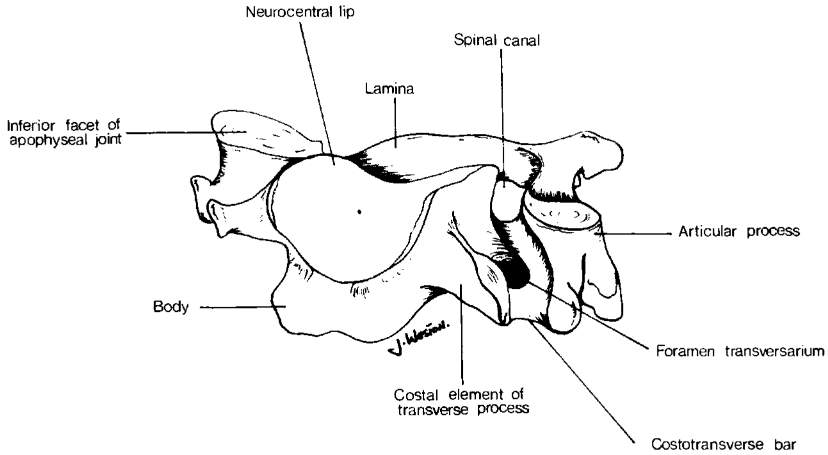

Figure 1.5 Typical cervical vertebra; oblique view

projecting edge a discrete name (*Gray's Anatomy*, 1969), but Frazer calls it the neurocentral lip (Frazer, 1958) (*Figure 1.5*), and European anatomists refer to it variously as the unciform or uncinate process, or the semilunate process. It is a structure of sufficient identity to deserve a name, and it is a significant structure in the pathology of cervical spondylosis. In this book it will be referred to as the neurocentral lip. The antero-inferior margin of the body projects downwards. This normal epistany increases with the inexorable development of spondylytic osteophytes, a point to be remembered during discography and anterior interbody fusion.

The spinal canal is large to accommodate the cervical enlargement of the cord. The laminae are slender, and in youth each slightly overlaps the one below. This overlap increases markedly with age.

The pedicles, apophyseal joints, transverse processes and neurocentral lips are peculiar and specific to the cervical spine (*Figure 1.6*). Together they constitute the boundaries of the intervertebral foramen and enclose the foramen transversarium. This foramen, which affords passage to the vertebral artery, separates the costotransverse bar from the pedicle. The groove which forms the floor and walls of the intervertebral foramen, becomes progressively more shallow as the vertebrae descend. Medial to the vertebral artery the groove is floored by the pedicle. Here lie the anterior root of the spinal nerve and the posterior root ganglion; the former usually, though not invariably, above the latter (Abdullah, 1966). Running alone the nerve root are the radicular and spinal branches of the vertebral artery, and their accompanying veins. Tapering into the groove are the blending layers of the meninges and the nerve sheaths forming the dural root sleeve.

Passing behind the vertebral artery, the spinal root divides. The posterior primary ramus winds around the lateral aspect of the articular mass, or 'pyramidal process' (Veleanu, 1975) and therefore lies behind scalenus medius, which arises from the posterior tubercle of the transverse process. The anterior primary ramus crosses, and grooves the costotransverse bar, and passes between the two scaleni. Given the configuration of the articulated cervical column, it follows that the so-called intervertebral foramen is a funnel at least a centimetre in length and variable in height and width. Its width is determined by the length of the pedicle, and here the funnel is at its most narrow. The walls of the dry bone diverge laterally, but in life only to accommodate the vertebral artery and its surrounding venous plexus. The functional diameter of the funnel may be smaller here than at the pedicle.

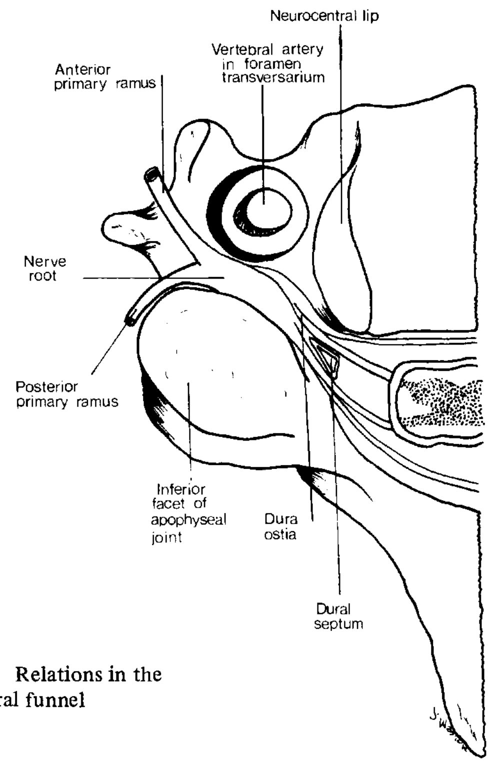

Figure 1.6 Relations in the intervertebral funnel

The height of the funnel is determined by the height of the articular mass (or pyramidal process). The tip of this process engages with the apex of the proximal articulo-transverse angle. It is subject to normal variations in shape and size, and is also modified with age and the inevitable osteophytic deformation of degenerative spondylosis. Medially, the intervertebral disc, the vertebral body and the neurocentral lip are equally liable to variations in shape and height.

The costal or anterior element of the transverse process, with the side of the vertebral body, forms the floor of the shallow groove which houses longus capitis and longus cervicis muscles. In a muscular man these muscles may extend almost to the midline of the vertebral body, becoming continuous with the anterior longitudinal ligament. When this happens they can be a nuisance during an anterior approach to the cervical spine. On these muscles and anterior to the costal element lies the sympathetic chain, vulnerable to an enthusiastic retractor.

The seventh cervical vertebra is transitional. Its spine is long and not bifid. It ends in a tubercle which affords attachment to the ligamentum nuchae. The spine may or may not be longer than that of the first thoracic vertebra. If it is, the seventh is the vertebra prominens. The transverse processes are large and often lack a foramen transversarium. When one is present, it is traversed by veins and branches of the ascending cervical artery; never by the vertebral artery*. The costal element may be discrete as a cervical rib; a structure whose existence has provoked acrimonious discussion out of all proportion to its size and significance. It is the 'unciform sac' of orthopaedic surgery.

THE JOINTS OF THE CERVICAL SPINE

The intervertebral discs

There is no disc between the first and second vertebrae. The odontoid process is separated from the body of the axis by a layer of cartilage which ossifies before puberty. This cartilaginous layer is not an epiphyseal plate but a notochordal remnant. A fracture through the base of the odontoid in childhood is not an epiphyseal injury (Friedburger, Wilson and Nicholas, 1965; Seimon, 1977).

The intervertebral discs are composed of an outer annulus fibrosis containing a nucleus palposus. The posterolateral margins of the annulus lie between the neurocentral lip and the inferior aspect of the body above. After the second decade of life, clefts appear in the annulus in this area. These clefts persist throughout life. They acquire linings indistinguishable from synovial membrane. Adjacent to the clefts, the neurocentral lip develops osteophytic outgrowths similar to the osteoarthritic osteophytes of the apophyseal joint across the pedicle. An academic controversy has existed for many years over the question of whether or not these clefts are true synovial joints. The current orthodox teaching is that they begin as stress fissures of the annular fibres, which appear in the second decade of life, and are later converted into cartilage-lined joint surfaces. They are known as the neurocentral joints (of Lushka); or, in European literature, as uncovertebral joints. They are of considerable importance, in the pathogenesis of cervical radiculopathy and myelopathy; and in the operative treatment of cervical myelopathy and the vertebrobasilar syndrome (Von Lushka, 1858; Rathke, 1934; Cave, Griffiths and Whiteley, 1955; Payne and Spillane, 1957; Tondbury, 1955; Ecklin, 1960).

* 'What, never?
Hardly ever'. (HMS Pinafore)

The discs are biconvex to conform with the concavity of the vertebral bodies, but are deeper anteriorly. The normal lordosis of the cervical spine results from this. The nucleus does not occupy the centre of the disc but lies somewhat posterior, a point to remember when performing cervical discography.

The annulus is reinforced in front and behind by fibres from the anterior and posterior longitudinal ligaments. Elsewhere around the circumference of the vertebral body the annulus blends with the periosteum, but is bound down to bone and can only be separated by incision.

The apophyseal joints

These synovial joints lie oblique in the sagittal plane, and incline medially in the coronal. This alignment lacks the architectural stability of the dorsal and lumbar areas of the spine, but permits more movement. A 'fail-safe' locking mechanism is provided by the abutment of the superior leading edge of the inferior facet into the articulo-transverse angle of the joint above (Veleanu, 1975). The joint capsules are richly innervated with pain and propioceptive receptors, more so than in the corresponding joints lower in the spine, so that awareness of head and neck movement is enhanced (Wyke, 1978). Wyke has described three types of nerve endings, Types I and II which he refers to as mechanoreceptors, and Type IV which are nociceptors. His Type III receptors are not found in the cervical spine. He also observes that while the apophyseal joint capsule and the supporting ligaments of the neck are so innervated, the intervertebral discs are not.

The atlanto-axial and atlanto-occipital joint facets are aligned to permit the movements of nodding and turning peculiar to this level. The atlanto-odontoid joints lie between the facets on the tip of the process and the anterior arch of the atlas in front, and the transverse ligament behind. Two synovial cavities are present, and the posterior articulation is unique in that the facet on the transverse ligament is covered with articular cartilage.

THE LIGAMENTS OF THE CERVICAL SPINE

The occipitovertebral ligaments (*Figure 1.7*)

The transverse ligament of the odontoid is diamond shaped and embraces the process securely. Two bands, one passing up to the occiput, the other down to the body of the axis, complete the cruciform ligament of the atlas, but the vertical arms of the cross play little part in containing the odontoid. In front of the upper arm lies the apical ligament of the odontoid, a vestigial remnant; and the alar ligaments, running either side from the tip of the odontoid to the margins of the foramen magnum. They are robust cords which check atlanto-axial rotation.

The anterior atlanto-occipital membrane (*Figure 1.8*) extends upwards from the antero longitudinal ligament to connect the anterior margin of the foramen magnum with the anterior arch of the atlas.

The membrana tectoria is a fan shaped continuation of the posterior longitudinal ligament to the basi-occiput. Its superficial lamellae blend with the dura.

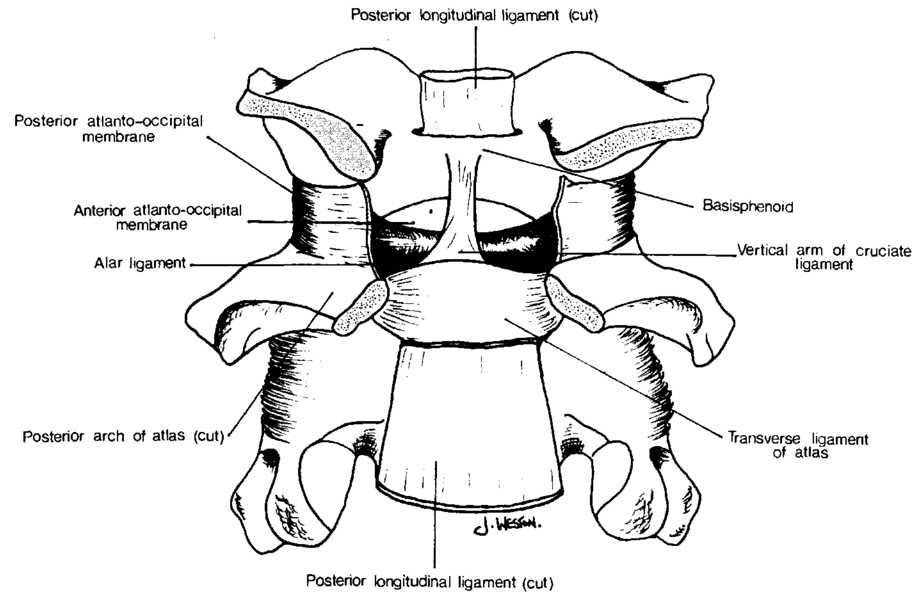

Figure 1.7 The ligaments of the atlanto-axial-occipital joints

The posterior atlanto-occipital membrane arches over the vertebral artery. It is not as strong as the flavum, and during cisternal puncture the advancing needle does not encounter the characteristic 'brown paper' resistance felt during lumbar puncture.

The longitudinal ligaments

The anterior longitudinal ligament hugs the front of the vertebral bodies and loosely blends with each annulus as it crosses the disc spaces. The posterior ligament is firmly bound to each disc, but stands proud of the posterior concavity of the vertebral body. The space is occupied by the retrocorporeal veins. By standing away from the back of the vertebral body, the posterior ligament ensures that the spinal canal is a smooth-walled tube. This also means that any pathological thickening, such as is seen in ossification of the ligament, will compromise the capacity of the canal even in the absence of any spondylotic protrusion of the disc.

The ligamentum flavum is strong and elastic. The ligamentum nuchae runs from the vertebra prominens to the occiput. It is inelastic and can be regarded as the posterior edge of the interspinous ligament, which is an intermuscular septum providing origin for the trapezius and splenius muscles. The stabilizing influence of these posterior ligaments is small. Plication of the ligamentum nuchae in extension of the spine can be seen clearly in xeroradiograms of the neck.

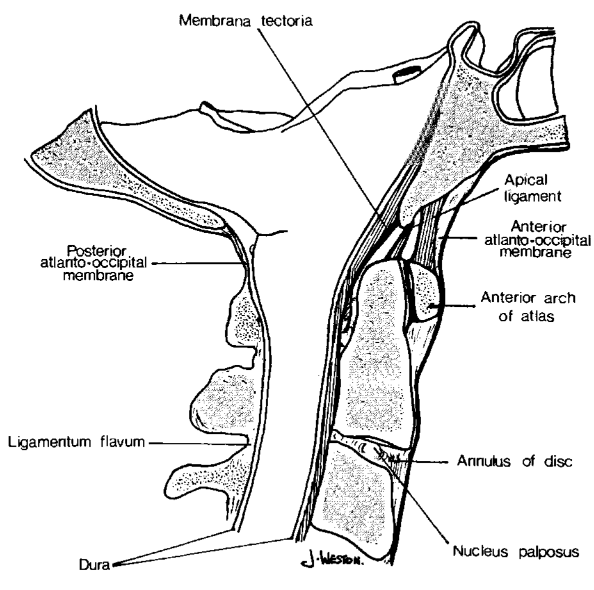

Figure 1.8 Sagittal section of the atlanto-axial-occipital joints

MOVEMENTS OF THE CERVICAL SPINE

The erect posture, binocular vision and cervical mobility of man enable him to recognize the enemy behind his shoulder more efficiently than most animals. His ability to gaze up at the stars or peer down a microscope depends on neck movement. Electronic vision may render neck movement evolutionarily unnecessary; and we may be more concerned to restrict neck movement in automobile man than to encourage it. But head and neck movements remain as social signals indicative of mood or emotion.

Movements of the head on the neck, and movements of the head and neck on the trunk can be described separately, and there is some anatomical justification for doing so. The muscles which move the head on the neck are confined to the occipitocranial segments, although their actions are supplemented and reinforced by muscles which cross these articulations. Muscles which move the whole cervical spine and head span several segments; with the exception of the intertransverse muscles which are, in the normal spine, functionally negligible, apart from a doubtful role in anchoring nerve roots.

Movements of the atlanto-occipital joints
At these joints we nod our heads. The corresponding curved articular surfaces allow a limited range of flexion and extension. The long axes of the joints are set slightly obliquely; both joints act as one and no movement around a vertical axis can occur. Slight curvature in the coronal plane allows a small degree of lateral tilt.

Extension is arrested when the posterior arch of the atlas is trapped between the occiput and the axis, as is lateral tilt. Flexion stops when the posterior ligaments are taut and when the tip of the odontoid (to which the atlas is firmly linked by the transverse ligament) abuts against the anterior margin of the foramen magnum. During both these movements the movement of atlas on axis is insignificant. After atlanto-axial fusion the range of flexion–extension is undiminished.

Atlanto-occipital flexion is powered by the rectus capitis anterior muscle, supplemented by the longus capitis. Extension is produced by the rectus capitis posterior (major and minor); lateral flexion by the rectus capitis lateralis. The semispinalis and splenius capitis, the trapezius and the sternomastoids assist.

Movements of the atlanto-axial joints
The atlas and the occiput rotate as one around the odontoid. All three atlanto-axial joints take part in the movement. The odontoid is firmly united to the occiput by the alar ligaments which, together with the joint capsules of the atlanto-axial apophyseal joints limit rotation to some 45 degrees.

The muscles producing this rotation are the obliquus capitis and the rectus capitis posterior major, assisted by the splenius capitis of the same side and the sternomastoid of the opposite side.

It can be seen that the strong connections are between atlas and axis, and axis and occiput. Some anatomists even regard the atlas as a mere sesamoid between the skull and the axis, and certainly the occipito-axial-atlantic complex is a functional entity (Werne, 1957). Werne regards the whole complex as a ball and socket joint.

Intervertebral movement between C2 and C7
While the range of movement between any two cervical vertebrae is not great, the summation of these movements provides for the wide range of movement possible in the intact normal neck. The thick intervertebral discs, in the healthy young adult, are compressible and deform to accommodate the range made possible by the flat, upward obliquity of the apophyseal joints.

Flexion and extension are free. Arrest of both is inflicted by bone. Extension is stopped by the contact of superior or inferior facets; flexion by the apposition of the projecting lower edge of the body above on the sloping upper surface of the body below. Lateral flexion is always accompanied by rotation, thanks to the slight medial inclination of the superior facets. This movement is stopped by the lateral locking mechanism of the apex of the inferior facet engaging the transverse-articular angle above.

If bony architecture was the only limiting force in neck movement control would be vested in the acting muscles alone. Restriction is supplemented by the elastic restraining properties of the two longitudinal ligaments, the ligamentum flavum and the intervertebral discs.

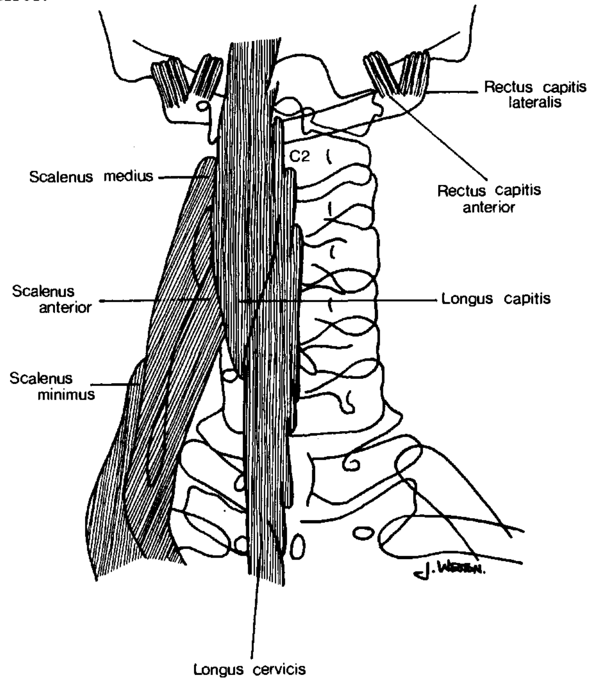

Figure 1.9 The prevertebral muscles

Neck movement diminishes with age. In childhood the free range of flexion and extension can be such as to allow considerable displacement of one vertebral body upon another (Cattel, 1965 and *see* Chapter 2).

Forward flexion should normally allow the chin to touch the chest. Extension of the neck, in children and the young adult, can sometimes allow the back of the skull to touch the back but this is exceptional. Lateral rotation should encompass a 180 degree arc, and in lateral flexion the ear should touch the shoulder. These movements can be measured accurately by radiographs, when any segmental restriction can also be detected. The detection of restricted movement on clinical examination in one or more than one direction, is a physical sign of value.

There is a commonplace neck movement which has no precise anatomical term. It is the movement of 'craning the neck'*. It is the movement we use, when

* The etymology of 'craning' leads down strange philological paths. It is a British word meaning to stretch one's neck like a crane. The Old English word is 'cran'. There are no cranes in Britain: but they do exist in Jutland and the Friesian coast, whence our Anglo-Saxon invaders came. Native to Britain however, is the heron; whose forward thrust of beak to impale the foolish eel is the exact neck movement under discussion. The Welsh (or British) name for 'heron' is 'garan'. The crane proper is a rare passage migrant from Scandinavia to Spain.

'Crane' has no connection with 'cranium', which comes from the Greek 'kranion'. The Middle English word for the cranium was 'scolle', hence 'skull'.

standing in a crowd, we try to catch a glimpse of a passing celebrity. The movement involves simultaneous extension of the atlanto-occipital joints, and flexion of the cervical column on the trunk. The muscles responsible are the two sternomastoids acting together, assisted by the rectus capitis posterior major and minor.

The effect of neck movement on the spinal cord, the nerve roots and the blood vessels of the cervical spine are described later.

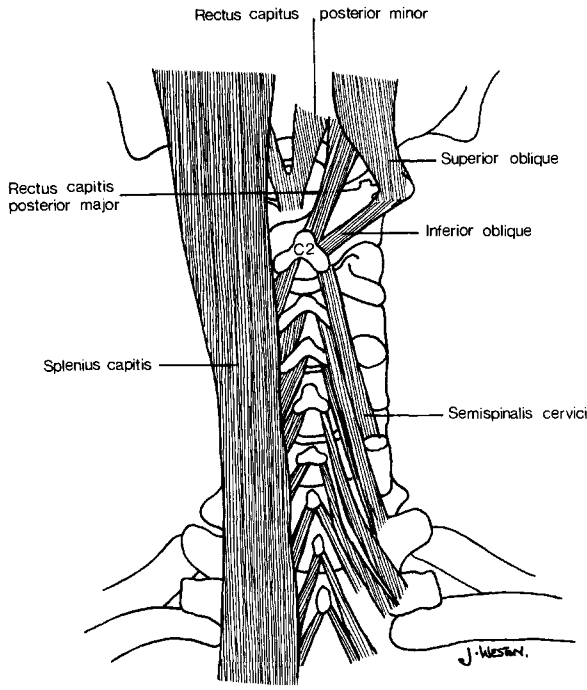

Figure 1.10 The posterior cervical muscles

The muscles acting on the neck, with the exception of those acting on the occipitovertebral complex, span many segments. Some are confined to the neck, some extend from the neck to the trunk, and some are attached to the skull and trunk. They are illustrated in *Figures 1.9* and *1.10*. They are landmarks for the operating surgeon, and their innervation is of diagnostic value to the examining clinician.

THE CERVICAL FASCIA (*Figure 1.11*)

Knowledge of the cervical fascia saves the surgeon from becoming lost in the neck. Deep to the platysma, the investing layer is attached above to the occiput and mandible; below to the clavicle. It splits to enclose the sternomastoid muscle. The prevertebral fascia covers the anterior aspect of the vertebral column and the paraspinal muscles. Between these two sheets, the areolar tissue surrounding structures such as the thyroid, and the neurovascular bundle, is condensed into visceral fascial investments, which can be parted by gentle blunt dissection with the finger. The fascial arrangements are easier to depict than to describe in words, and can be properly appreciated only in the operating theatre.

THE SPINAL CORD AND ITS MENINGES

The cord is invested by the dura, arachnoid and pia mater (*Figure 1.12*). The dura is closely applied to the posterior longitudinal ligament behind the vertebral body, and blends with the membrana tectoria in the foramen magnum. Elsewhere in the spinal canal it is separated from bone by a space containing little extradural fat and an enveloping plexus of vessels, mostly

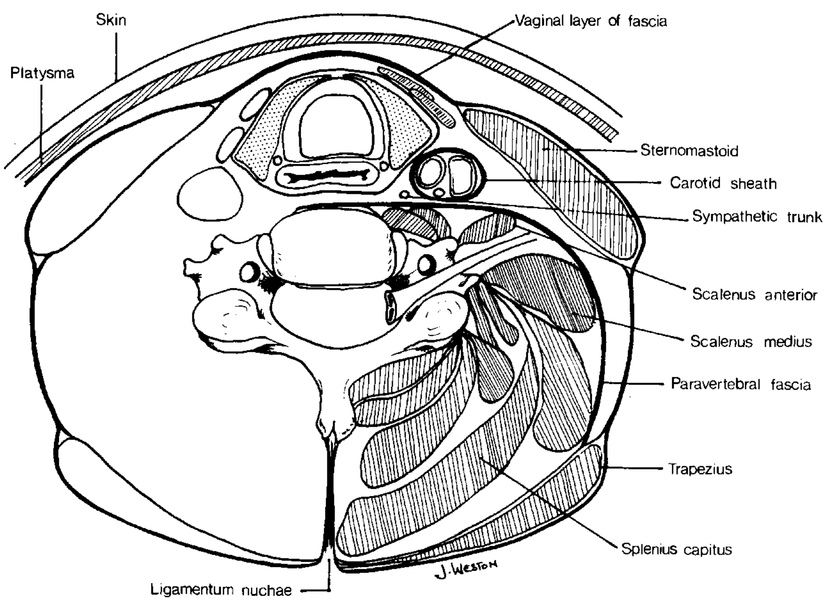

Figure 1.11 Transverse section at the level of C5 showing the arrangement of the cervical fascia

venous. It follows the spinal roots through the intervertebral foramen into the funnel where it blends with the perineurium of the emitting nerve. Here it is also attached, albeit loosely, to the capsule of the apophyseal joint.

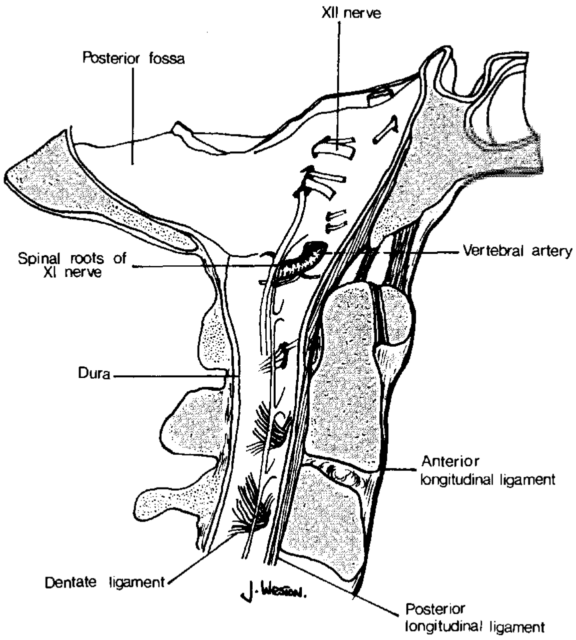

Figure 1.12 Sagittal section of the upper cervical spine showing the interior of the dura

Each dorsal and ventral nerve root penetrates the dura by a separate ostium, so that a dural septum separates each sleeve. These blend into a single envelope just beyond the dorsal root ganglion. Occasionally this penetration, or invagination, of the dura occurs below the relevant foramen, the roots having followed an intradural course of perhaps half a centimetre below. When this occurs the nerve roots, enclosed in their dural sleeves, enter the foramen over its lower edge. The angulation of the roots is at the dural ostia. Such angulation is more common in the lower cervical spine and becomes more frequent with advancing age (Abdullah, 1966; Adams and Logue, 1971; Frykhom, 1951; Reid, 1958; Sunderland, 1974).

The arachnoid is applied to the dura and is invaginated with it by the emerging nerve roots. The pia is closely applied to the cord and roots. The dentate ligament is attached to the arachnoid longitudinally between the dorsal and ventral roots and passes laterally to the dura to which it is fixed by a number of triangular (or tooth-like) processes. After cervical laminectomy, the dentate ligament must be divided if the anterior aspect of the cord is inspected.

When the neck is flexed, the length of the dura equals that of the spinal canal. The canal shortens when the neck extends, and the dura bulges into concertina-like folds (Breig, 1960).

The cervical enlargement of the cord occupies most of the spinal canal except at the level of the atlas. It is oval in cross section, and in addition to carrying much white matter, has a large proportion of grey matter because it gives origin to the cervical and brachial plexuses, as well as accommodating the spinal nuclei of the Vth and XIth cranial nerves (down to the second or third spinal segments). Knowledge of the various ascending and descending tracts in the white matter is of clinical and radiological diagnostic value (*Figure 1.13*).

The cord undergoes elastic deformation during flexion and extension of the neck as the spinal canal alters in length (Breig, 1960). To some extent the cord is tethered by the nerve roots as they enter the intervertebral foramina. The blending of nerve sheath and dura in the foramen forms a similar anchor for the dura (O'Connell, 1955). To the extent that the pia and dura are linked by the dentate ligament, cord and dura deform together, but there is no blending between nerve root and dura in

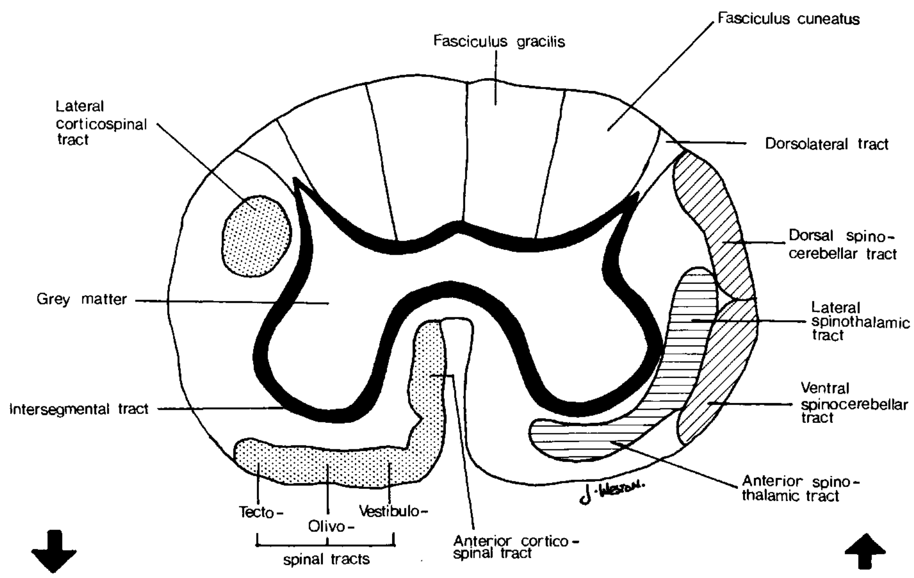

Figure 1.13 Transverse section through spinal cord

the foramen except when there has been adhesive arachnoiditis. The cord has more leeway laterally. Excessive tension on the opposite nerve root (and excessive compression of the ipsilateral vertebral artery) is prevented by the locking mechanism previously described. This delicate balance between freedom and

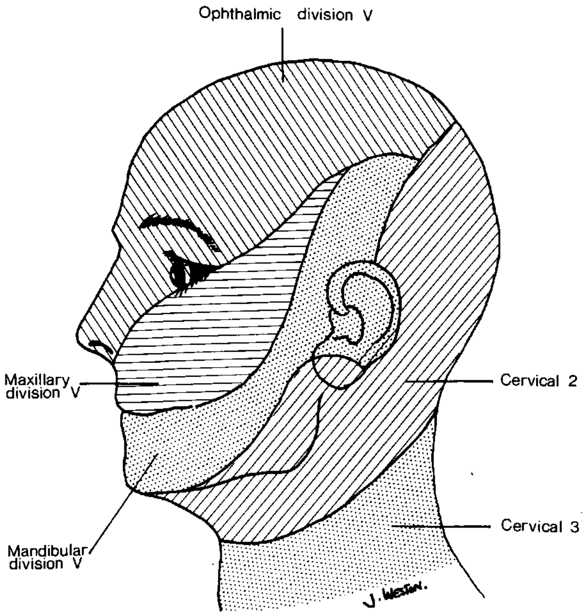

Figure 1.14 Areas of skin supplied by C2 and C3

security can too easily be upset by the altered biomechanics of degeneration or the violence of injury.

The upper three or four cervical nerves contribute to the cervical plexus; the lower five and first thoracic to the brachial.

The first cervical nerve arises above its vertebra, but emerges behind its articular mass. The anterior primary ramus then passes forwards under the vertebral artery. The second cervical nerve also emerges behind the articular mass. All other cervical nerves come out in front of their respective joints. This morphological change has led some anatomists to regard the neurocentral lip of the lower cervical vertebrae as an articular process, and the annular cleft associated with it as a synovial joint 'in series' with the atlanto-occipital and atlanto-axial joints.

The posterior primary rami of the first, second and third cervical nerves are called the suboccipital, great occipital and small occipital nerves (*Figure 1.14*). They convey sensory fibres to the back of the head as far forwards as the vertex of the skull and the angle of the mandible. A vivid description of the area of skin innervated by C2 is given in *Rest and Pain,* and is worth full quotation:

> 'A short time since, a man, who is now undergoing the punishment of penal servitude, attempted to cut his wife's throat. In drawing the razor across her neck, he divided the auricular branch of the second cervical nerve, and gave me the opportunity of ascertaining the distribution of that nerve. My dresser, as well as myself, pricked with a needle over the whole of the auricular surface, and ascertained minutely the precise position of the loss of sensation consequent upon the division of the cervical nerve; whilst the skin which retained its sensation indicated with equal precision the distribution of the fifth cerebral nerve on the external ear.' (Hilton, 1863.)

The dermatomes and muscles innervated by the cervical and brachial plexuses are shown in *Figure 1.15*. The brachial plexus is formed from the roots of C5 to T1. A pre-fixed plexus is formed from the lower five cervical roots; a post-fixed plexus from the lower three cervical and the upper two thoracic roots. The lowest trunk of such a formation is said to be vulnerable to compression by a cervical rib or scalenus medius band. Such an anomaly however has little significance in the analysis of cervical root lesions. Innervation of muscle groups by segments is constant, regardless of which peripheral nerve conveys the axon to its motor endplate.

	Trunk	Shoulder	Arm	Forearm	Hand
C 1	Deep muscles of neck (C1–2)				
2					
3					
4	Diaphragm (C3–5)				
5	Splenius and Scalenus (C3–7)	Rotator cuff and deltoid (C5–6)	Biceps and Brachialis (C5–6)		
6				Extensors and Flexors of wrist (C6–7)	
7			Triceps brachii (C6–8)		
8				Extrinsic extensors and flexors of fingers (C7–8)	
T 1				Rotators of forearm	Small muscles of hand (C8–T1)

Figure 1.15 Segmental innervation of neck and arm muscles