THE INNERVATION OF THE LUMBAR ZYGAPOPHYSIAL JOINTS WITH SPECIAL REFERENCE TO LOW BACK PAIN

By

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in

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" And of the knowledge, you have been given but a little "

THE QUR'AN

' Surat Al-Isra, Chpt.15, V.85 '

Dedicated with gratitude to

my parents

in recognition for

their love, patience

and

tremendous support

ABSTRACT

ABSTRACT

There has been considerable interest recently in the role of the lumbar zygapophysial joints and the structures innervated by the posterior primary rami in the pathogenesis of low back pain, and in the effects of facet joint injections.

Accordingly, the anatomy of the zygapophysial joints of the lumbar region and the posterior primary rami which supply them was studied by microdissection in 28 dissecting room cadavers and a short series of operative specimens. In a further two intact cadavers, injections simulating clinical facet joint injections were carried out.

Our study provides new data on the branching pattern, distribution and course of the posterior primary rami.
The posterior primary rami of L1-4 form medial, intermediate and lateral branches. Each medial branch supplies two zygapophysial joints, the adjacent joint and the joint one level below and ramifies in the multifidus.

The posterior primary ramus of L5 divides into two branches, medial and intermediate.

In one case there was objective evidence of entrapment of the medial branch of the posterior primary ramus of L2 by the mamillo-accessory ligament.

Controversy also exists regarding the innervation of the synovial folds. These intra-articular synovial folds were studied using both histology and immunohistochemistry, to identify PGP 9.5 and Substance P.

The zygapophysial joint capsule has not only been found to be well innervated, but substance P which is associated with nociception, has also been localized in the joint capsule and its synovial folds.

The experiments with facet joint injections in the cadaver suggest that injected material spreads from the joint into the epidural space and the paravertebral muscles.

These results put the diagnosis and treatment of pain arising from the zygapophysial joint on a firmer structural basis.

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PREFACE

PREFACE

The Anatomy Department in Glasgow was involved over a period of 5 years in collaborative research on the stability of the back and the function of the thoracolumbar fascia (TESH, SHAW DUNN & EVANS, 1987).

This research provided specialist museum dissections of the back, and the present investigation was designed to complete the series with dissections of the nerve supply to the joints, ligaments and muscles. A paper on injection of the facet joints read to the Society for Back Pain Research by Lt. Col. C. A. Gauci suggested a clinical interest and with this in mind we consulted Professor G. A. B. Waddell, head of the West of Scotland Back Pain Research Unit in the Western Infirmary, Glasgow.

Professor Waddell introduced us to Dr. Keith Rogers, an honorary clinical lecturer in anaesthetics, who runs a pain clinic at Gartnavel Hospital, Glasgow, who injected the facet joints under fluoroscopic control for the relief of back pain. In discussion with Dr. Rogers we decided that it would be worthwhile to repeat the clinical injection in the cadaver, using similar fluids and volumes, but adding a marker so that at dissection we could trace the structures which had been affected by the injection.

This was not of course a new kind of experiment, and is open to some objections, but it is one of the few methods available in purely human research, and was entirely new to

the particular practitioners involved.

In the X-Ray Department in the Western Infirmary we met Dr. Nigel Raby, a consultant radiologist with a wide military experience, who was familiar with Col. Gauci's work and was himself interested in the treatment of musculo-skeletal disorders, and in facet joint injections. Dr. Roger's and Dr. Raby's techniques were slightly different and it was agreed that a comparison of the anatomical results of the different injections might be informative.

In the initial stages it was hoped that the anatomical results might be correlated with the pattern of pain relief in a series of patients who had received a similar injection in life, but this has not proved possible in the time available.

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ACKNOWLEDGEMENT

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I am indebted to Professor Waddell, Head of the West of Scotland Back Pain Research Unit in the Western Infirmary, for his tremendous help in not only introducing us to this field of research but providing us with fresh surgical material as well.

Special thanks are due to Dr. Keith Rogers and Dr. Nigel Raby for their enthusiasm shown towards our work and for injecting cadavers with the routine 'facet joint injection' technique.

I thank all the technical staff for their excellent help and assistance with charm and sincerity, during my time in this Department.

My sincere thanks also go to Mr. G. Gillespie, who has always been there when I needed him.

I am especially grateful to my wife Rubina and my adorable children Sadia, Sarah and Omran for their patience, co-operation and love.

Above all, I am indebted to my parents for their support throughout my life, especially in respect to education, in particular to my father, whose personal support, encouragement and belief throughout the last three years has made the completion of this thesis a reality. I hope one day I may be able to reciprocate.

I would also like to thank the British Council in Bahrain for their partial support in granting me an Overseas Research Scholarship which covered two years tuition fee.

To anyone else whom I may have missed - Thank You.

Nasir Abdul Latif

DECLARATION

DECLARATION

I hereby declare that this thesis embodies the results of my own original work, that it has been composed by myself and has not been submitted for consideration for any other degree in this or any other University.

Nasir Abdul Latif

GENERAL INTRODUCTION

GENERAL INTRODUCTION:

A) THE CHALLENGE OF LOW BACK PAIN

Low Back Pain (LBP) is an enormous medical, social and economic problem (Kahmann et al., 1990; Stankovic and Johnell, 1990; Waddell, 1990). It is one of the most frequent and incapacitating disorders in our modern society (Nachemson, 1971; Dixon, 1976; Edgar, 1984; Giles and Taylor, 1984; Sedlak, 1985).

Low back pain is the second most frequent cause of being absent from work, next to common cold (Kiernan, 1981; Bronford and Jochumsen, 1984; Lewinnek and Warfield, 1986), and is the third major cause after cardiac and arthritic conditions in patients over 45 years of age (Lucas, 1983; Vukmir, 1991).

The symptoms of backache usually begin in the late 20's. The highest incidence is reached in the late 40's, and there is only a small difference between males and females (Hirsch et al., 1969; Deyo, 1983; Hourigan, 1989; Waddell, 1990).

Although it is estimated that 80 to 88 per cent of people experience low back pain at some time during their adult life (Nachemson, 1971, 1976, 1985; Deyo, 1983; Waddell, 1990; Vukmir, 1991; Giles, 1992), at any one time 46 per

cent of the entire population of the United Kingdom suffers from back pain (Fairbank, 1986), compared to the United States where, more than half of the population suffers from LBP (Frymoyer, 1988).

13.2 million working days per year are lost in Great Britain (Benn and Wood, 1975) and 1400 working days per 1000 workers a year are lost in the United States (Nachemson, 1976; Wiesel et al., 1984) because of low back pain.

It has been estimated that seven million Americans are off work at any particular moment in time because of backache (Fisk and Rose, 1982).

Low back pain has also been labelled as a most expensive disease (Nachemson, 1976). It has been estimated that backache in the United Kingdom costs the nation at least one million pounds per day (Mehta and Sluijter, 1979) or fifteen billion dollars each year in the United States (Haldeman, 1990). In fact, in 1984 more than seven billion dollars were spent on compensation and medical payments in LBP related disorders (Frymoyer and Cats-Baril, 1987).

No wonder, low back pain has been labelled as "the nemesis of medicine" (Frymoyer et al., 1984).

B) DIAGNOSTIC PROBLEMS

In spite of all the effort and money devoted to the diagnosis and management of low back pain, and in spite of its clinical impact, its cause in 80% to 90% of patients remains largely obscure (Nachemson, 1985; Spratt et al., 1990).

Of the 10-20% cases for which a firm diagnosis is available, a large proportion is attributed to prolapse of the intervertebral disc described by Mixter and Barr (1934), which may cause local pain and also direct irritation to the spinal nerves. Many investigators confirm this pathology (Taylor and Akeson, 1971; Hazelett, 1975; Maroon and Onik, 1992).

On the other hand, herniated lumbar discs could often be asymptomatic, especially when the diameter of the spinal canal is not affected (Bassam, 1990).

However, several other authors believe that disc lesions have been over emphasized as being the main sources of low back pain, thus ignoring the pathology of the zygapophysial joints with their related ligaments and muscles which are supplied by the posterior primary rami (Putti, 1927; Macnab, 1977; Bogduk, 1980a; Yang and King, 1984).

Some authors have in fact, focused their particular interest on the zygapophysial joints (Hirsch et al., 1963; McCall et al., 1979; Bogduk, 1980; Fairbank et al., 1981; Paris, 1983; Lynch and Taylor, 1986; Cavanaugh et al., 1989; Giles, 1984).

It is currently thought that if a patient is complaining of tenderness in the lower back, muscle spasm, and LBP referred to the back of the thigh, to the mid-calf and/or the ankle, this pain is none the less, originating from zygapophysial joints (Kirkaldy-Willis, 1983; Giles, 1992). Alleviation of zygapophysial joint pain by injecting local anaesthetic and/or steroid into the joint, under fluoroscopic control does support this diagnosis (Mooney and Robertson, 1976; Carrera, 1980; Maldague et al., 1981; Fairbank et al., 1981; Destouet et al., 1982; Carrera and Williams, 1984; Lau et al., 1985; Lewinnek and Warfield, 1986; Lynch and Taylor, 1986; Jackson et al., 1988; Warfield, 1988; Marks, 1989).

The continued interest shown in the recent years by epidemiologists, rheumatologists, bioengineers, pathologists, anatomists and other biomedical researchers in low back pain, not only reflects the magnitude of this problem, but also shows lack of definitive solutions as well (Harvey, 1980). What causes the zygapophysial joints to become painful, remains a mystery (Bogduk, 1992a).

C) LIMITATIONS OF INVESTIGATIVE METHODS

Taking plain x-rays of the zygapophysial joints is not easy, because only one plane of the curved articular surface presents itself tangentially to the x-ray beam (Reichmann,

1973; Park, 1980). Porter (1991) emphasizes that routine plain radiographs of the lumbar spine do not often provide diagnosis for back pain. There is also sometimes a discrepancy between the degree of pain and the severity of radiographic changes. Degenerative changes in the vertebral disc and the vertebral bodies is a very common radiographic finding in the middle-aged and older people, but is often asymptomatic (Isherwood and Antoun, 1980; Bassam, 1990).
Bassam (1990) in fact, indicates that the soft tissue involvement is the most common cause of low back pain, which does not show on radiographs.

Butt (1989), quoting numerous studies, shows that the plain radiographic findings of degenerative disc disease are as common in patients who have had no symptoms of backache as they are in patients with low back pain. In fact, Magora and Schwartz (1976) suggest that degenerative changes are more frequent in patients who have never had low back pain.

Degenerative changes in the zygapophysial joints are often seen in x-rays, but that does not necessarily mean that the patient is complaining of pain.
Mehta and Sluijter (1979), suggest that the zygapophysial joint capsules could well be the source of pain, and not the bone itself.

In quite a number of people suffering from low back pain, the computed tomography (CT) and magnetic resonance (MR)

imaging do not reveal the actual cause of pain.
The nerve compression, for instance, which is due to bulging of the intervertebral disc and thickening of ligamentum flavum, may resolve when the patient is supine for imaging (Nowicki et al., 1990).

Many spinal structures probably play a role in pain production, and in fact, all innervated structures in the motion segment are possible sources of pain production (Nachemson, 1985).

D) INNERVATION OF THE ZYGAPOPHYSIAL JOINTS

The current revival of interest in the role of the posterior primary ramus in pain production came after introducing three new procedures in treating low back pain. "Rhizolysis" by an Australian physician, Rees in 1971, "Facet Denervation" by Shealy in 1974, and "Lumbar Medial Branch Neurotomy" by Bogduk in 1982.

All of the three procedures aimed at the zygapophysial joints as sources of pain. Therefore, denervating these joints was thought to be indeed an appropriate form of therapy.
"Rhizolysis" was a procedure performed under local anaesthesia to destroy the nerve supply to the lumbar

zygapophysial joints by using a special knife.

"Facet Denervation" was devised to carry out the same procedure but by using a coagulating electrode.

"Lumbar Medial Branch Neurotomy" was devised basically as a modification of "Facet Denervation" which was meant to divide the medial branch of the posterior primary ramus.

Although the principles behind both the first and second procedures are quite clear, but unfortunately neither of these was introduced with an accurate description of the relevant anatomy. The third procedure by which division of the medial branch took place, not only denervated the zygapophysial joints, but other structures as well, notably the multifidus muscle.

"Facet Joint Injections" are currently used under fluoroscopic control, both extra-capsular or intra-capsular with local anaesthetic and steroid to relieve pain originating from the zygapophysial joints.

E) OBJECTIVES OF THE STUDY

In order to achieve our goal, the following objectives have been formulated:-

1. Confirm the anatomy of the lumbar zygapophysial joints.
2. Investigate the innervation of the lumbar zygapophysial joints.
3. Perform histological examination to confirm the presence and location of nerves and nerve endings in the joint capsule and its synovial folds.
4. Assess the anatomical effects of the injection treatment of low back pain involving the zygapophysial joints.

CHAPTER I

LITERATURE REVIEW

The main objective of this literature review is to provide a detailed critical review of the zygapophysial joints and related structures.

1.1 ANATOMY OF THE LUMBAR SPINE

1.1.1 INTRODUCTION

The human vertebral column is a unique and remarkable structure, consisting of several parts seen as an integrated unit (Hilton, 1980).
It not only combines qualities of strength but flexibility as well (Taylor and Twomey, 1980).

The lumbar spine in an average adult male is 18 centimeters in length (Koreska et al., 1977), consisting generally of five lumbar vertebrae. Hippocrates (460-377 BC) was apparently the first to mention the number of vertebrae in man, and Galen (150-200 AD) was the first to describe correctly the number of vertebrae in the various spinal segments (Shapiro, 1990).
Each vertebra is composed of two main parts; anteriorly the

vertebral body and posteriorly the vertebral arch and its processes, enclosing the vertebral foramen. The vertebral body is composed of trabecular bone enveloped by a thin layer of compact bone. The vertebral arch extends posteriorly from the body and consists of two short, stout pedicles which project backward, and two broad, flat laminae merging at the midline. They close the vertebral foramen by uniting in the median plane where the spinous process arises. The two short pedicles are very strong and extend posteriorly from each side of the vertebral body to form the beginning of the vertebral arch. The upper surface of the pedicle has a shallow indentation and the lower surface is deeply indented to form the superior and inferior vertebral notches. When an upper notch of one vertebra is aligned with the lower vertebral notch of the next vertebra, they form together an intervertebral foramen.

The laminae, which are broad, strong plates join the pedicles from the posterior end forming the vertebral arch,complete the closure of the vertebral canal by fusing with each other at midline.

Several bony projections, referred to as processes, arise from the junction of the lamina with the pedicles (transverse, articular, mamillary and accessory processes), and one from the junction of the two laminae (spinous process). 'see figure 1.1'

FIGURE: 1.1

Lumbar vertebra: postero-superior aspect, viewed obliquely from the left side.

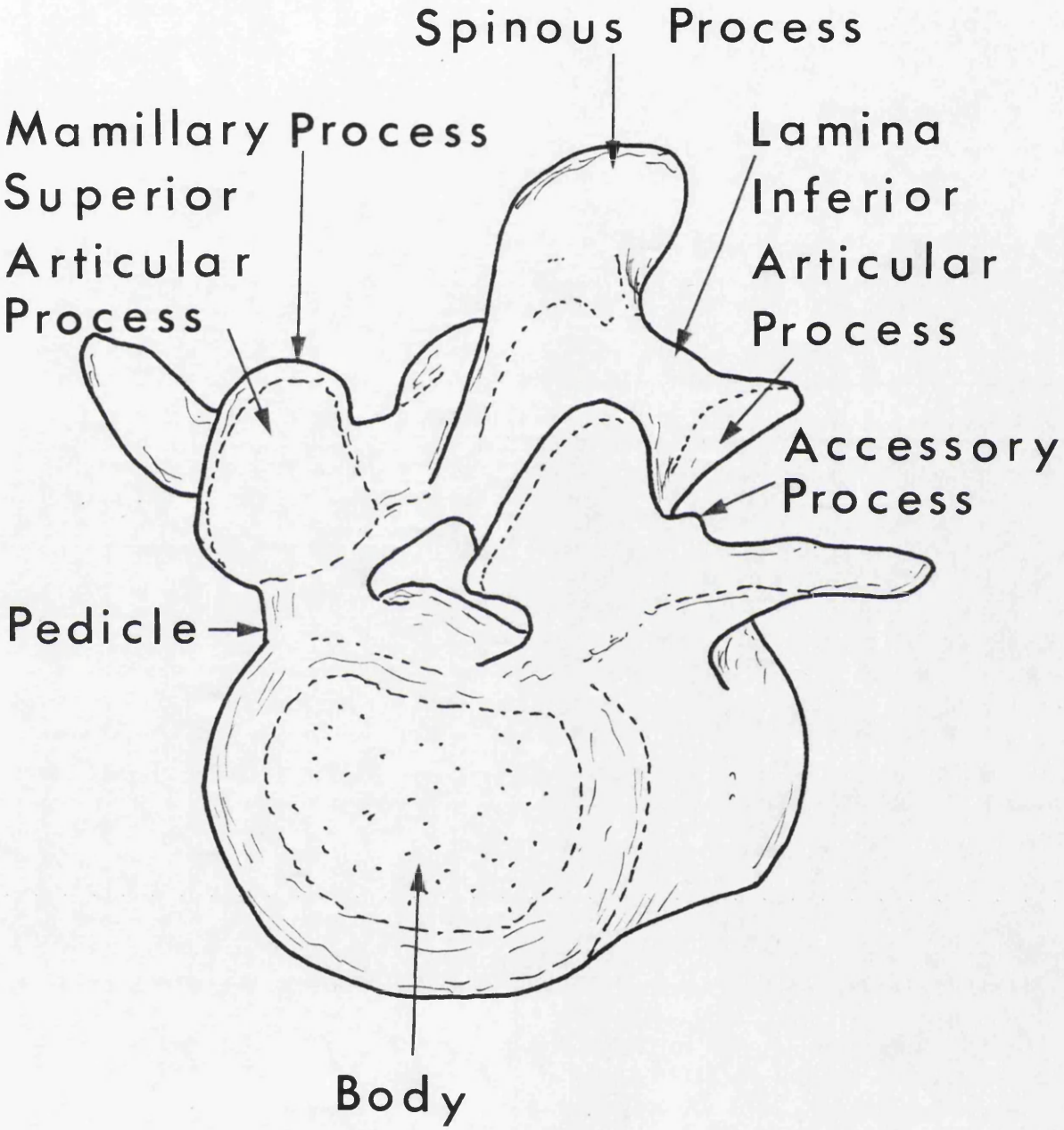

Spinous Process
Mamillary Process
Superior
Articular
Process
Lamina
Inferior
Articular
Process
Accessory
Process
Pedicle
Body

Figure 1-1

1.1.2 THE MOTION SEGMENT

The anatomical unit of the spine is its vertebra. Lewin et al.(1962), and Hirsch et al. (1963), called the basic anatomical and functional unit of the vertebral column the articular triad.

The three-joint complex '(figure 1.2)' (Yong-Hing and Kirkaldy-Willis,1990), is part of the motion segment. It consists of two vertebrae, three joints (two zygapophysial joints and one intervertebral joint) and the soft tissue structures like joint capsules, ligaments and muscles.

The intervertebral disc forms the primary articulation between the vertebral bodies. Until recently, the intervertebral discs were said to be the "largest avascular structures in the human body" (Nachemson, 1985; Pope, 1989). Dixon (1973) said, "discs contain no pain nerve endings, so cannot hurt". But Bogduk (1991), claims that the outer third of the intervertebral discs is innervated, and since the disc serves to sustain compression loads and is subject to tension and shear, it can be a source of pain.
A detailed review of the intervertebral disc will not be carried out, as this thesis is mainly concerned with the anatomy and innervation of the posterior structures only.

FIGURE: 1.2

The motion segment.
For example, L3 & L4 may be referred to as the L3-4 segment.

The arrows show the limited movement of the vertebrae.

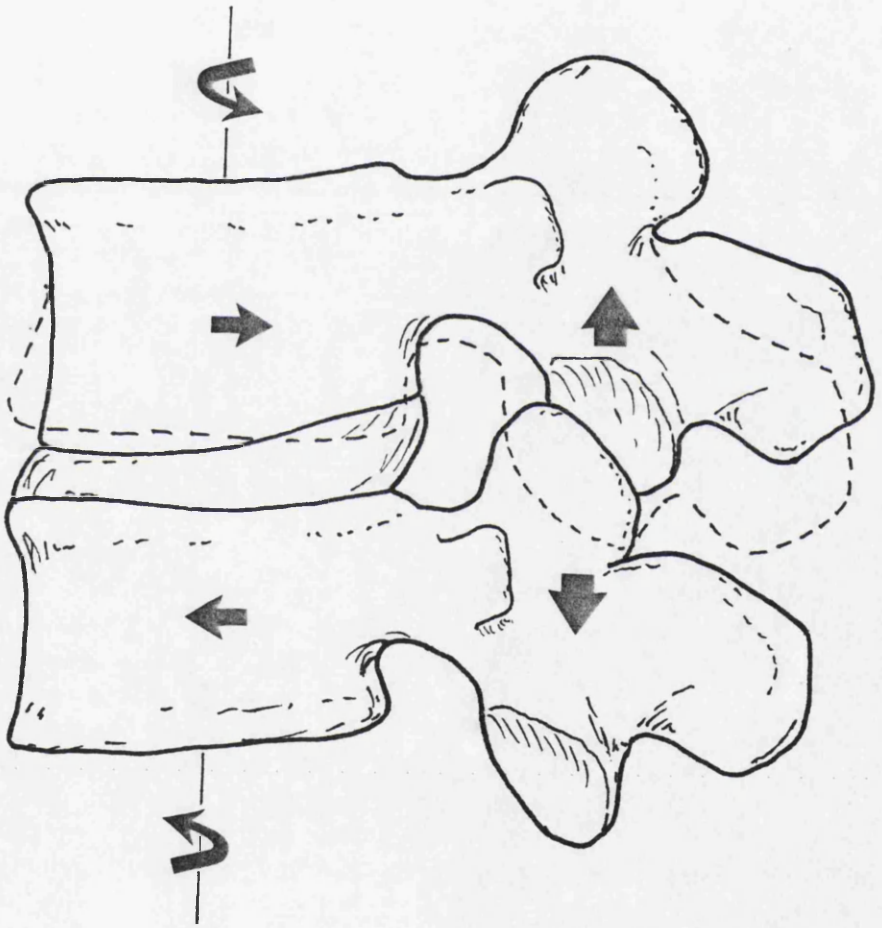


Figure 1-2

1.1.3 THE JOINTS BETWEEN THE VERTEBRAL ARCHES

The joints between the vertebral arches are formally known as the "zygapophysial joints" (Nomina Anatomica, 1989). Other names which are also used are "apophysial joints" and "facet joints". Although 'Facet' joint has become quite popular because of being short, but since every small joint has a facet, I personally feel that the official term "Zygapophysial Joint" should be used.

The zygapophysial joints lie postero-lateral to the lumbar spinal canal and posterior to the intervertebral foramina. They are obliquely oriented to the sagittal plane. This obliquity does vary occasionally from one side to the other, leading to tropism or joint asymmetry (Lippitt, 1984).

A prominence of variable size at the dorsolateral surface of the superior articular process, is called the mamillary process. A second bony prominence at the dorsal surface of the transverse process, near its junction with the superior articular process is called the accessory process. Between the mamillary and accessory process is a fibrous band, called the mamillo-accessory ligament (Bogduk, 1981), which forms a tunnel through which passes the medial branch of the posterior primary ramus, as well as some small blood vessels to the posterior paraspinal muscles (Farfan, 1973).

The mamillo-accessory ligament is occasionally ossified rather than being fibrous (Bogduk, 1981).'see figure 1.3'

1.1.4 THE SPINAL CANAL

The lumbar spinal canal is almost triangular in shape (Eisenstein, 1980). The diameter of the canal could be measured by plain radiographs of the lumbar spine (Eisenstein, 1977).

Seen in cross section, the canal becomes wider from L1 to L5, and nearly triangular or trefoil in shape (Giles, 1989).

Eisenstein (1980), concludes that the trefoil configuration is a common non-pathological variation which is not dependent or related to increase in age, osteophytosis or spinal stenosis.

Smith et al. (1993) used computerized tomography to measure vertebral canal dimensions. They concluded that although the 3D CT does provide qualitative images of the path of the nerve root canal, it underestimates the true foraminal dimensions and therefore cannot be recommended for quantitative measurement.

FIGURE: 1.3

An oblique view of the postero-superior aspect of the lumbar vertebra showing the mamillo-accessory ligament.

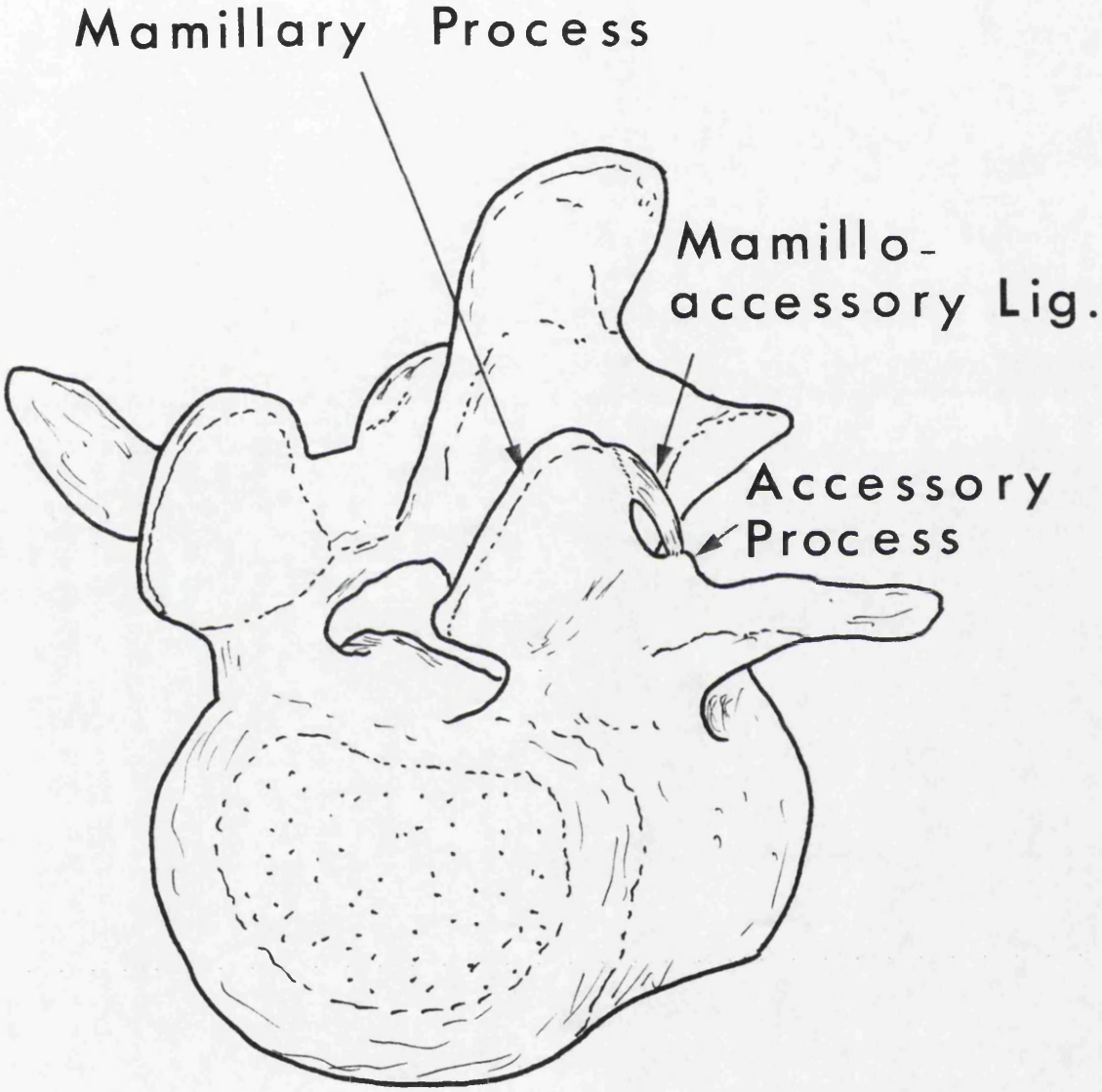

Mamillary Process
Mamillo-
accessory Lig.
Accessory
Process

Figure 1-3

A narrow vertebral canal, according to Kirkaldy-Willis et al.(1974) and Naylor (1979), could be acquired by the development of osteophytes from the zygapophysial joints or the intervertebral discs.

1.1.5 THE INTERVERTEBRAL CANAL

The intervertebral foramen has long been recognized as a prime source of back pain (Hadley, 1935). Anatomically, it is bounded from above and below by the vertebral pedicles. Its posterior wall is from above downwards, formed by the postero-inferior margin of the superior vertebral body, the intervertebral disc, and the postero-superior margin of the inferior vertebral body. The ligamentum flavum, at the outer free edge, the pars interarticularis (part of lamina that intervenes between the superior and inferior articular processes on each side) and the zygapophysial joint posteriorly form the roof of this foramen (Crock, 1981).

Although the standard anatomical text-books such as Gray's Anatomy (Williams et al., 1989), Cunningham's Textbook of Anatomy (Romanes, 1981), and Clinically Oriented Anatomy (Moore, 1992), use the term "intervertebral foramina" to describe both the osseous nerve root canals and their both medial and lateral "openings", more recently with increasing appreciation of the functional pathology, the foramen has

been seen as a limiting description and that of a canal as a more appropriate one.

The foramen contains antero-superiorly the nerve root and the sinu-vertebral nerve, and scattered sympathetic fibres. In addition, it contains intervertebral arteries and veins as well as numerous small lymphatic vessels that traverse the fatty areolar network that fills the foramen (Golub and Silverman, 1969).

Ligaments within the neural foramina, reduce the space available for nerve roots. They are therefore, seen as possible contributing factors to nerve root compression or entrapment (Nowicki & Haughton, 1992). Bulging of the intervertebral disc and thickening of the ligamentum flavum has been implicated in causing nerve root entrapment or impingement (Rauschning, 1987; Nowicki et al., 1990)

1.2 ANATOMY OF THE LUMBAR ZYGAPOPHYSIAL JOINTS

1.2.1 INTRODUCTION

While there has been a plethora of articles devoted to the intervertebral disc, the same cannot be said about the zygapophysial joints.

The role of the lumbar zygapophysial joints was first proposed by Goldthwait (1911), who turned the attention to these joints as being a source of pain by stating that "the peculiarities of the facet joint" were responsible for low back pain and instability (Jackson et al., 1988). Goldthwait had a patient whom he treated with manipulation under ether, but the patient developed a flaccid paralysis of both legs with disturbance of the genito-urinary system and rectum. A laminectomy was performed by Harvey Cushing who did not find any lesion of the cauda equina except for "narrowing of the osseous canal at the lumbosacral junction". Goldthwait, in reviewing the various possible causes, dismissed tumor, hemorrhage and spondylolisthesis and concluded that the posterior displacement of the lumbosacral disc, with pressure on the cauda equina, was the logical explanation. This accident then stimulated his considerable anatomical studies into the concept of the unstable lumbosacral junction, as being more prone to sublux. This was later reinforced by Putti (1927).

Ghormley (1933), stated that "to anyone who studies the skeleton, the vertebrae particularly, and their anatomy, the importance of articular facets must be obvious". He regarded the articular facets as true joints, and concluded that degenerative changes in the articular cartilage and constant pressure on the facets may well be a source of pain. He coined the term "facet syndrome".

1934 led to the birth of "dynasty of the disc" when Mixter and Barr's paper was published on the rupture of the intervertebral disc, which overshadowed the role of the zygapophysial joints in low back pain for many years.
The pendulum was somewhat shifted away from the disc when Badgley (1941), emphasized the importance of the zygapophysial joints in low back and leg pain. He thought that 80 per cent of low back and sciatica were on the basis of referred pain and not on the basis of direct nerve irritation. He suggested that irritation of the capsule of the lumbar articular facet stimulates its sensory innervation to produce pain.

Hirsch in 1963 was the first to demonstrate that low back pain could be produced by injecting hypertonic saline into the zygapophysial joints (Hirsch et al., 1963).

Pedersen et al. (1956), presented their paper suggesting that the posterior primary rami contained pain fibres and that stimulation of the joint innervated could give rise to low back pain.

The zygapophysial joints did not get exceptionally much of an attention until an Australian surgeon Rees, made some far-fetched claims for his facet rhizotomies (Rees, 1971,1975). These extra-ordinary claims gathered attention of Shealy (1975), Mooney and Robertson (1976), to study the joint from the clinical aspect, and Bogduk (1980b) from its

anatomical aspect with clinical implications.

As a result of these studies we reached to the stage where it is recognized that the zygapophysial joint has a multiple level innervation, and stretching of the capsule of these joints could elicit back pain.

Therefore, the zygapophysial joint has indeed emerged as a significant structure in the production of low back pain.

1.2.2 THE ZYGAPOPHYSIAL JOINTS

The lumbar zygapophysial joint is a synovial joint formed by the convex laterally facing inferior articular process of the vertebra above, and the concave medially facing superior articular process of the vertebra below (Hadley, 1961; Lippitt, 1984; Taylor and Twomey, 1986).' see figure 1.4 '

Like other synovial joints, the zygapophysial joint has an articular cavity, surrounded by a capsule and lined by articular cartilage on the articular surfaces, with a synovial membrane bridging on the margins of the articular cartilages of the two facets in each joint (Bogduk and Twomey, 1991).

FIGURE: 1.4

A lateral view showing the formation of the zygapophysial joint between two vertebrae.

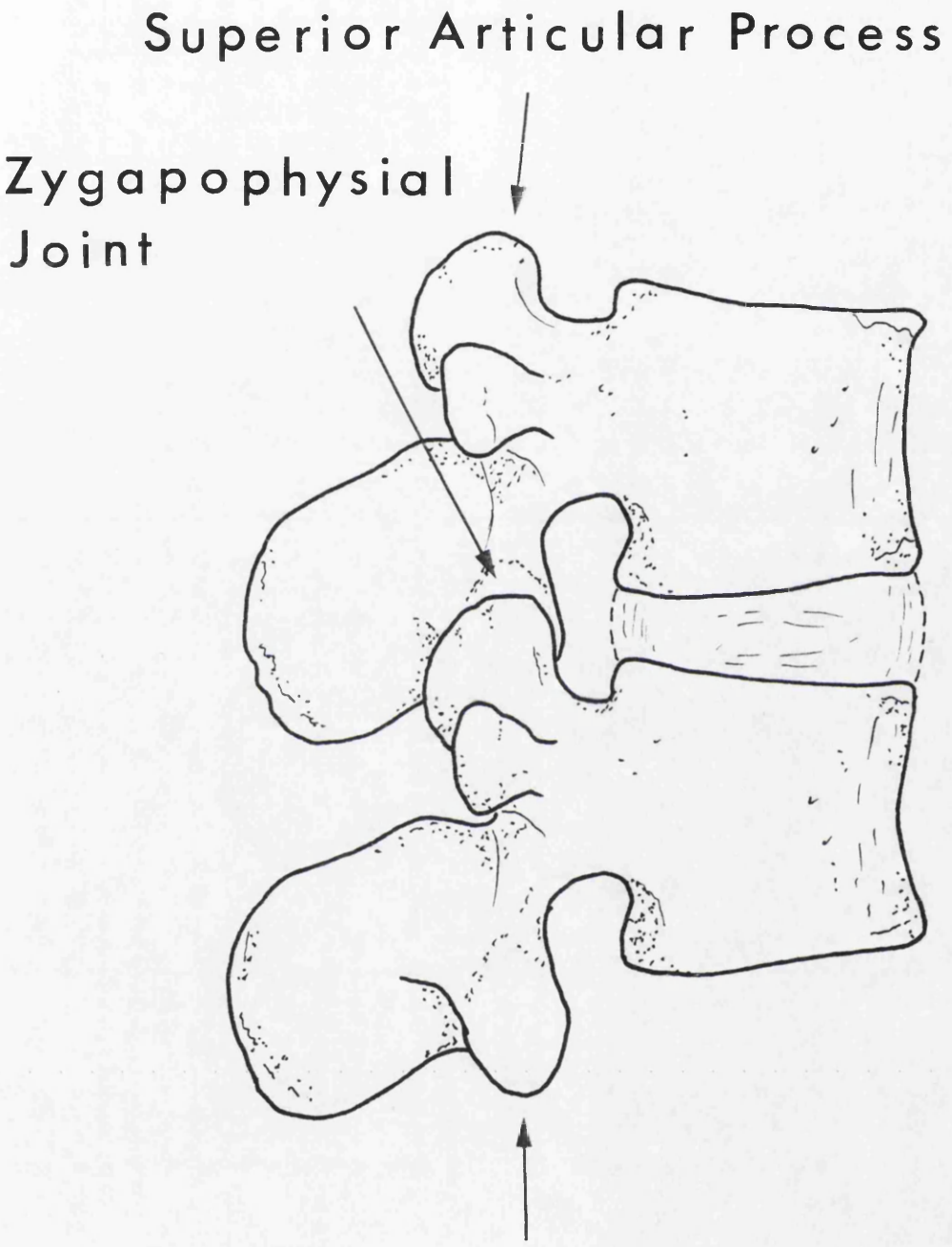

Superior Articular Process
Zygapophysial Joint
Inferior Articular Process

Figure 1-4

1.2.3 ARTICULAR CARTILAGE OF THE ZYGAPOPHYSIAL JOINTS

The articular cartilage covers the facets of both the superior and inferior articular processes, and assumes the same concave or convex curvature as the underlying facet '(figure 1.5)'. It essentially provides a wear resistant, low friction, lubricated surface for ease of movement over a similar surface but able to accommodate the enormous forces of compression generated during weight-bearing and muscle action (Williams et al., 1989).

Putti (1927), measured the joint surfaces as being 8mm to 10mm across and 9mm to 11mm vertical.
In a normal joint, the cartilage is thickest over the centre of each facet, rising to a height of about 2mm (Bogduk and Twomey, 1991).

Normal adult cartilage is composed of approximately 75 per cent water and 25 per cent solids (Brower and Hsu, 1969).
It is said to be an aneural and avascular tissue (Ghadially, 1981), except at its periphery (Stockwell, 1979). Kellgren and Samuel (1950), found that the articular cartilage gave rise to no sensation when stimulated.
The articular cartilage is neither covered by perichondrium nor by synovial membrane (Ghadially, 1981).

The cartilage as a whole, serves to transmit loads and allows repetitive joint motion without any breakdown

(Fulkerson et al., 1987).

The articular cartilage as noted by Hadley (1961), is reflected around the bone ends well beyond the limits of bony contact on the posterior aspect of the inferior articular process. This is possibly related to the pressure and friction of the joint capsule over the articular process. It is like the situation at the knee where cartilage is present on the non-articulating medial aspect of the femur deep to the medial ligament.

1.2.4 CAPSULE OF THE ZYGAPOPHYSIAL JOINTS

Each zygapophysial joint is enclosed by a fibrous capsule from its dorsal, superior and inferior margins (Bogduk, 1991). Antero-medially, the capsule is reinforced by ligamentum flavum . This makes these joints unique, as they differ from other synovial joints (Hirsch et al., 1963). The fibrous capsule is to some extent loose from above and below where it forms the superior and inferior recesses filled with small synovial "fat pads" (Lewin et al., 1962).

The joint capsule is thick dorsally, and is reinforced by some deep fibres of the multifidus muscle (Heylings, 1978; Taylor and Twomey, 1986).

The fibrous capsule consists of an **outer** or **peripheral portion** of strong, dense fibro-elastic connective tissue layer continuous with the periosteum of bone, and a **middle vascular fatty layer** of subsynovial loose connective tissue. A **synovial membrane** which lines the non-articular margins of the synovial cavity and participates in the production of the synovial fluid, is also present (Giles et al., 1986). The sensitivity of the joint capsule and its response to pain appears to be in the fibrous portion. The evidence of having receptors and nerve plexus as well as recording pain sensation under mechanical or chemical stimulation, supports this observation (Cavanaugh et al., 1989).

1.2.5 THE LIGAMENTUM FLAVUM

The ligamentum flavum is a short, paired, 2-10mm thick ligament (Giles and Taylor, 1984), that joins the laminae of consecutive vertebrae. It lies immediately behind the spinal canal (Bogduk and Twomey, 1991), adjacent to the nervous structures within the canal 'see figure 1.6'.

According to Yong-Hing et al. (1976), the ligamentum flavum histologically consists of 80 per cent elastin and 20 per cent collagen fibers.
Because of its elastic nature, it is said be in a position not only to restore the flexed lumbar spine to its extended

FIGURE: 1.6

A mid-sagittal section showing the ligamentum flavum and related structures.

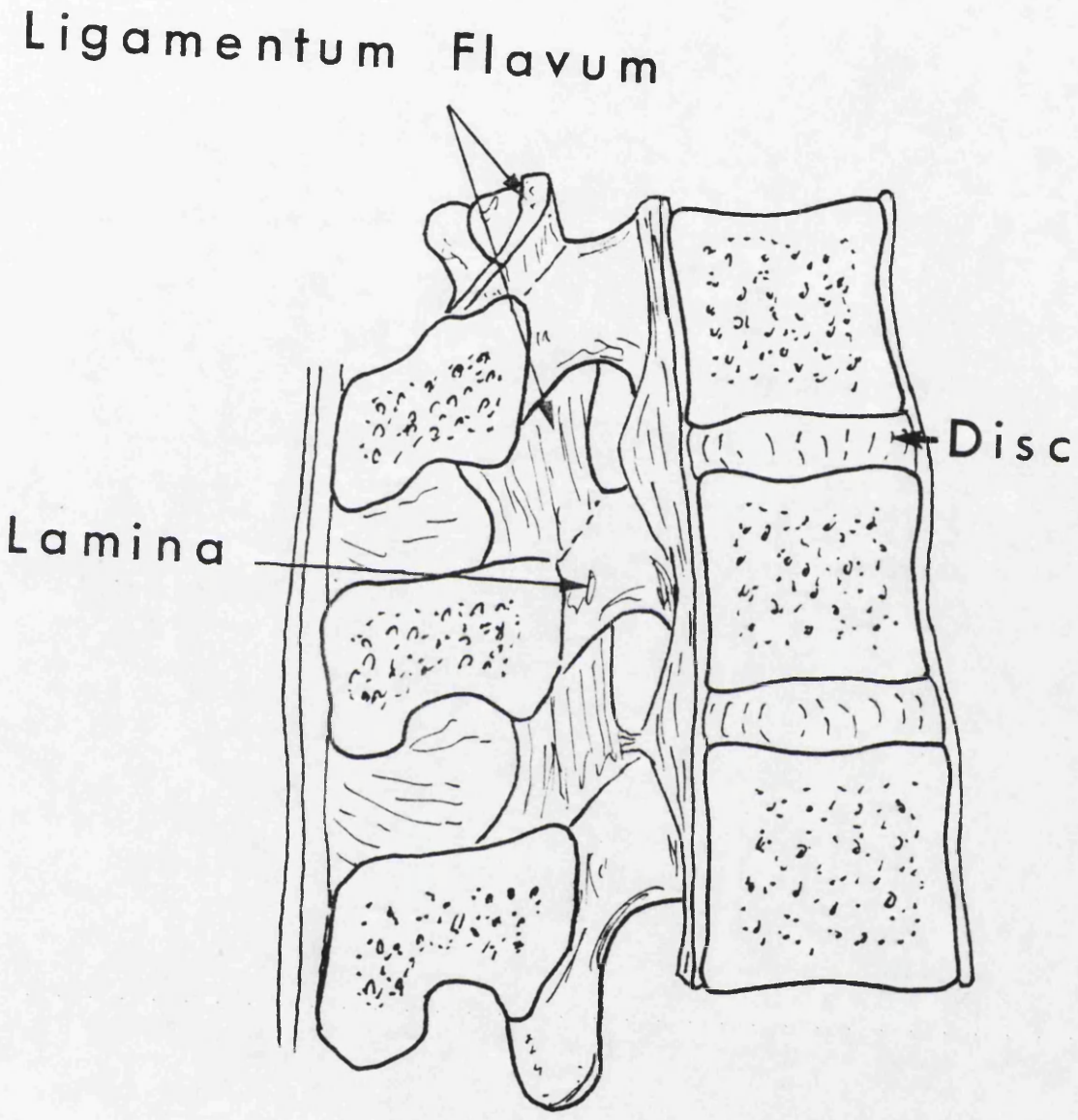


Figure 1-6

position by restoring the articular surfaces to their normal position, but serves to prevent the anterior capsule of the zygapophysial joint from being nipped between the articular surfaces during movement as well (Bogduk and Twomey, 1991).

The main function of the ligamentum flavum is probably to provide a smooth covering for the posterior part of the spinal canal in all positions of the spinal column (Rolander, 1966).

1.2.6 THE MULTIFIDUS MUSCLE

The multifidus muscle is the most medial among the lumbar back muscles (Macintosh et al., 1986; Bogduk and Twomey, 1991).

The standard textbooks of Anatomy like Cunningham's (Romanes, 1981) and Gray's (Williams et al., 1989) describe the multifidus under the transverso-spinalis system, as arising from the dorsal surface of the the sacrum, the posterior sacro-iliac ligaments, and the mamillary processes, and being inserted into the spines of all the vertebrae. But Macintosh et al. (1986), describe this muscle as a spino-transverse muscle which consists of a repeating series of fascicles that stem from the laminae and spinous processes of the lumbar vertebrae and insert into the

mamillary process of the vertebrae two segmental levels lower.

Since L5 laminar fibres have no mamillary process for insertion, instead these fibres are inserted on the sacrum above the dorsal sacral foramen (Bogduk and Twomey, 1991).

The posterior zygapophysial joint capsule and its recesses are covered by the multifidus muscle (Lewin et al., 1962; Hirsch et al., 1963; Bogduk, 1979).

A "common tendon" (Bogduk and Twomey, 1991), arises from the caudolateral edge of the spinous process to be attached at the mamillary processes, the iliac crest and the sacrum. Thus, fascicles from L1 spinous process are inserted into L4 mamillary process, while those from the common tendon are inserted into the mamillary processes of L5, S1 and posterior superior iliac spine. Some of the deeper fibres are attached to the capsule of the zygapophysial joints (Lewin et al., 1962).

This attachment (Bogduk and Twomey, 1991), allows the multifidus muscle to protect the joint capsule from being caught inside the joint during the movements executed by the multifidus.'see figure 1.7'

FIGURE: 1.7

Schematic illustration of the multifidus muscle fascicles seen as:

A = under transverso-spinal system

B = as a spino-transverse muscle

m medial branch of the posterior primary ramus

MP mamillary process

SP spinous process

From: Macintosh et al. (1986)

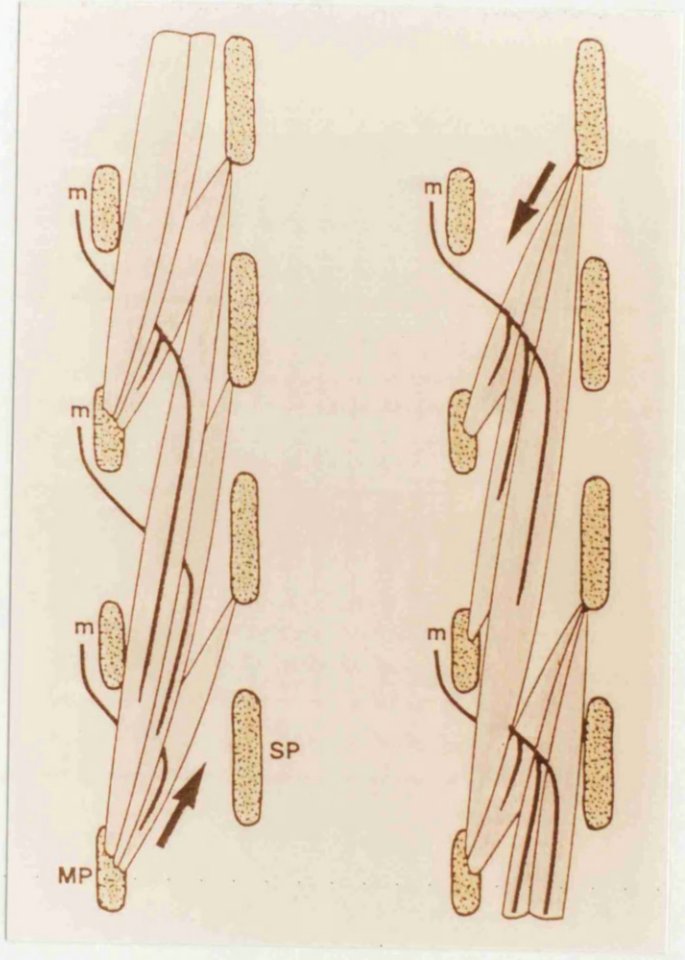


Figure 1-7

1.2.7 FUNCTION OF THE ZYGAPOPHYSIAL JOINTS

Function of the zygapophysial joints, as Adams and Hutton (1983) explain, is to allow limited movement between the vertebrae and to protect the discs from shear forces, excessive flexion, and axial rotation. In addition, they also stabilize the spine (Pope, 1990).
Any injury or surgical procedure that effectively removes the protective action of these joints, will fundamentally alter the mechanics of the lumbar spine and can thus lead to low back pain (Pope, 1990).

Hakim and King (1976), made an indirect measurement of facet load by using an intervertebral load cell to determine the disc load from which they were able to deduce the facet load.

Lorenz et al. (1983), inserted a pressure-sensitive film between the articulating surfaces of the two facets prior to load application. The motion segments were tested before and after removal of the left facet.
Their results indicate the existence of facet load. However, this load is seen as a representation of a transverse contact force rather than a vertical force transmission.

Yang and King (1984), postulated that the transmission of facet load ocurred through bony contact between the tip of the inferior facet with the lamina below. They found that

normal facets carry 25 per cent of the recumbent body weight. The facet load may in fact increase to as high as 47 per cent of the total axial load.
They also found that over-loading of the zygapophysial joint resulted in rearward rotation of the inferior facet, the tip of which pivoted about the lamina below and stretched the capsule in an unnatural manner.

The facet load transmission has been verified by El-Bohy et al.(1989), by using a direct measurement of the facet tip contact pressure. Their results support the hypothesis of Andersson (1983) who stated that the load applied to the lumbar spine is normally shared between the zygapophysial joints and the intervertebral discs.

Yang and King (1984), found that the zygapophysial joint capsule undergoes significant stretch when the spine is loaded. This observation was later confirmed by El-Bohy et al.(1989). They found that the stretch was larger in extension than flexion.

1.2.8 STRUCTURE AND FUNCTION OF THE ZYGAPOPHYSIAL JOINT SYNOVIAL FOLDS

The synovial folds of the lumbar zygapophysial joints have long been a source of interest and controversy, although not

being described in many modern textbooks of anatomy.

These intra-articular synovial folds are seen in various shapes and sizes, having numerous small blood vessels in fibrous connective and adipose tissue, have been described in all the zygapophysial joints (Hadley, 1961; Giles and Taylor, 1982), being best developed in the lumbar region.

Mainly two types of these intra-articular structures have been demonstrated.

a) adipose tissue pads covered by synovium that filled the subcapsular pockets at the superior and inferior poles of the joint (Engel and Bogduk, 1982).

b) dense, fibrous, intra-articular synovial protrusion projecting from the joint capsule into the upper medial part of the joint (Giles and Taylor, 1982).

A third type has also been described as a connective tissue rim, seen as an internal thickening of the capsule which does not enter between the articular surfaces (Bogduk and Twomey, 1991).

These intra-articular synovial folds are often referred to as meniscoids or menisci (Bogduk and Engel, 1984).

Confusion exists regarding the histology of these synovial folds. "Areolar synovium" is perhaps adapted for lubrication and better movement, whereas "fibrous synovium" is seen in areas of strain (Schumacher, 1975). The free irregular margins of these synovial folds (Hadley, 1964), could be

quite long and thin.

Intra-articular synovial folds are a constant feature of the lumbar zygapophysial joints (Giles and Taylor, 1982). They are not artifacts of fixation, for their form, histology, extent and position vary with age and the lumbar vertebral level. Since these intra-articular synovial folds extend between the articular surfaces, and since the lumbar zygapophysial joints accept a proportion of body weight, therefore these synovial folds are vulnerable to being nipped between the joints (Giles and Taylor, 1982). They are also seen as "space-fillers" that allow lubrication.

1.3 ANATOMICAL STUDIES OF THE POSTERIOR PRIMARY RAMI

1.3.1 INTRODUCTION

The posterior primary rami have not been given a great deal of attention in the standard textbooks of Anatomy.
They are described, but not in a suitable detail to support any diagnostic or surgical procedure.

Gray's Anatomy (1989), offers the following description:
"Lumbar dorsal rami pass back medial to the medial intertransverse muscles, dividing into medial and lateral branches. Medial branches run near the vertebral articular

processes to end in the multifidus; they are related to the bone between the accessory and mamillary processes and may groove it, traversing a distinct notch or even a foramen. Lateral branches supply the erector spinae (sacrospinalis)". Innervation of the zygapophysial joints from the medial branch of the posterior primary ramus has been completely ignored.
Cunningham's Textbook of Anatomy (1981), does not mention the distribution of the medial branch at all.

According to Etemadi (1963), Griffith and Oliver's paper (1890), seems to be one of the early investigations on the posterior primary rami, both of whom noted the origin of these nerves in relation to their distribution on the skin of the back. Johnston (1908) and Etemadi (1963), studied the detailed cutaneous distribution of the lateral branches, thus confirming the textbook descriptions.

Badgley (1941), requested Professor McCotter and Dr. Strong to dissect the lumbar nerves, as the anatomists of the time began to consider the posterior primary divisions of the spinal nerves to be innervating the zygapophysial joint capsules. The outcome of their dissection revealed that although the medial branch of the posterior primary ramus ran very close to the inferior margin of the joint, it did not have any actual contact with it. Therefore, a recurrent branch of the anterior primary ramus was thought to be innervating the zygapophysial joints.

Other than this, there was rarely any mention of the posterior primary ramus until around 1956 when Stillwell (1956),and Pedersen et al., (1956), published their papers with increasing interest in the zygapophysial joints.

The L1 to L4 posterior primary ramus which has a diameter of 2mm or less (Giles, 1989), branches from the anterior ramus at the level of intervertebral foramen, at an angle of about 90^{o} (Bradley, 1974). It is a short nerve of about 5mm in length (Bogduk et al., 1982) that runs dorsally towards the upper border of the subjacent transverse process.
The L5 posterior primary ramus is longer and travels over the ala of the sacrum (Bogduk et al., 1982).
The division of the dorsal ramus is controversial.
Bogduk et al.(1982) and Cavanaugh et al.(1989), describe three branches; medial, intermediate and lateral. Whereas Bradley (1974), Edgar and Ghadially (1976), Ninghsia (1978) and Giles (1989) have found the posterior primary ramus dividing into two branches, medial and lateral.

1.3.2 INNERVATION OF THE ZYGAPOPHYSIAL JOINTS AND RELATED STRUCTURES

The innervation of the zygapophysial joints has been of interest to those involved in the innervation of the lumbar

spine, and to those struggling to reveal the causes of idiopathic low back pain.

Smith-Petersen (1924), stated that the zygapophysial joints receive their innervation from the recurrent branch that springs off the spinal nerves as they emerge from the intervertebral foramen, without mentioning the medial branch of the dorsal ramus.

Badgley (1941), indicated that the anatomical possibilities for the zygapophysial joint to be involved in the production of low back pain were obvious, but lack of pathological evidence hindered these facts.

Professor McCotter and Dr. Strong who dissected the lumbar nerves upon his request, saw no connection between the medial branch of the posterior primary ramus and the zygapophysial joint capsule. Therefore, Badgley presumed that the recurrent branches of the anterior primary rami could be innervating the capsules of these joints. 'see figure 1.8'

Pedersen et al. (1956), highlighted what they found to be the innervation of the lumbar zygapophysial joints. In their view, the medial branch of the posterior primary ramus sends a small branch to the zygapophysial joint.
Thus, they have shown a single level, single-nerve innervation to this joint.
Their description and illustration have ever since, been

used as the standard to be quoted in orthopaedic literature. Hollinshead's textbook (1982) has incorporated the illustration.

Lewin et al.(1962), included a description of the medial branch of the posterior primary ramus in their paper, but did not illustrate articular branches from the medial branch to the zygapophysial joint immediately below each medial branch. 'see figure 1.9'

Bradley (1974), described proximal and distal articular branches to the lumbar zygapophysial joints. A branch from the nerve supplying the joint in question, and a branch from the nerve one level above. He thus, described a two-level innervation to each joint. 'see figure 1.10'
He also suggested the possibility of entrapment of the medial branch of PPR as it passes under the mamillo-accessory ligament.

Ninghsia Medical College (1978), describe anastomoses taking place between the posterior primary rami of all the lumbar nerves. They grouped the anastomoses into four categories, seen as:

a) anastomoses between two neighbouring medial branches.
b) anastomoses between two lateral branches.
c) anastomoses between medial and lateral branches.
d) anastomoses between the posterior primary rami and the lateral branches. 'see figures 1.11 a,b,c & d'

FIGURE: 1.8

Schematic drawing showing the medial branch of the posterior primary ramus (A), the lateral branch (B), and the zygapophysial joint articulation (C).

From: Badgley (1941)

FIGURE: 1.9

A drawing showing the topographical relations between the intertransverse ligament, the ligamentum flavum and the distribution of the posterior primary ramus.

From: Lewin et al. (1962)

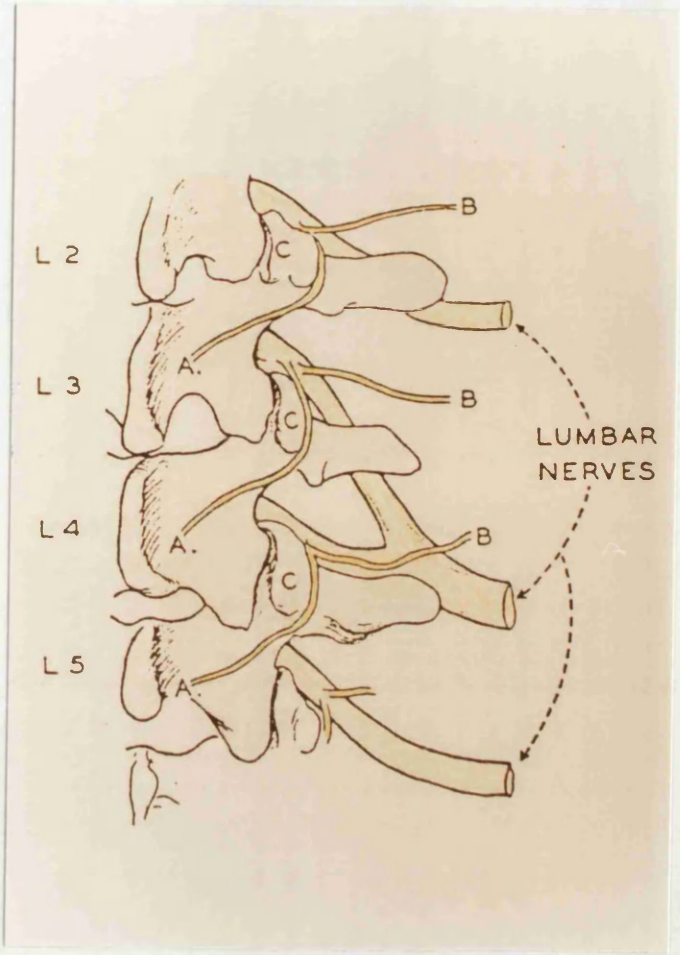


Figure 1-8

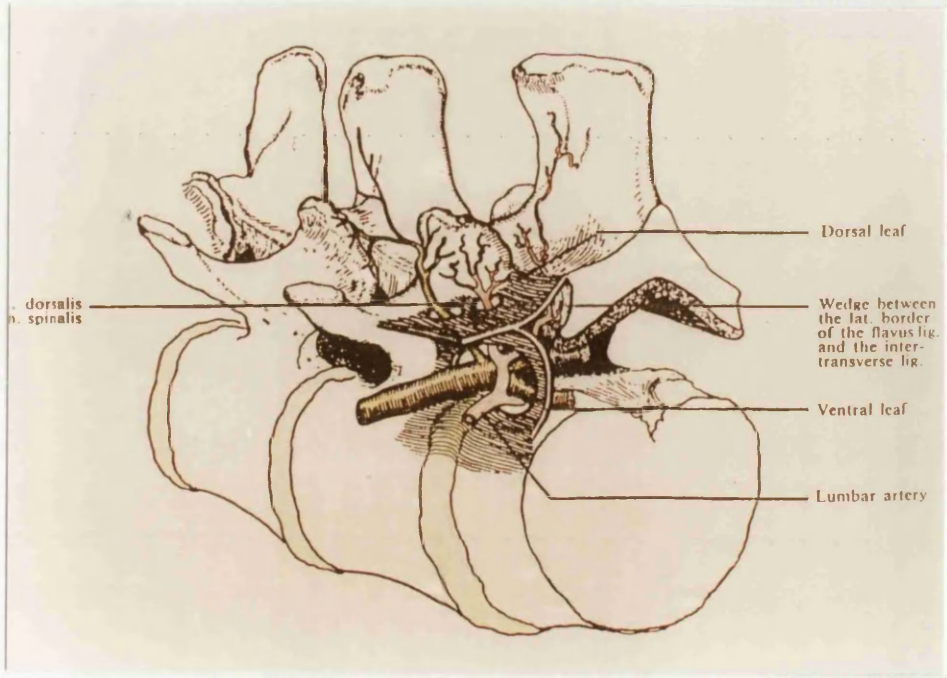


Figure 1-9

FIGURE: 1.10

A drawing from a dissection of the lumbar region. The posterior primary rami of the lumbar nerves are appearing in the posterior compartment of the back via osseofibrous foramina.
The medial and lateral divisions and the nerves connecting adjacent segmental nerves are seen. The double innervation of the posterior vertebral joint is shown.

From: Bradley (1974)

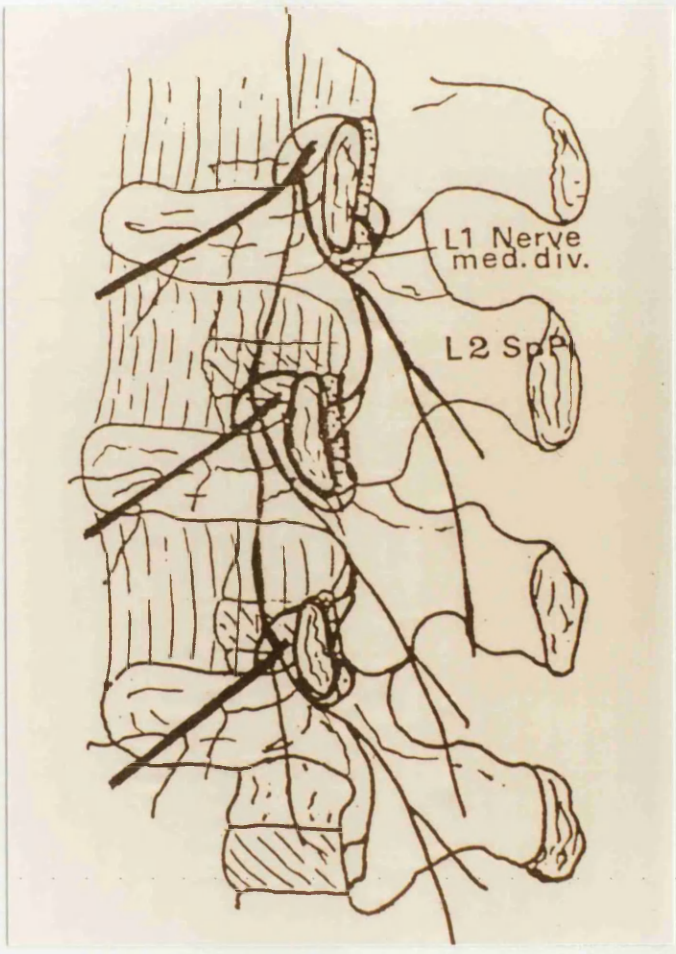


Figure 1-10

FIGURE: 1.11 (A)

The posterior primary rami and the medial and the lateral branches of the lumbar nerve.

(B)

Anastomoses between the posterior and lateral branches of the lumbar nerves, and anastomoses between the medial and lateral branches.

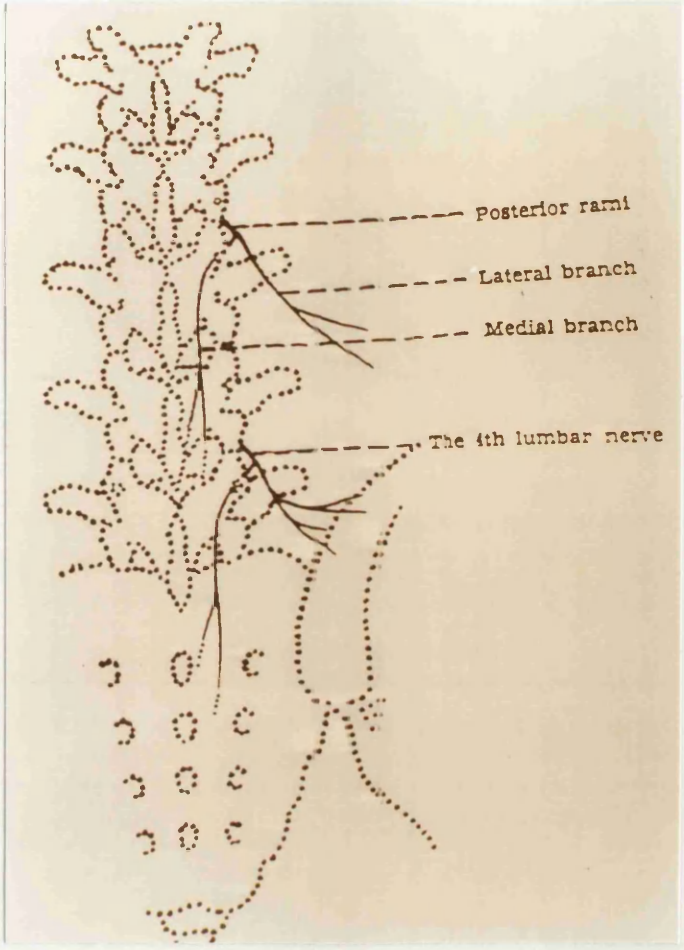
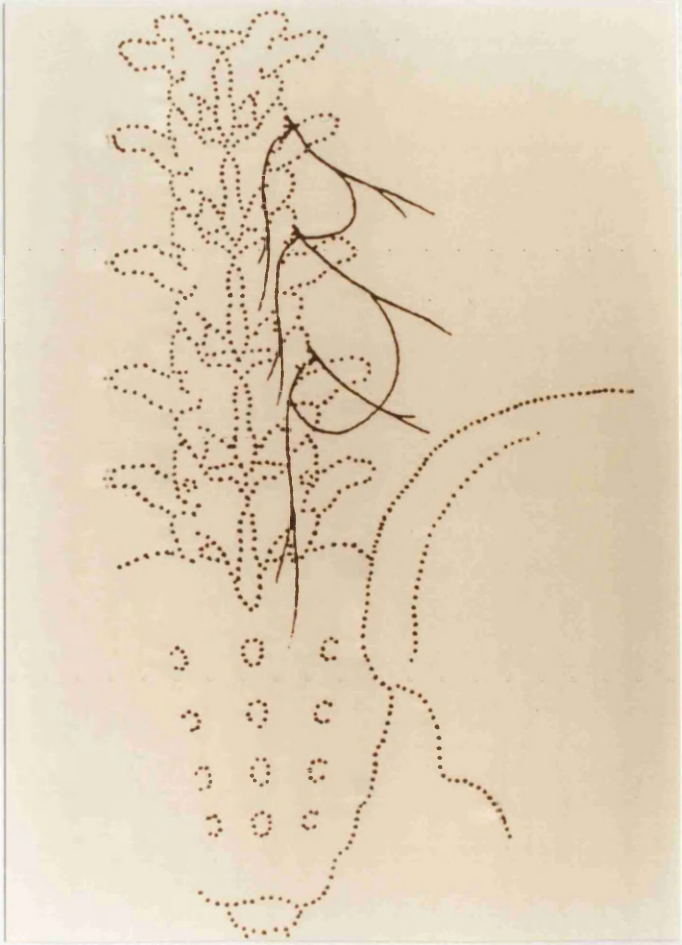


Figure I-II

(A)

(B)



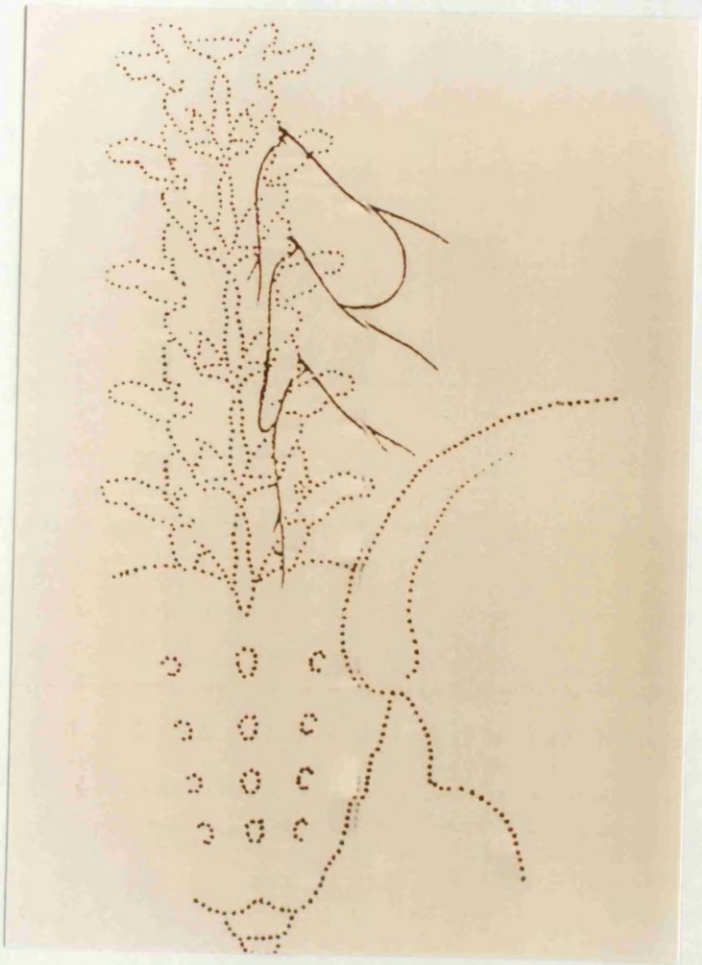
(C)

Anastomoses between the lateral branches of the lumbar nerves, and anastomoses between the medial branches.

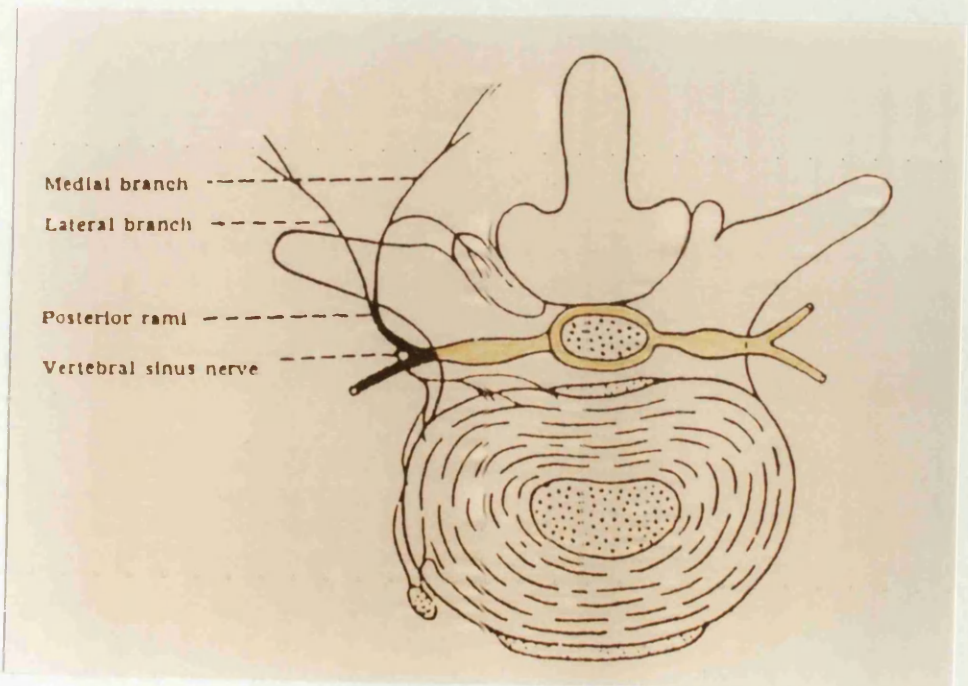
(D)

Distribution of the bramches of the posterior primary ramus to the zygapophysial joint.

From: Ninghsia Medical College (1978)



(C)


Medial branch
Lateral branch
Posterior rami
Vertebral sinus nerve

(D)

Mooney and Robertson (1976), by injecting hypotonic saline were able to map out pain reference from the zygapophysial joint. They also illustrated two-level, two nerves innervation. '(figure 1.12)'

According to Bogduk (1979), each zygapophysial joint is innervated by the medial branch of the posterior primary ramus, by a proximal branch at the joint in question, and a distal branch from the nerve one level higher.'(figure 1.13)'

Paris (1983), claims that the zygapophysial joint is innervated from three segmental levels. Thus, introducing a triple-level innervation. His claim is based on having two branches of the medial branch of the posterior primary ramus, as explained by Mooney and Robertson (1976), and Bogduk (1979), plus an additional branch arising from the mixed spinal nerve. He named it as the ascending nerve.'see figure 1.14 a & b'

Wyke (1981), also states that each lumbar spinal joint is innervated from not less than three branches.

On the other hand, Auteroche (1983), not only describes a recurrent branch from the postero-superior aspect of the lateral branch of the posterior primary ramus innervating the zygapophysial joint, but the medial branch giving off three to five ascending branches that innervate the lateral and the posterior surface of the joint capsule as well.

FIGURE: 1.12

Diagram of the innervation of the zygapophysial joint. The medial branch of the posterior primary ramus descends " through " the mamillo-accessory ligament.

A : the medial branch continues distally

B : the medial branch sending multiple filamentous branches to the medial side of the superior aspect of the lumbar zygapophysial joint.

From: Mooney and Robertson (1976)

FIGURE 1.13

Sketch of the left posterior view of the lumbar spine showing the branches of the dorsal rami.

VR - ventral ramus. DR - dorsal ramus. mb - medial branch. ib - intermediate branch. lb - lateral branch. ibp - intermediate branch plexus. is - interspinous branch. a - articular branch. Zj - zygapophysial joint.

From: Bogduk and Twomey (1991)

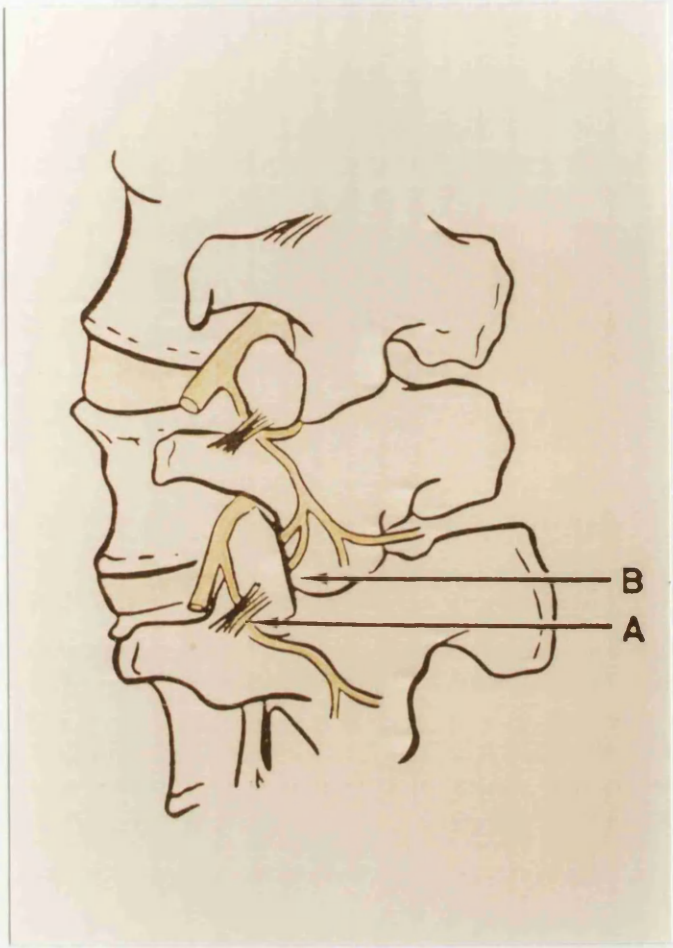


Figure 1-12

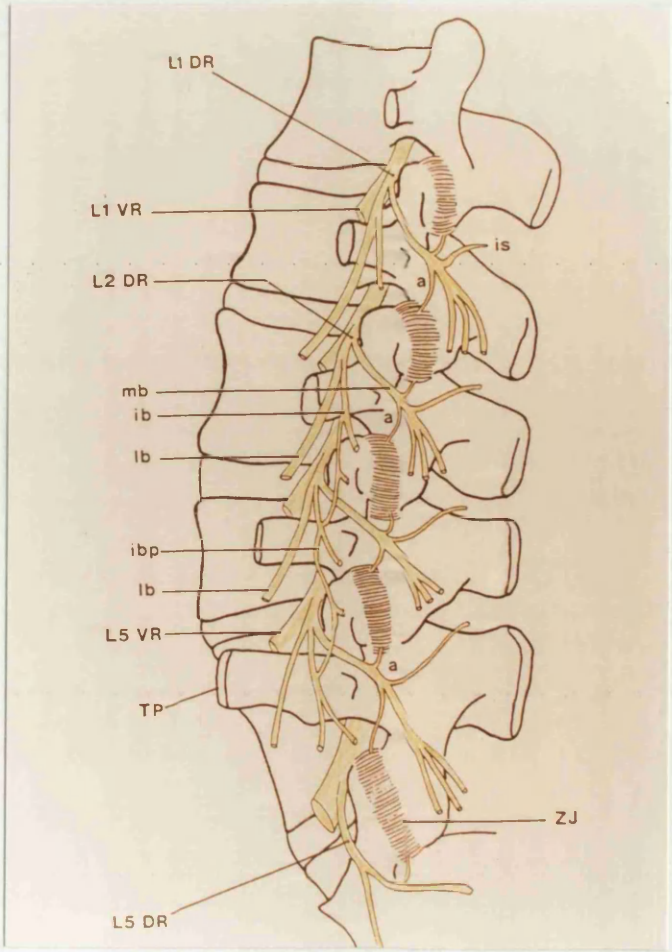


Figure 1-13

FIGURE: 1.14 (A)

Diagram showing the segmental distribution of the innervation in the lumbar spine.

(B)

Horizontal view of segmental innervation.

1 : posterior primary ramus
2 : lateral branch of the posterior primary ramus
3 : muscular branch to multifidus and to facet capsule
4 : medial branch of the posterior primary ramus
5 : branch to the posterior sacroiliac joint
6 : muscular and cutaneous branches
7 : muscular and ligamentous branch
8 : local branch to facet
9 : anterior primary ramus

From: Paris (1983)

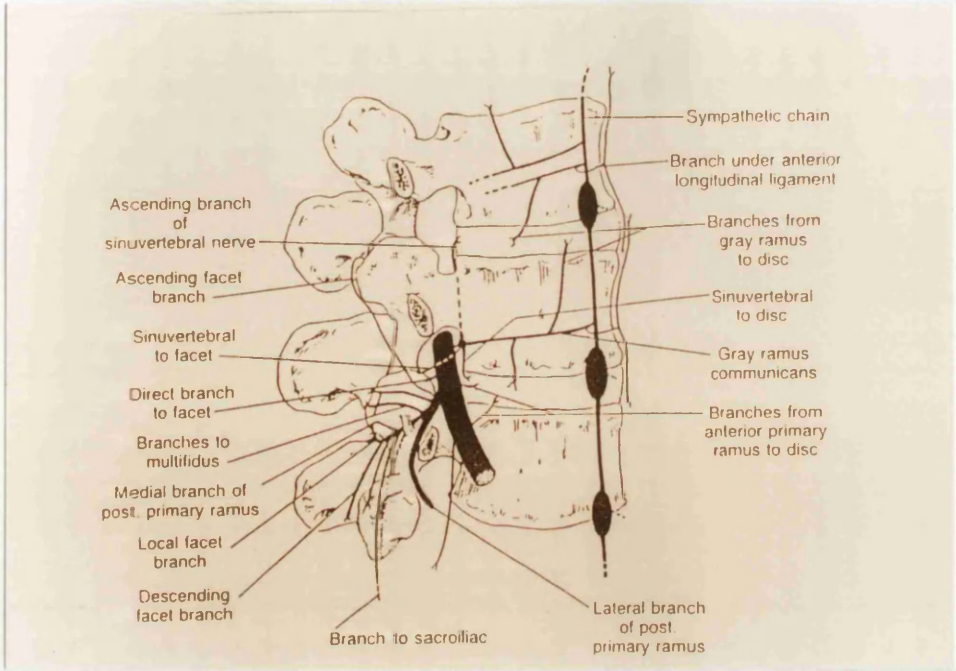
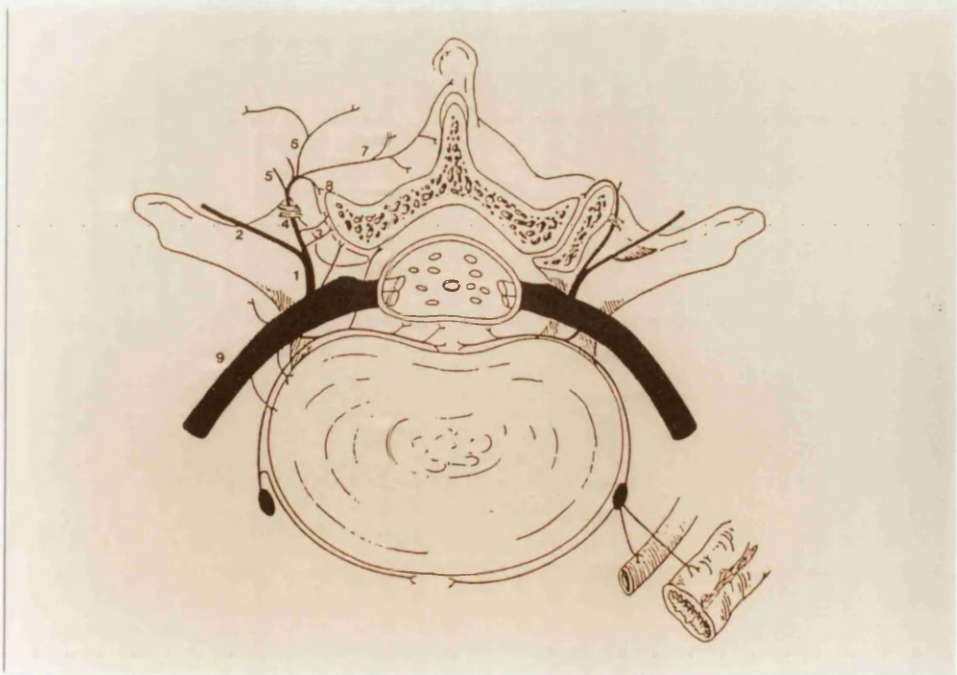


Figure 1-14 (**A**)



(**B**)

He explains that one or two branches run upwards to supply the postero-medial surface of the joint, and two to five branches innervate the joint arising from the spinal nerve proximal to the origin of the anterior and posterior primary ramus. One or two nerve filaments reach to the upper part of the subjacent joint as well.'see figure 1.15a,b & c'

In most of the cases, he adds, the ventral ramus gives off a single branch from its posterior or lateral surface that runs to innervate the lateral surface of the zygapophysial joint. Anastomoses also takes place between the medial and lateral branches. He believes that a significant part of the anterior innervation of each joint is derived from nerves arising from the anterior primary ramus itself.

Auteroche (1983) quoting Lazorthes (1956,1964), indicates that six articular branches arising from the posterior primary ramus, run towards the superior and inferior articular processes, out of which four to five are ascending. 'see figure 1.16a & b'

According to Lucas (1983), the posterior primary ramus not only innervates the zygapophysial joints and the dorsal musculature of the spine, but it anastomoses with the posterior primary rami of other levels as well.'(figure 1.17)'. He does not name any branches of PPR or describe them, although he states that each posterior primary ramus supplies at least two zygapophysial joints, and each joint

FIGURE: 1.15 (A)

Posterior view of the innervation of the lumbar zygapophysial joints.

(B)

Left posterior oblique view of the innervation of the zygapophysial joints.

A : ventral ramus

P : dorsal ramus

M : medial branch of the dorsal ramus

L : lateral branch of the dorsal ramus

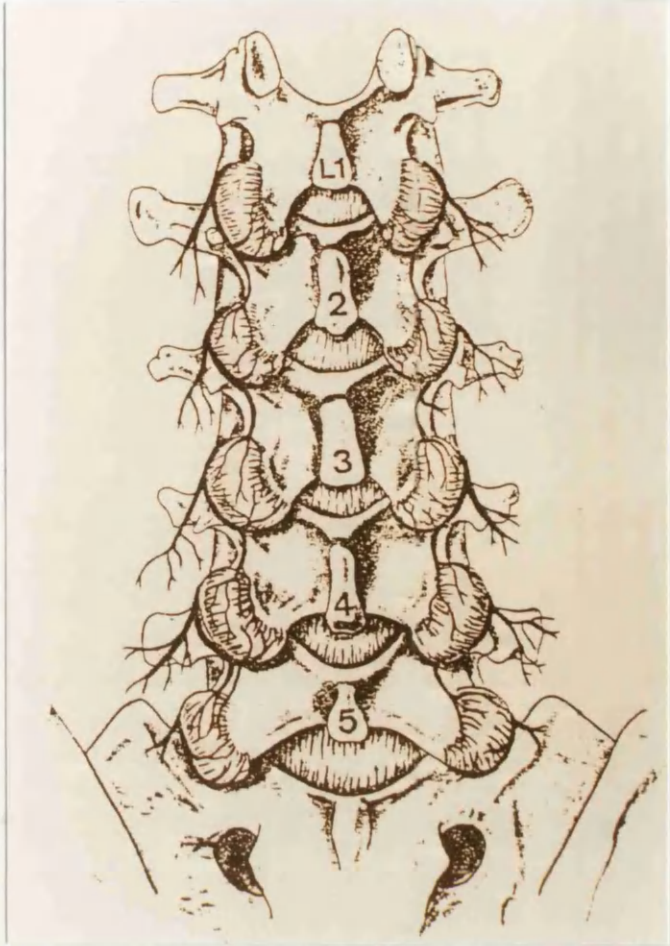


Figure
1-15
(A)

(B)

(C)

Origins of the different nerves distributing to the lumbar zygapophysial joints.

1 : dorsal ramus

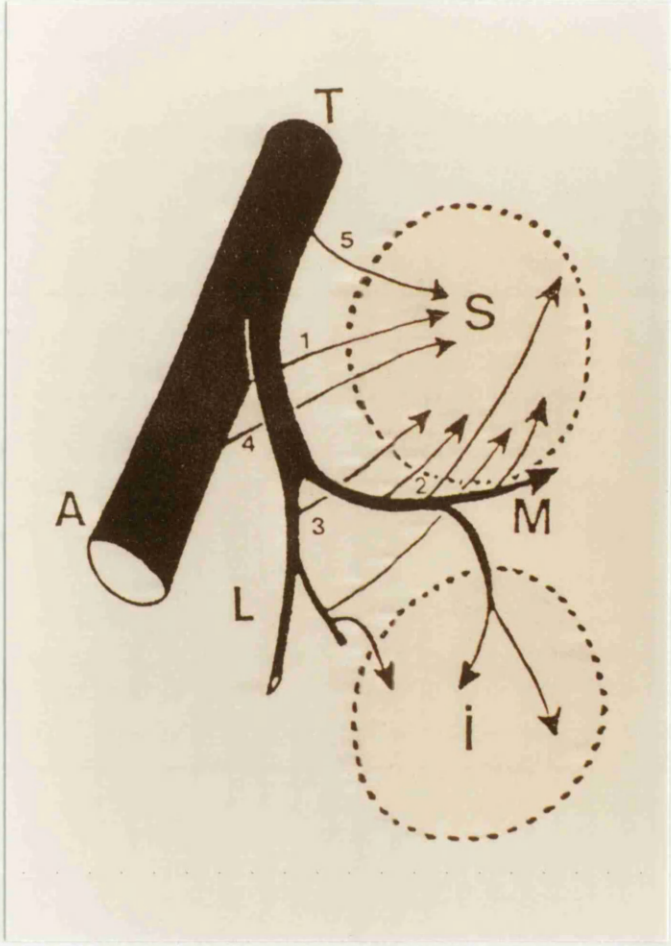
2 : medial branch

3 : lateral branch

4 : ventral ramus

5 : trunk of spinal nerve prior to its bifurcation into ventral and dorsal rami

From: Auteroche (1983)



(C)

FIGURE: 1.16 (A)

Distribution of the dorsal ramus of the spinal nerve in the lumbar spine (according to Lazorthes and Winckler).

1 : articular nerves

2 : interspinal muscle

3 : posterior branch of the spinal nerve

4 : intermamillary bundle

5 : mamillostyloid bundle

6 : interstyloid bundle

7 : lateral intertransversary bundle

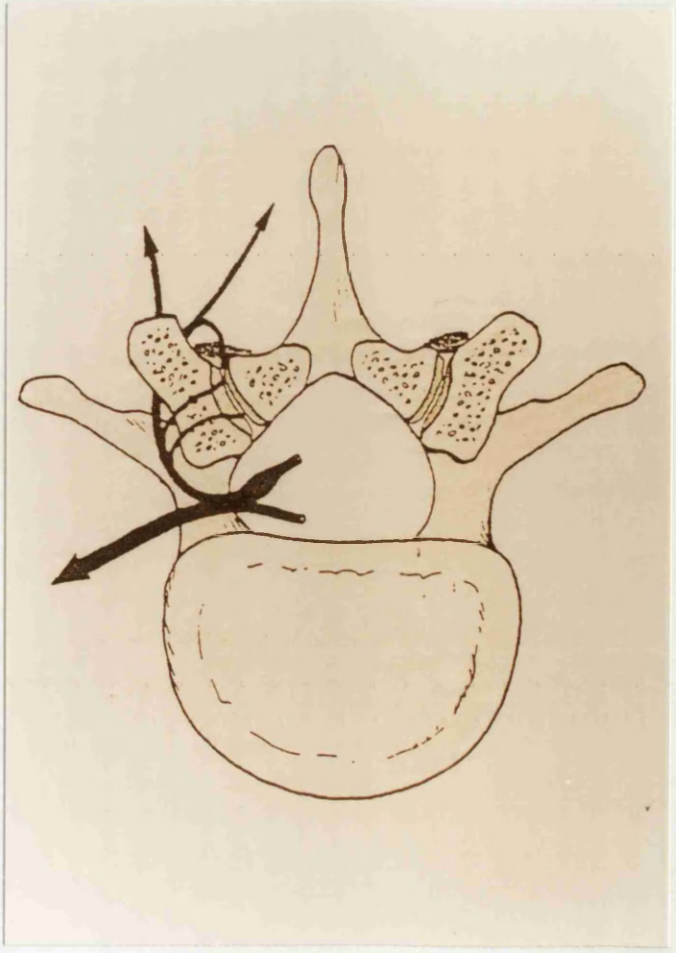
(B)

Drawing to show the innervation of the posterior articulations in the horizontal plane (according to Lazorthes)

From: Auteroche (1983)

Figure
1-16
(A)

(B)



receives innervation from at least two nerves.

Carrera (1984),concludes that the medial branch of the posterior primary ramus supplies the zygapophysial joint at its own level, with a lateral branch from each posterior primary ramus sending sensory innervation not only to the zygapophysial joint at its own level, but also to the joint one segment below. 'figure 1.18'

Illustrations in Vadeboncoeur et al. (1986), show that each zygapophysial joint is innervated by not only a branch from the posterior primary ramus to the lateral surface, but also by a branch from the anterior primary ramus as sino-vertebral nerve to that surface as well. This is besides having a branch from the spinal nerve one level above. They also illustrate innervation from the contralateral posterior primary ramus one level higher. 'see figure 1.19a & b'

Giles (1989), in his investigations, observed that not only the zygapophysial joints are solely supplied by the medial branch of the posterior primary ramus, but each PPR supplies two zygapophysial joints. Thus, confirming the findings of Mooney and Robertson (1976), and Bogduk (1979).'figure 1.20a & b'

FIGURE: 1.17

Section of the lumbar spine showing herniated disc with relationship of ventral nerve root; also shown is the posterior primary root, which supplies facets and muscles, and the sinuvertebral nerve, which innervates disc.

From: Lucas (1983)

FIGURE: 1.18

Diagrammatic representation of the innervation of the lumbar facet joints.

S : spinal nerve

P : posterior primary ramus

L : lateral branch of the posterior primary ramus

M : medial branch of the posterior primary ramus

From: Carrera and Williams (1984)

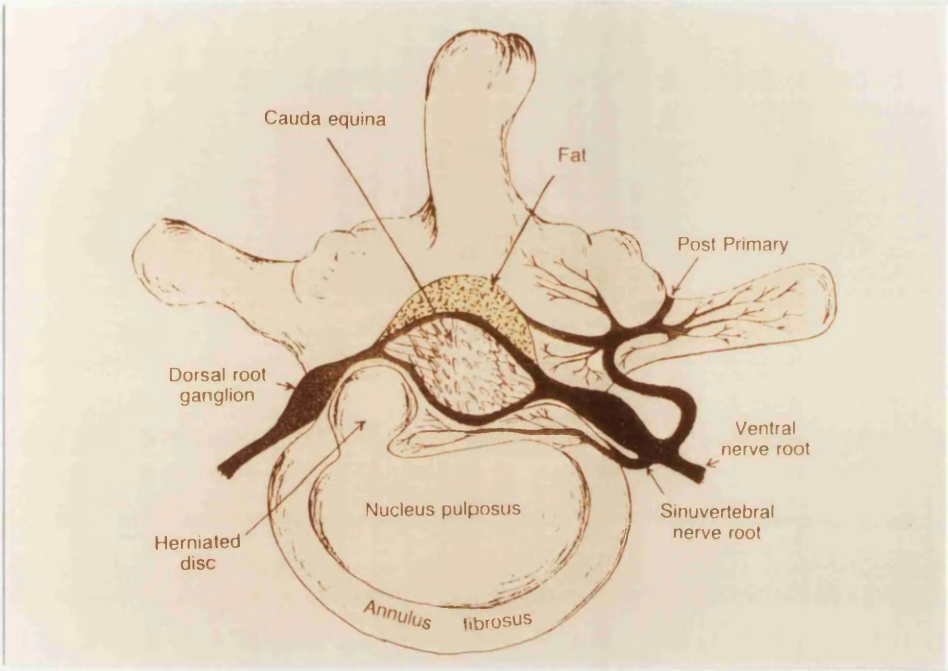


Figure 1-17

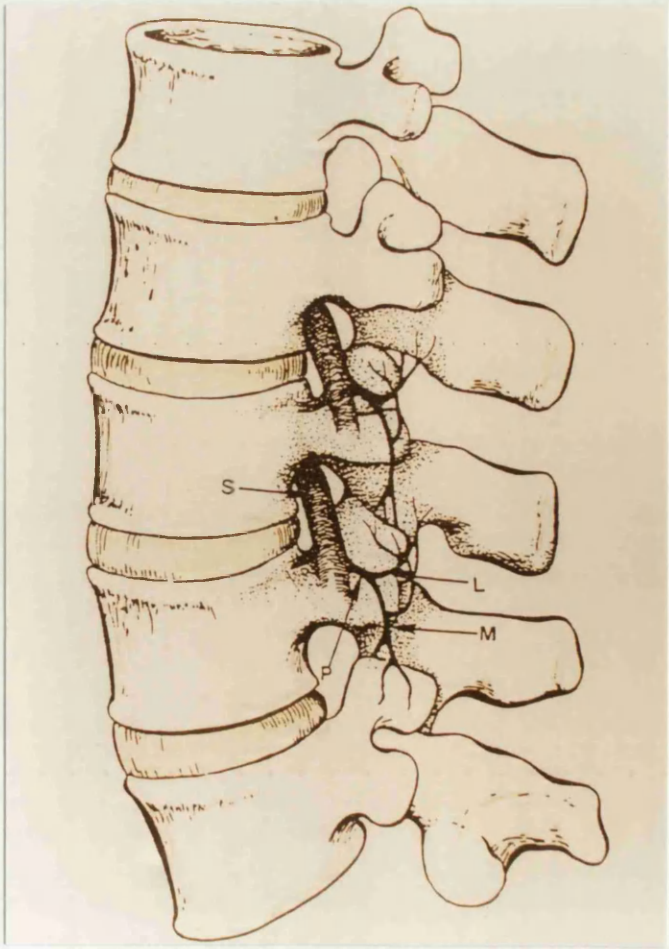


Figure 1-18

FIGURE: 1.19 (A)

Diagram showing the complexity of the innervation of the lumbar zygapophysial joints.

A : anterior primary ramus

B : posterior primary ramus

C : sinuvertebral nerve

(B)

Diagram of the distribution of the muscular and cutaneous branches of the posterior primary ramus.

From: Vadeboncoeur (1986)

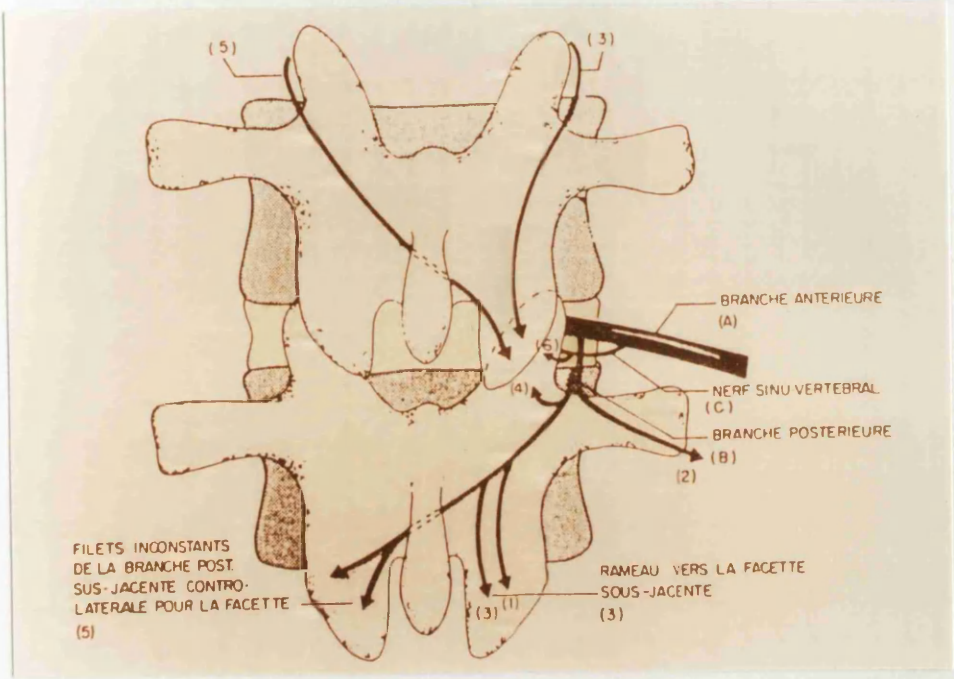
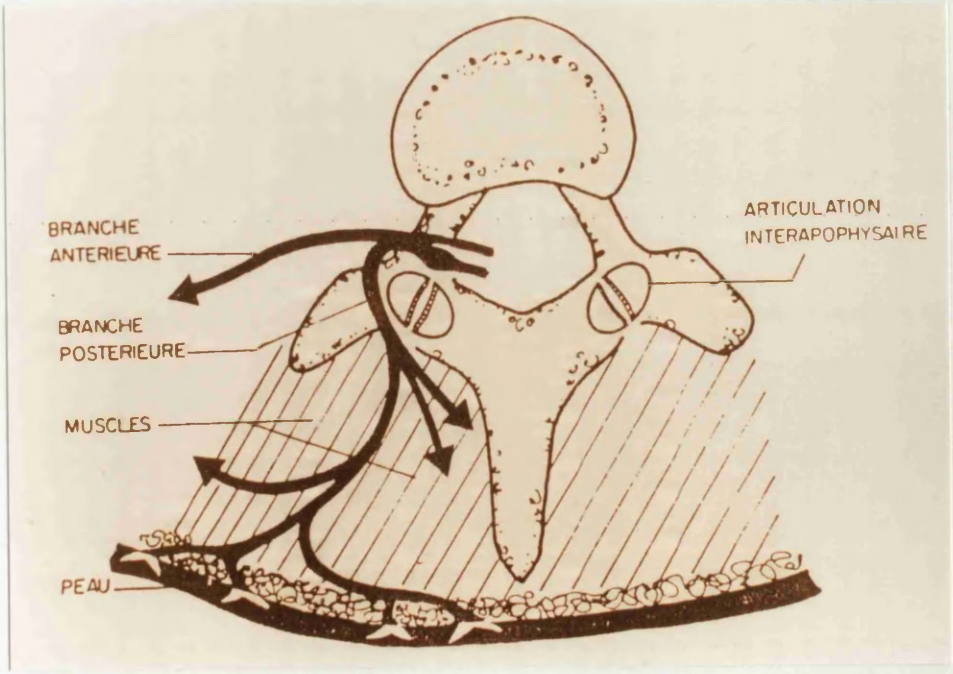


Figure 1-19 (A)



(B)

FIGURE: 1.20 (A)

Lateral view of the lower spinal innervation.

1 : anterior primary ramus

2 : anterior primary ramus branch to the intervertebral disc

3 : posterior primary ramus

4 : medial branch of the posterior primary ramus

5 : lateral branch of the posterior primary ramus

GRC grey ramus communicans

TVP transverse process

ZJC zyapophysial joint capsule

arrow = mamillo-accessory ligament

(B)

Posterior view of the lower spinal innervation

3 : posterior primary ramus

4 : medial branch of the posterior primary ramus

5 : lateral branch of the posterior primary ramus

MP mamillary process with mamillo-accessory lig.

ZJC zygapophysial joint capsule

From: Giles (1989)

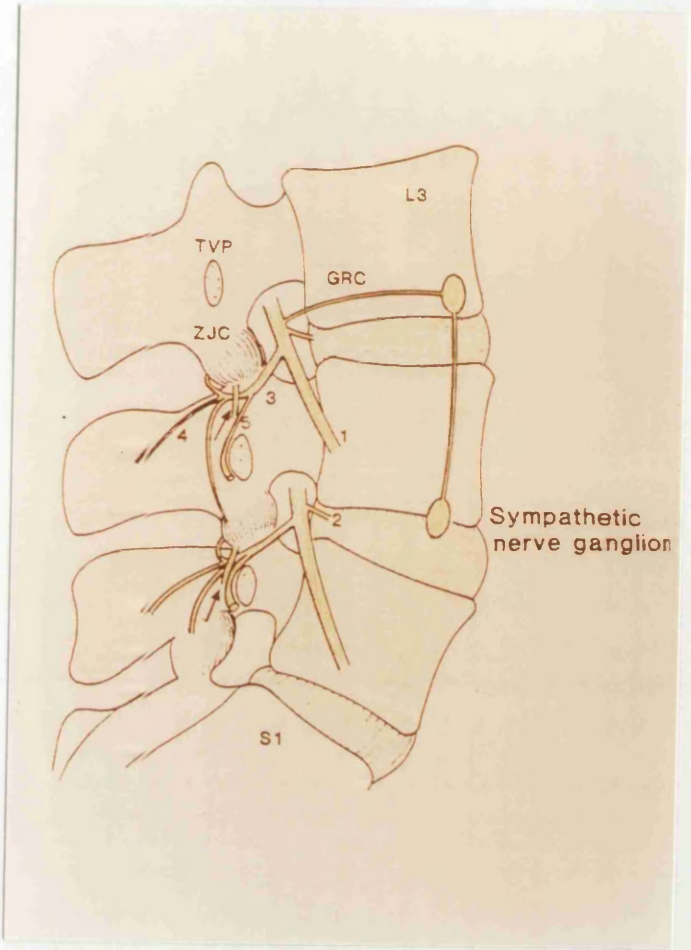
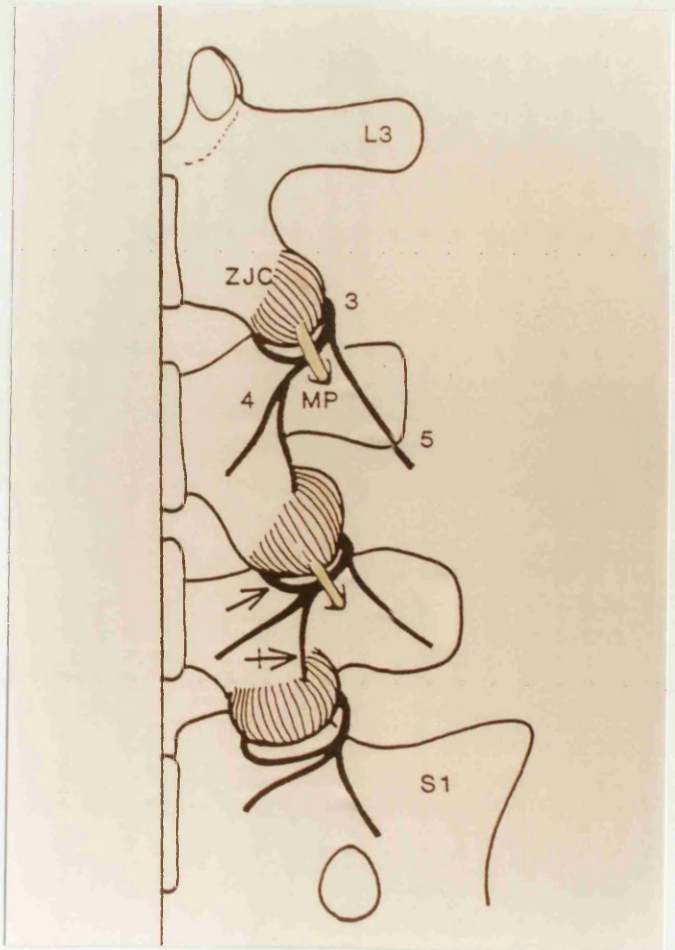


Figure
1-20
(A)

(B)



1.4 GENERAL ANATOMY OF THE PERIPHERAL NERVE FIBRES

1.4.1 INTRODUCTION

Each peripheral nerve is a collection of nerve fibres. These nerve fibres are conducting elements of the nerve cell, or neuron, and are capable of conducting impulses in either way, from any stimulus applied (Woodburne and Burkel, 1988).

Each **nerve fibre** consists , of the axon or axis cylinder, the myelin sheath (when present) and the neurolemmal sheath of Schwann (Barr and Kiernan, 1983)

According to Daube et al.(1986), the **axon** consists of axon membrane, or axolemma, and the axoplasm which contains mitrochondria, microtubules, microfilaments and neurofilaments.

The **epineurium** is a loose areolar connective tissue which surrounds and separates the individual fascicles of a peripheral nerve. It protects the nerve from mechanical pressure.

The **perineurium** is a thin dense sheet of fibrous tissue that surrounds the fasciculi. The collagen bundles are arranged in circular, oblique and longitudinal manner.
It functions as a diffusion barrier, preventing chemical irritants. It also maintains intrafascicular pressure and is

seen as a major structure in resisting tensile forces applied to a peripheral nerve.

The **endoneurium** is a delicate connective tissue that encircles each axon with its myelin sheath. It contributes to the tensile strength (Murphy, 1977). 'see figure 1.21'

1.4.2 NERVE RECEPTORS

According to Bannister (1976), it is possible to distinguish between the free nerve endings and encapsulated nerve endings, histologically.

The **free nerve endings** are those which form plexuses or are otherwise spread freely without any particular association with other cell types.

The **encapsulated nerve endings** are those where the neural process is completely covered by specialized non-nervous cells, in several or many layers.

Sensory receptors have been classified by Junqueira et al.(1986), with regard to their particular modalities to which they are especially sensitive.
For example, **mechanoreceptors** are particularly responsive to mechanical disturbances such as pressure and touch,

FIGURE: 1.21

Diagram illustrating the peripheral nerve components.

Modified from: Bailey's Textbook of Microscopic Anatomy (1984), eds. Kelly, D.E., Wood, R.L. & Enders, A.C. 18th edition. Baltimore: Williams & Wilkins.

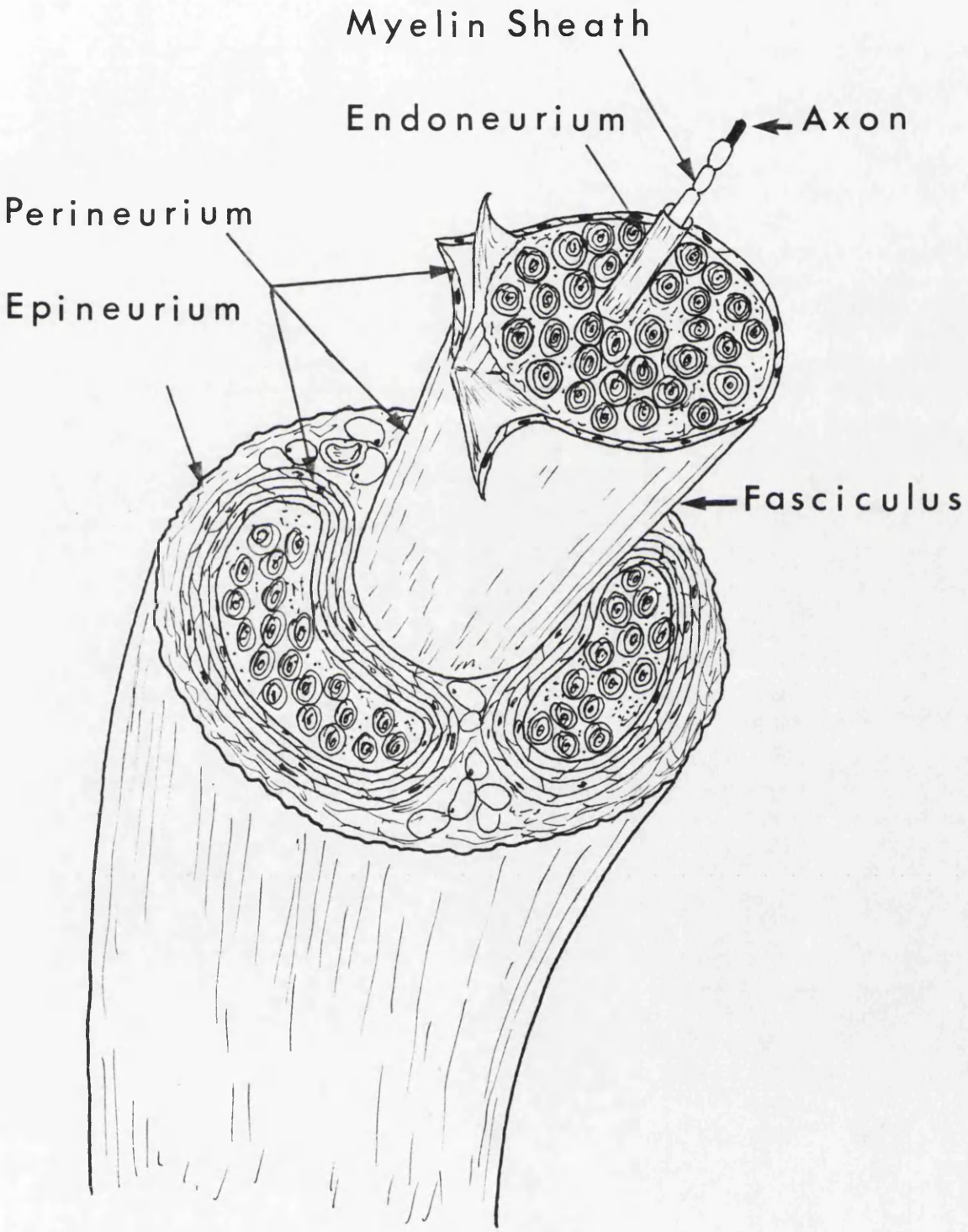

Myelin Sheath
Endoneurium
Axon
Perineurium
Epineurium
Fasciculus

Figure 1-21

chemoreceptors are sensitive to chemical changes, **nociceptors** are related to the transmission of pain or irritation, and **proprioceptors.**

Williams et al.(1989), indicate that proprioceptors respond to stimuli in deeper tissues, especially of the locomotor system, mechanical stress, and position; they include for example, neuromuscular spindles, Pacinian corpuscles, and endings in joints. These proprioceptors are stimulated by the contraction of muscles, movements of joints and changes in the position of the body or of its parts.

(A) FREE NERVE ENDINGS:

Free nerve endings are nerve axons which are small and usually myelinated or unmyelinated, found in all types of connective tissue, including joint capsules (Williams et al., 1989).

They are classified as Type IV endings by Wyke (1967), and are considered to be pain receptors with a high threshold and non-adapting in their response to stimulation.

(B) SPRAY ENDINGS:

The spray nerve endings are spray-like and extremely variable in their configuration and cellular complexity.
They are also called Ruffini endings, after Ruffini who first described them.
They are classified by Wyke (1967), as Type I.
They are physiologically slow adapting and are of low threshold. Polacek (1965), states that spray endings represent a link between the simple free endings and the encapsulated endings.

(C) ENCAPSULATED ENDINGS:

The encapsulated nerve endings are the most organized of the common joint receptors, and are characterized by having the nerve fiber enveloped by a capsule or wrapped in concentric layers of cells, or lamellae.

The encapsulated nerve endings may be called Pacinian, Golgi-Mazzoni, or Krause endings.
They are classified by Wyke (1967), as Type II.
They are considered to be very slowly adapting low threshold receptors. 'see figure 1.22a,b & c'

FIGURE: 1.22

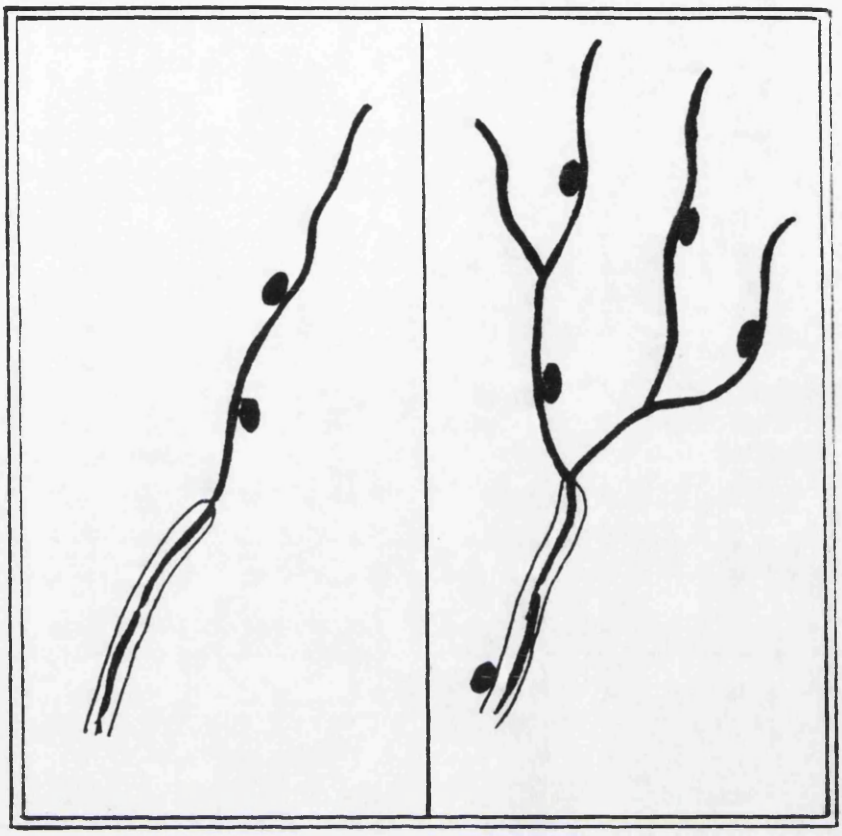
Diagram illustrating types of nerve endings.

(A)

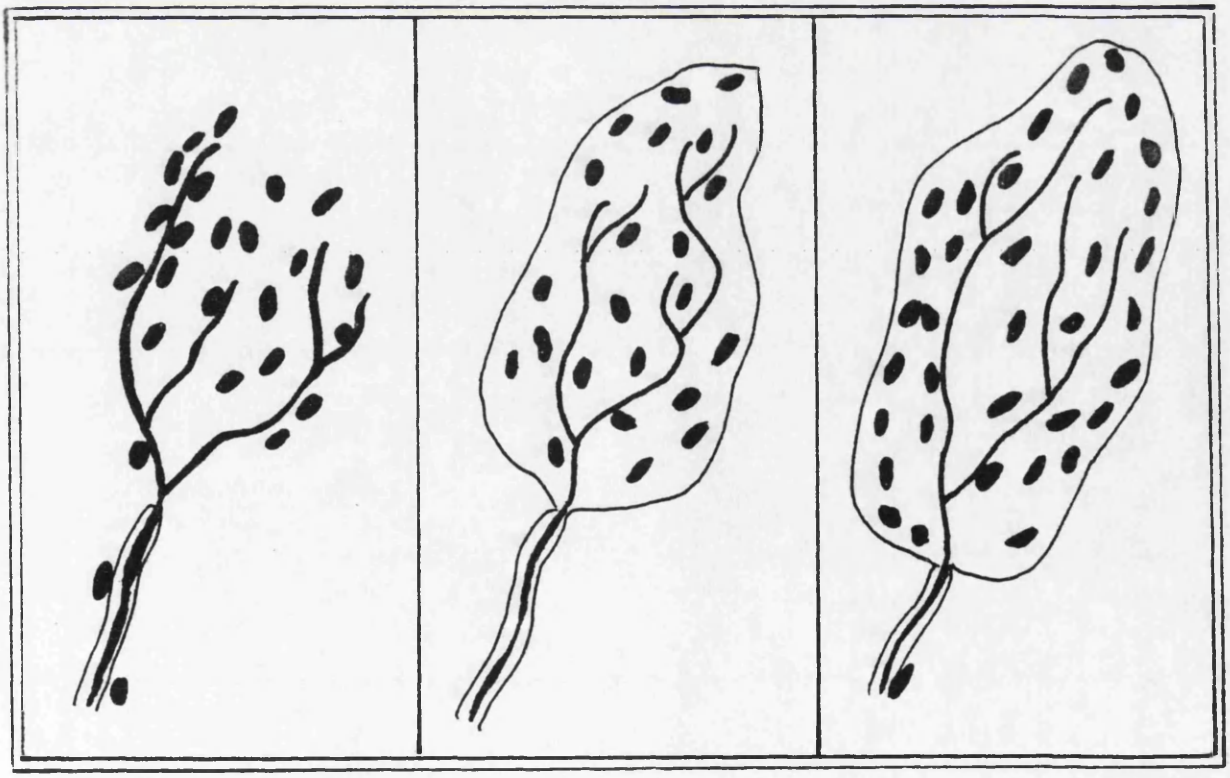
Free nerve endings

(B)

Spray - like endings



a) FREE ENDINGS



b) SPRAY-LIKE ENDINGS

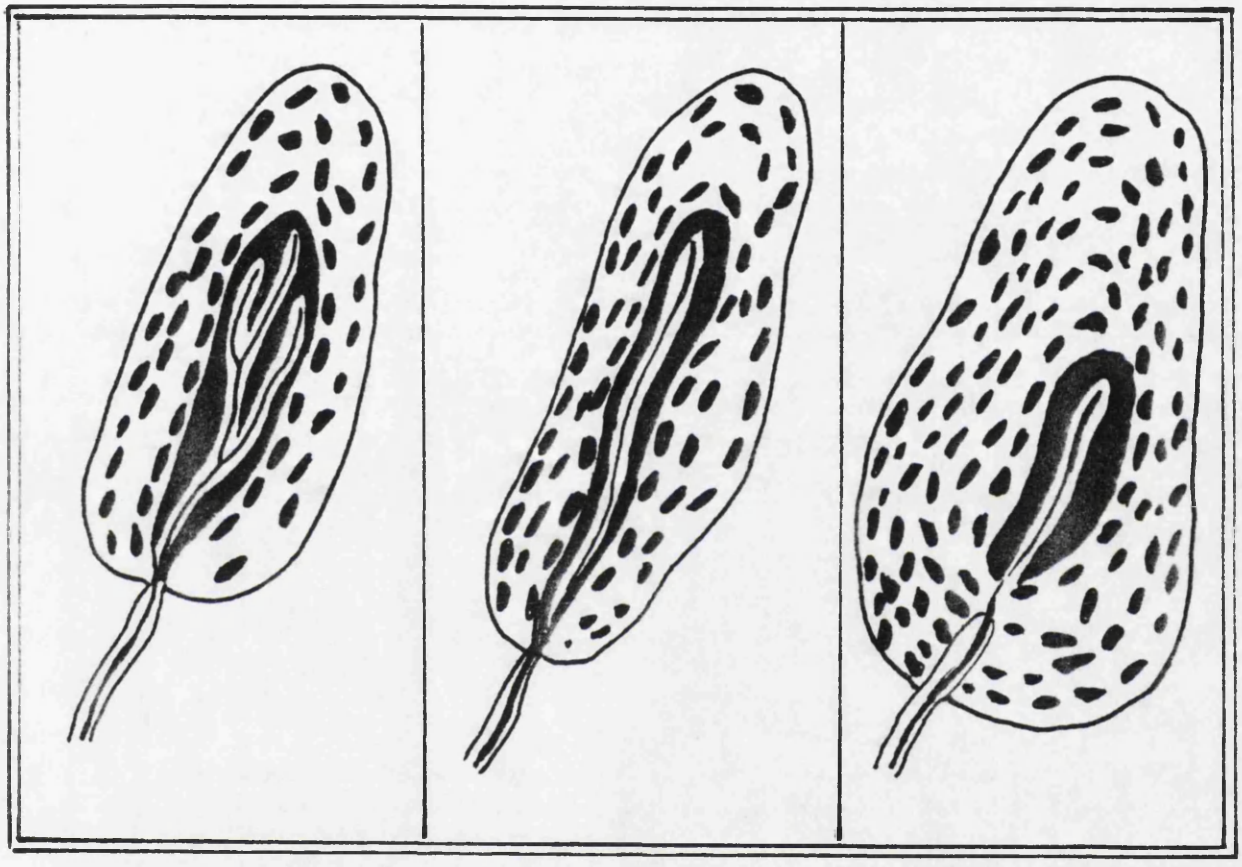
Figure 1-22

(C)

Encapsulated endings

(lamellated corpuscles)

From: Polacek (1965)



c) ENCAPSULATED ENDINGS

1.5 DISTRIBUTION OF NERVES IN THE SYNOVIAL JOINTS

1.5.1 INTRODUCTION

The innervation of joint capsules of synovial joints has been extensively investigated, especially those of the knee joint (Polacek, 1961,1965; Freeman and Wyke, 1967; McCall et al., 1974; Halata and Groth, 1976).
As a result of this, studies on the innervation of other joints use the knee joint for comparison, which may lead to a slight confusion, because the mechanoreceptor properties and functional capacities of the zygapophysial joints differ from the knee joint.

1.5.2 NERVE RECEPTORS IN THE JOINT CAPSULE

The fibrous capsule is richly innervated with nociceptive fibres. In the normal human knee joint, a plexus of unmyelinated nerve fibres, and a nerve bundle in the capsule are observed (Kellgren and Samuel, 1950).
Free nerve endings have also been observed in the synovial membrane of human joints in amputated limbs (Ralston et al., 1960).
Samuel (1949), described myelinated and unmyelinated nerve fibres distributed in the synovial membrane of human knee joints, in a plexiform manner, which ended in various types

of free nerve endings.

Using transmission electron microscopy, Halata et al.(1985), observed three types of nerve endings in the human knee joint capsules; free nerve endings, Ruffini and Pacinian corpuscles.

Human zygapophysial joint capsules stained with methylene blue, silver impregnation or cholinestrase histochemistry, showed myelinated and unmyelinated nerve fibres with free endings, complex un-encapsulated endings, and small encapsulated endings (Hirsch et al., 1963; Jackson et al., 1966).

According to Wyke and Polacek (1975), all the synovial joints of the body in mature individuals, including the zygapophysial joints, are provided with four varieties of receptor nerve endings.
Wyke1296H(198¢)assified them as:

Type I Mechanoreceptors: these consist of clusters of thinly encapsulated globular corpuscles embedded in the outer layers of the fibrous capsule.

Type II Mechanoreceptors: these are thickly encapsulated conical corpuscles embedded in the deeper layers of the fibrous capsule.

Type III Mechanoreceptors: they are much larger, thinly encapsulated corpuscles applied to the surfaces of joint ligaments, but are absent from the spinal ligaments.

Type IV Mechanoreceptors: this is a receptor system in the fibrous capsules of joints, which is represented by a plexus of unmyelinated nerve fibres, that weave in three dimensions throughout the entire thickness of the joint capsule, but are, on the other hand, entirely absent from the synovial tissue and intra-articular menisci. The irritation of this system is said to be responsible for evoking joint pain.

Giles et al.(1986), and Giles and Taylor (1987), using silver impregnation, gold chloride and electron microscopy of freshly removed human zygapophysial joint capsule, showed both encapsulated and free nerve endings in the capsule. They also demonstrated Substance-P immunoreactive fibres in their preparation.

Cavanaugh et al.(1989), have demonstrated by using neuro-anatomical and neuro-physiological techniques, the presence of mechanosensitive, slowly adapting nerves in the rat zygapophysial joint capsules. Pain fibres were identified as being high threshold units.

Gronblad et al.(1991a), by using immunohistochemical methods, confirm the presence of nerves in the zygapophysial

joint capsule, and relate them to pain by demonstrating Substance-P reaction in these nerves.

Ashton et al.(1992), assess the entire innervation of the joint capsule, by using protein gene product (PGP 9.5), and confirm the presence of nerves in the zygapophysial joint capsule. Demonstration of Substance P in these nerves indicate that they are sensory afferent fibres.

1.6 INNERVATION OF THE LIGAMENTUM FLAVUM

Innervation of the ligamentum flavum that forms the anterior aspect of the zygapophysial joint capsule, is not only controversial but inconclusive as well.

According to Bogduk (1983), the medial branch of the posterior primary ramus is the most likely source of innervation to this ligament.

Pedersen et al. (1956), and Hirsch et al. (1963), have demonstrated the presence of fine nerve endings in the outer-most posterior surface of this ligament, but not in its deeper regions.

On the other hand, Bridge (1959), indicates that the ligamentum flavum has many nerves in its upper and deep

regions.

Korkala et al. (1985), did not find any immunoreactivity for Substance P in small pieces of the ligamentum flavum. Therefore, they concluded that no nociceptive-type nerves were present in this ligament.

According to Ashton et al. (1992), the ligamentum flavum shows no signs of innervation. They used protein gene product (PGP 9.5), which has been used as a general marker for innervation of the uterus, cardiovascular system, and respiratory system.
In joints, PGP 9.5 proved to be much more sensitive than any other neural marker. Therefore, Ashton et al. (1992), suggest that the ligamentum flavum has less significant role in low back pain compared to other soft tissues of the spine.

Rhalmi et al. (1993) by using neurofilament protein (NFP) antiserum, found nerve fibres distributed most numerously around blood vessels in the ligamentum flavum.

1.7 INNERVATION OF THE SYNOVIAL FOLDS

According to Mooney and Robertson (1976), the zygapophysial joint synovial membrane contains a rich nerve supply, but their claim is not supported by any histological evidence.

Gardner (1950), and Hadley (1976), were unable to find any nerves in the human zygapophysial joint synovial folds.

Wyke (1981), states categorically that there are no receptor nerve endings of any description in the synovial tissue or intra-articular "menisci" in the zygapophysial joints. Therefore, he concludes, there is no mechanism whereby articular pain can arise from the synovial tissue.

Goldie and Wellisch (1969), reported seeing nerve fibers in the synovium of the knee, elbow, and wrist joints in pathological specimens.

Giles and Taylor (1987), state that all human zygapophysial synovial folds are innervated. By using silver impregnation methods, they conclude that the majority of nerves seen are independent of blood vessels, therefore, the entrapment of the intra-articular synovial inclusions claimed earlier (Giles and Taylor, 1982), does stand valid in relation to low back pain.

Da Silva and Carmo-Fonseca (1990), by using immunohistochemistry, observed Substance P (SP) containing small nerve fibres remote from blood vessels, which they say probably represents nociceptive afferent C fibres.

Using protein gene product (PGP 9.5) and neuropeptides SP and CGRP, Mapp et al. (1990), assessed the entire innervation of the synovium. They not only confirm the presence of nerve fibres in the synovium, but having seen both SP and CGRP which are associated with sensory nerves in similar location to those staining for PGP 9.5, a nociceptive role seems a likely hypothesis.

Similar studies carried out by Gronblad et al.(1991a), using PGP 9.5 and SP, they confirm the findings of Giles and Taylor (1987), Da Silva and Carmo-Fonseca (1990), and Mapp et al. (1990).

Indirect histological evidence suggesting entrapment of these synovial folds between the joint surfaces has been presented (Giles and Taylor, 1982; Konttinen et al., 1990). Although nerves in the synovial folds or plicae are mainly perivascular (Gronblad et al., 1991b), but nerves with no topographic relationship to blood vessels very close to fat tissue, have also been observed indicating nociceptive role.

The presence of putative nociceptive nerve fibres in the capsule and synovial folds , supports the hypothesis that

the synovial folds become pinched between the facets of the zygapophysial joints or the synovial fold being pulled against the joint capsule.

1.8 REFERRED PAIN IN RELATION TO ZYGAPOPHYSIAL JOINTS

The phenomenon of referred pain is well recognised but not fully understood.

In 1937, it was generally believed that referred pain was peculiar to the viscera, and pain arising from the deep somatic structures of the limbs and trunk was accurately localized. Therefore, the investigation and treatment was directed to the part where the pain was felt (Kellgren, 1977).

Mooney (1987) indicates that he carried out a study in which the lumbar zygapophysial joints were injected with hypertonic saline, in volunteers and himself, under radiographic control, and confirms that the phenomenon of referred pain does exist.

In fact, when larger amounts of the saline were injected, pain was felt radiating to the buttocks, thigh and even calf. A clear relationship was seen between the amount of stimulus and the distribution of pain.

Unlike local pain which is seen at the site of tissue

damage, **referred pain of root involvement** is pain experienced in tissues which are not the site of primary tissue-damage, but are generally innervated by neurons involved in tissue-damage.
Root pain may be accompanied by pain referred from the joint problem in its own right, as well as from the root.
Referred pain without root involvement is pain experienced in tissues which are not the site of tissue-damage,and whose afferent or efferent neurons are not physically involved in any way, e.g body-wall pain in gall-bladder disease (Grieve, 1988).

Oudenhoven (1977), indicates that derangement of the zygapophysial joints is a major cause of referred pain which arises from the posterior primary ramus.

Bogduk (1992b), on the other hand, classifies referred pain as pain perceived arising from a region of the body which is topographically distinct from that where the actual source of pain is located.

According to Kellgren (1977), the deep lying structures including the zygapophysial joints, are all structures which give rise to referred pain.

Clinically, the characteristic features of somatic referred pain as Bogduk (1987) describes, are that it is perceived deeply, it is diffuse and hard to localize and is of aching

quality.

Bogduk (1992b), argues that although the critical feature of somatic referred pain is that it is evoked by stimulation of nerve endings in the structure which is the primary source of pain, the nerves that innervate the region of referred pain are not activated by the primary stimulus.
It is the misperception of the origin of the signal which reaches the brain by a convergent sensory pathway.

1.9 NEUROTRANSMISSION IN SENSORY NERVES

1.9.1 INTRODUCTION

Neurotransmitters have been known since Elliot (1904) suggested adrenalin as a chemical messenger in sympathetic nervous system.
Until early 1960's, acetylcholine, adrenalin, and noradrenalin were the only known neurotransmitters. This situation changed dramatically in the last two decades, and upto 1980 the number of neurotransmitters was well over 20 (Snyder, 1980).
Out of those that have been added relatively recently to the

transmitter family, is Substance P (SP).

1.9.2 LOCALIZATION OF SUBSTANCE P IN THE ZYGAPOPHYSIAL JOINTS AND SYNOVIAL FOLDS

Substance P is a physiologically potent peptide discovered by Euler and Gaddum (1931) in mammalian brain and intestine.

It is probably the neuropeptide whose neurotransmitter role is best established, and is the first peptide for which the transmitter function was suspected (Otsuka and Yanagisawa, 1990).

According to Pernow (1953), SP-like biological activity was found to be higher in the dorsal horn than the ventral roots of the mammalian spinal nerves.

The role of SP as a sensory transmitter is now well supported by many lines of evidence.

SP is concentrated in a subpopulation of primary afferent fibres terminating in superficial layers of spinal dorsal horn in many species including human (Takahashi and Otsuka, 1975; Hokfelt et al., 1975; Cuello et al., 1976). These SP containing primary afferents mostly belong to the

C-fibre group (Hokfelt et al., 1975; Nagy et al., 1981). Type C fibres are the very small, unmyelinated nerve fibres that conduct impulses at low velocities. They constitute more than half the sensory fibres in most peripheral nerves (Guyton,1992).

Kuraishi et al. (1989), investigating the location of SP release in the spinal cord upon noxious peripheral stimulation, found that the main location of the SP release being the superficial layers of the dorsal horn, where most of the SP containing primary afferents terminate.

Several studies have shown that SP produces slow excitatory postsynaptic potentials (EPSPs) in second-order neurons in the dorsal horn, and thus serves as a pain transmitter of primary afferent C fibres (Dun and Jiang, 1982; Nowak and MacDonald, 1982; Konishi and Otsuka, 1985; Helke et al., 1986; Otsuka and Yanagisawa, 1988).

1.10 "NEURON-SPECIFIC" PROTEIN GENE PRODUCT 9.5 (PGP 9.5)- Immunohistochemical Marker for Nerves

Protein gene product 9.5 (PGP 9.5) is a soluble protein, originally detected in human brain extracts by high resolution two dimensional polyacrylamide gel electrophoresis, having a mobility of 9.5cm in one

dimension. Its molecular weight is about 27,000. (Jackson and Thompson, 1981).

PGP 9.5 is a general cytoplasmic marker demonstrating all types of efferent and afferent nerve fibres (Gulbenkian et al., 1987; Lundberg et al., 1988).

Protein gene product 9.5 as Wilson et al. (1988) state, "is the best immunohistochemical marker for nerves currently available".

MATERIALS AND METHODS

CHAPTER II

MATERIALS AND METHODS

2.1 MATERIALS

2.1.1 EMBALMED CADAVERIC LUMBAR SPINES FROM ADULTS

Adult lumbar spines were obtained from twenty-eight cadavers, chosen from those which are normally accepted for research and teaching purposes at University of Glasgow, Anatomy Department.

These cadavers were used for gross anatomical dissection, and for histological processing. The cadavers were of the ages ranging from 57 years to 99 years, and were perfused with embalming fluid '(table 2.1)', within 24 to 48 hours of death.

Embalmed cadavers are stored at 50^{o} F, in transparent plastic body bags, after excess fluid being drained for a day or so. Cadavers are stored for a year in this manner, without drying out, or mould forming.

TABLE 2.1

EMBALMING FLUID

Methylated Spirit 64.O.P		12.5 Litres
Phenol	80%	2.5 "
Formaldehyde	38%	2.0 "
Glycerol B.P		3.5 "
Phonoxetol		5 ml

2.1.2 FRESH SURGICAL MATERIAL

Three surgical specimens were obtained from the posterior aspect of the lumbar zygapophysial joint capsules.
They were obtained from two females, age 29 years and 44 years, and one male, age 30 years.

The surgeon, upon our request, provided us with the specimens that included the following:

a) the posteromedial fibrous joint capsule.
b) the adjoining part of the ligamentum flavum.
c) the synovial folds.

This process was carried out in collaboration with the University Department of Orthopaedics, at the Western Infirmary, Glasgow.

2.1.3 SKELETAL SPECIMENS OF THE LUMBAR VERTEBRAE

224 sets of the lumbar vertebrae were obtained from collections of the Department of Anatomy, University of Glasgow, for the purpose of examining the rate of prevalence of the ossification of the mamillo-accessory ligament.

2.1.4 CADAVERIC LUMBAR SEGMENTS FOR CLINICAL STUDIES

Two whole lumbar spine segments were sawed from Departmental cadavers for "Facet Joint Injections".
These were carried out in collaboration with the Radiology Department, Western Infirmary, and Back Pain Clinic, Gartnavel General Hospital, Glasgow.

2.2 METHODS

2.2.1 CADAVERIC LUMBAR SPINES FROM ADULTS

All cadaveric lumbar spines were sawed from the rest of the body for easy handling.

The twenty-eight spines obtained were divided into three groups.

(A) Gross dissection of the spinal nerves with particular reference to the posterior primary rami

Twenty-two lumbar spines were removed from the embalmed cadavers by means of a band saw.
Gross dissection of the spinal nerves was done using two approaches.

In the first approach, the lateral branches were identified and traced from the posterior layer of thoracolumbar fascia. These branches were traced through the erector spinae to their origin from the posterior primary ramus.
During this process, muscle fibres were resected fibre by fibre. Upon approaching the zygapophysial joint capsules, from the posterior aspect, the mamillo-accessory ligament was identified. The medial branch of the posterior primary ramus was thus identified and traced to its origin at each level. This branch is said to be the only branch that passes under the mamillo-accessory ligament.

In the other approach, which proved to be much better, the dissection was carried out through the ventral aspect.
In this approach, the ventral rami were identified first and traced to their origin, wherefrom the spinal nerves were identified. The posterior primary rami and their branches were then traced distally.

This approach in fact, allowed the branches to be studied more accurately. Therefore, this method of dissection was adopted in most of the dissection.

In both the approaches, the dissection was aided by using the dissecting microscope. Extra care was given to the branches of each joint capsule.
This is where the dissecting microscope was used in particular.

(B) Synovial folds or "menisci"

In three lumbar spines, the fibrous capsule of the zygapophysial joint was sectioned to enable the two opposing facet surfaces to be separated as to examine the presence of the synovial folds.
Sectioning was also done through the ligamentum flavum.

(C) Histological investigation

There was no doubt that the major branches of the posterior primary rami were indeed neural structures because of their clear continuity with the spinal nerves. But for the small articular branches, five spinal blocks were cut by means of a band-saw, having the zygapophysial joints with their adjacent soft tissues, and posterior parts of the vertebral bodies and intervening discs, so as to maintain stability of the zygapophysial joints.
The spinal blocks were then bisected. Three in horizontal plane and two in sagittal, to facilitate processing for histological examination.

Three blocks were prepared for Scanning Electron Microscopy (SEM). In two the joints were sectioned to have the opposing facet surfaces separated to examine the presence of synovial folds, which were then processed for SEM (table2.2).

TABLE 2.2

NORMAL PROCESSING OF TISSUE FOR SEM

A) Fixative and Dehydration

1. Tissue is perfusion fixed with buffered 5% Glutaraldehyde or Karnovsky (pH 7.4) when possible.
2. Transfer to pH 7.4 phosphate buffer for 1 hour.
3. Impregnate or post-fix with buffered 1% osmic acid for 30 mins (time dependant on tissue size).
4. Transfer to buffer pH 7.4 as in (2) for 30-60 mins.
5. Dehydrate specimens through one of the following series:
   a) 50% acetone, 1, 2 & 3 acetones, OR
   b) 70%, 90% Alcohol, 1, 2 & 3 absolute alcohols. 1 & 2 amyl acetate.

B) Critical Point Drying

1. Arrange specimens in the baskets and place in the boat which is filled with acetone.
2. Place boat inside chamber and seal door.
3. Open inlet valve and fill chamber with liquid CO2.
4. Run off acetone while keeping chamber filled with CO2 for approx. 4 mins.
5. Close all valves.
6. Flush chamber contents (Liquid CO2/acetone) with fresh CO2 and leave for 30 mins.
7. Repeat stage 6 and drop CO2 until level with the boat.
8. Switch on heater -35^{o} C .

9. Open outlet valve and bring pressure inside chamber to zero.
10. Remove specimens and mount on Stubs.

C) Gold Coating

Specimens are coated with gold to protect biological material from electron beam in a Polaron Sputter Coater.

Specimens are now ready for SEM screening.

The large histological blocks were processed through the stages of decalcification, dehydration and embedding in paraffin. (see table 2.3)

Three spinal blocks were then cut in horizontal plane, and two blocks in sagittal plane.
The thickness of the sections was 6 and 10 microns.
These sections were stained with Masson Trichrome Technique. (see table 2.4)
All the histological slides were examined by light microscopy and photographed using LEITZ VARIO-ORTHOMAT camera, using Vericolor III VPS film.

SCANNING ELECTRON MICROSCOPY (SEM)

Three specimens were processed according to the standard departmental protocol '(table 2.2)', with slight modification. Because our tissue was not impregnated with osmic acid, it was processed with 50% acetone and three changes in absolute acetone, in order to avoid having lipid droplets on the surface.
The specimens after being coated with gold, were examined using JEOL T300 Scanning Microscope, with an accelerating voltage of 30 KV, spot size 7, with varying magnification.
A photographic record was made with a 60 second scan using Technical Pan film TP 120.

TABLE 2.3

DECALCIFICATION AND PROCESSING OF TISSUE

1. Tissue was decalcified using R. D. C. supplied by Cellpath.
2. The tissue was placed in R. D. C. for a maximum of 8 hours then tested to see if decalcification was complete, if not, it was placed in phosphate buffer pH7.4 overnight. This sequence was repeated until we were sure that the tissue was completely decalcified.
3. The tissue was then washed for 12 hours.
4. The tissue was then dehydrated using a series of increasing concentrations of alcohols:
   a) 70% methyl alc. 2 changes total 8 hours.
   b) 90% methyl alc. 2 changes total 8 hours.
   c) Abs ethyl alc + 2% nitrocellulose DHM 10-25, 3 changes total 12 hours.
   d) Amyl acetate 3 changes total 12 hours.
   e) Molten wax 2 changes total 18 hours.
   f) Vacuum in molten wax 1 hour.
   g) Embed in wax.

TABLE 2.4

MASSON TRICHROME TECHNIQUE

1)	Dewax, section to water	
2)	Stain in Weigert's Iron Haematoxylin	20-30 mins.
3)	Wash in water	
4)	Differentiate in acid alcohol	
5)	Blue in tap water until only nuclei are stained	
6)	2% Poncea-fuchsin in 1% acetic acid	30 secs.
7)	Rinse rapidly in water	
8)	1% aqu. Phosphomolybdic	5 mins.
9)	2% Light green in 2% acetic acid 1mm	Build up 1 min. at a time to prevent over-staining. Up to 3 mins.
10)	Dehydrate, clear and mount.	

Results

Nuclei	-Blue - Black
Cytoplasm, muscle and acidophil granules	-Red
Collagen, cartilage, mucin and Basophil granules	-Green

N.B

Weigert Haematoxylin

Solution A

10% Haematoxylin Stock solution	200 ml
Distilled water	1350 ml
Absolute alcohol	450 ml

Solution B

30% Aqueous Ferric Chloride	80 ml
Distilled water	2 Litres
Hydrochloric Acid	20 ml

Mix 50% solution A and 50% solution B prior to staining.

Discard after use.

2.2.2 FRESH SURGICAL MATERIAL

Immediately following the removal at operations, the specimens were immersed in Zamboni's fluid (Stefanini et al., 1967) for 6 hours, after which the specimens were photographed as whole mount, using Wild M-400 camera.
The specimens were subsequently washed for five days in phosphate-buffered saline (0.1M, pH 7.6) containing 15% sucrose and 0.01% sodium azide.

The specimens after being photographed again, were snap frozen in melting isopentane and stored at -70^{o} C until further use.

a) Immunohistochemistry:

30 micron sections were cut on a cryostat, mounted on gelatin/chrome alum coated slides and air-dried for 2 hours prior to processing for immunostaining.
Slides were incubated over-night with antibodies against (PGP 9.5) and Substance P (SP). 'see table 2.5'

Immunohistochemical control studies were carried-out by incubating the slides with phosphate-buffered saline (PBS) (PGP 9.5 and SP).

TABLE 2.5

IMMUNOHISTOCHEMISTRY - PGP 9.5

Methods: At room temperature

- Cut cryostat sections at -25° C. Thaw-mount onto gelatin/chrome alum slides, and leave to dry for two hours

- Rinse with PBS 5 mins.
- Rinse with PBS 5 mins.
- Rinse with PBS 5 mins.

- Neutralise endogenous peroxidase with 1ml hydrogen peroxide in 50ml PBS, for 10 mins. in Coplin jar.

- Rinse with PBS 5 mins.
- Rinse with PBS 5 mins.
- Rinse with PBS 5 mins.

- Incubate overnight with primary antiserum added to the slides at +4° C (in fridge), in moist atmosphere. Different dilutions used (1:500, 1:2000, 1:10,000).

- Rinse with PBS 5 mins.
- Rinse eith PBS 5 mins.
- Rinse with PBS 5 mins.

- Incubate in biotinylated second antibody solution for 60 mins. added to the slide.

  Now make-up ABC complex and allow to stand

- Rinse with PBS 5 mins.
- Rinse with PBS 5 mins.
- Rinse with PBS 5 mins.

- Incubate with ABC reagent for 60 mins.

  Thow phials of DAB (wearing gloves)

- Rinse with PB 5 mins.
- Rinse with PB 5 mins
- Rinse with PB 5 mins.

  While rinsing, prepare DAB (see below recipe)

  Incubate in DAB plus 15ul H_2O_2 (about 2-4 mins.)

- Rinse 3 X 5 mins. in tap water (dispose of DAB contaminated, rinse in bleach)
- Dehydrate and clear.
- Mount in DPX.

Materials

Biotinylated second antibody (from VECTOR kit)

1ml PBS, 15 microlitres goat serum, 5 microlitres biotinylated antibody.

ABC complex (from VECTOR kit)

1ml PBS, 10 microlitres solution A + 10 microlitres solution B, mix immediately. Allow to stand for 30 mins.

DAB solution

50ml Phosphate Buffer, mix with 1 vial of DAB (thawed) from fridge freezer, filtered directly into Coplin jar, add 15 microlitres hydrogen peroxide to Coplin jar while filtration in process.

b) Silver Staining

10 to 15 micron cryostat sections were processed for silver staining, using Palmgren's method for nerve fibres. ' see table 2.6 '

2.2.3 SKELETAL SPECIMENS OF THE HUMAN VERTEBRAE

Examination for the prevalence of ossification of the mamillo-accessory ligament was made on 224 sets of lumbar vertebrae obtained from the departmental collections.

No information was available on the age or sex distribution of the samples.
Ossification of the ligament was considered to have occurred if spicules of bone, stemming from the mamillary process were observed to be directed towards the accessory process, and vice versa.

The extent of ossification was classified as:-

a) Open Notch:

   No identifiable spicules.

b) 1/2 Circle Notch:

   Spicules were observed, but the groove was wide open

c) 3/4 Circle:

Were at least 3/4 of the circle was bony.

d) Bony Foramen:

Where a complete bar of bone, regardless of thickness, bridged over the mamillary and the accessory processes, converting the notch into a foramen. 'see figure 2.1'

(A) Measurement of the mamillo-accessory foramen

Linseed oil "Putty" was used in this process, since it did not stick to the bone and did not shrink in size after being dry.

To get the proper interior size of the foramen, putty was pressed into the foramen and gently pulled out. The size of the oval shape foramen was then taken by using a micrometer.

TABLE 2.6

PALMGREN'S METHOD FOR NERVE FIBRES (1948)

Fixation

Formal saline or Bouin's fixative (Zamboni, is modified from Bouin's fixative)

Preparation of solution

a. Acid formalin

40% formaldehyde	25 cm^3
Distilled water	75 cm^3
1% nitric acid	0.2 cm^3

b. Silver solution

Silver nitrate	15 g
Potassium nitrate	10 g
Distilled water	100 cm^3
5% amino acetic acid	1 cm^3

c. Reducer

Pyrogallol	10 g
Distilled water	450 cm^3
Absolute ethyl alcohol	550 cm^3
1% nitric acid	2 cm^3

Allow to stand for 24 hours before using

d. Toning bath

Gold chloride	1 g
Distilled water	200 cm^3
Glacial acetic acid	0.2 cm^3

e. Intensifier

50% ethyl alcohol	100 cm^3
Aniline Oil	2 drops

f. Fixing bath

5% sodium thiosulphate

Method:

1. Take sections to distilled water.
2. Wash sections in acid formalin for 5 minutes or longer.
3. Wash in three changes of distilled water for 5 minutes.
4. Leave in silver solution for 15 minutes at 20-25^{o}C or 4-5 minutes at 35^{o}C.
5. Without rinsing, drain the slide and add reducer that has been heated to 40-45^{o}C. Rock the slide gently and add fresh reducer. Leave for 1 minute. A beaker placed on a hotplate is useful for this stage.
6. Rinse in 50% alcohol for 5-10 seconds.
7. Wash in three changes of distilled water. Examine microscopically and if necessary, repeat from stage 2, reducing the time in the silver solution and decreasing the temperature of the reducer to 30^{o}C.

8. Tone in gold chloride until yellow brown has faded.
9. Transfer directly into intensifier for 15 seconds or longer. Sections which contain nervous tissues only should be intensified after previously rinsing in 2% oxalic acid.
10. Wash in tap water.
11. Fix for a few seconds in 5% sodium thiosuphate.
12. Wash in water.
13. Dehydrate, clear and mount.

Results:

Nerve fibres - brown or black

FIGURE: 2.1

Ossification of the mamillo-accessory ligament

(A) Complete ossification

(mamillo-accessory foramen)

(B) Partial ossification

(3/4 circle - mamillo-accessory notch)

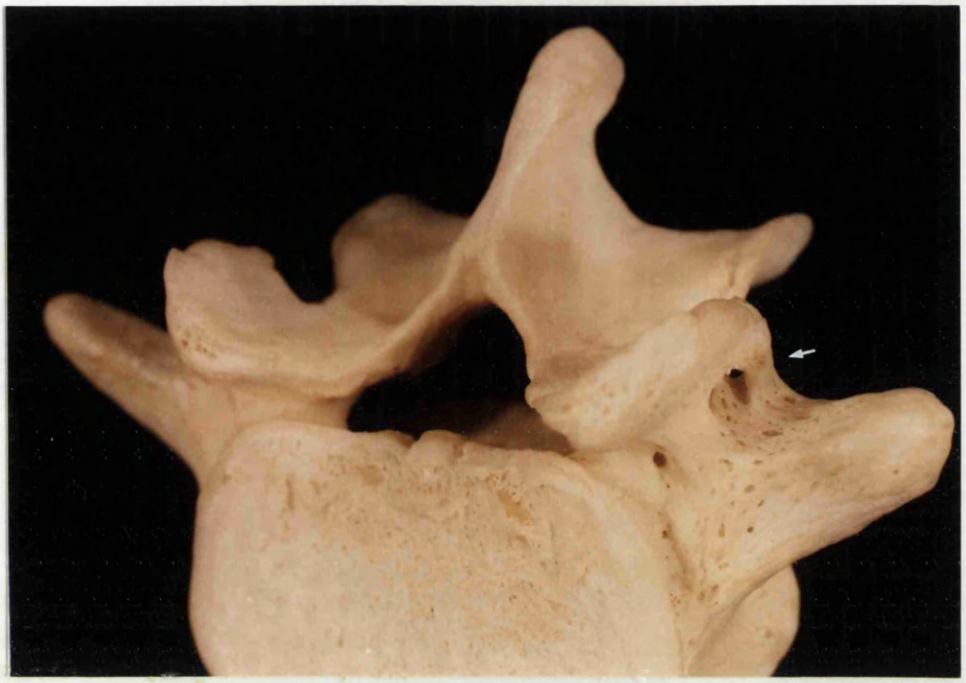
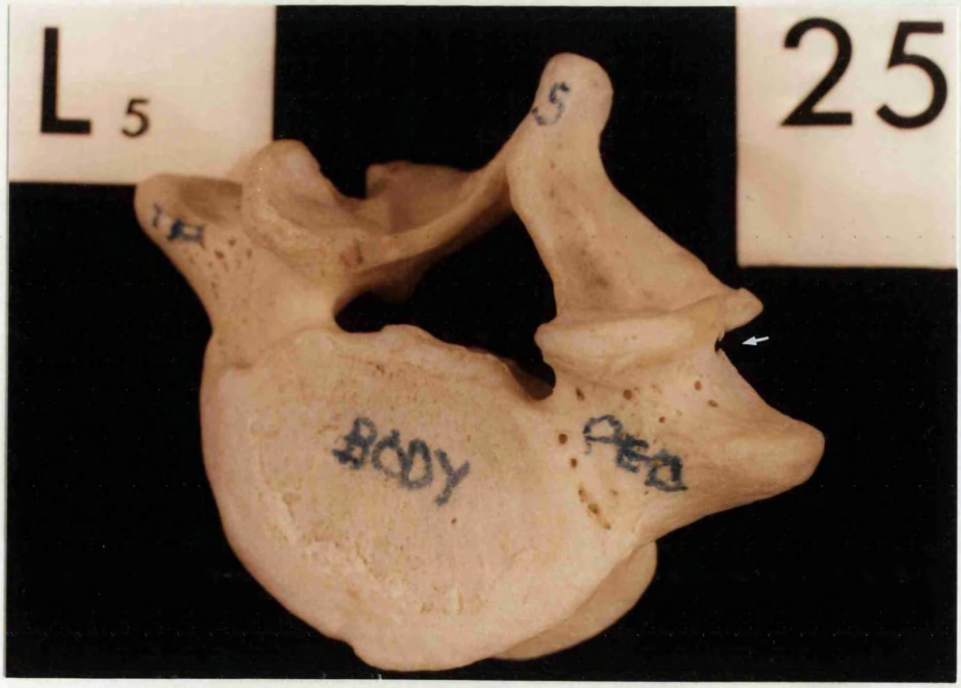


Figure 2-1 (A)



(B)

RESULTS

CHAPTER III

RESULTS

3.1 CADAVERIC LUMBAR SPINES FROM ADULTS

3.1.1 GROSS DISSECTION OF THE SPINAL NERVES WITH PARTICULAR REFERENCE TO THE POSTERIOR PRIMARY RAMI

Each lumbar nerve emerges from the upper part of the intervertebral canal, just below the pedicle, behind the vertebral body.
As it emerges from the intervertebral canal, the nerve divides into anterior and posterior primary rami.(figure 3.1a & b)

The distribution of the anterior primary rami has not been explored in this thesis.

The posterior primary ramus (PPR) always projected at less than 90^{o}angle to the spinal nerve.
Each PPR is about 5mm long, which is much shorter than the anterior primary ramus. It runs downwards and backwards, passing through an oval opening just medial to the medially extending fascial component of the intertransverse ligament (Lewin, 1962; Bradley, 1974).

FIGURE: 3.1 (A)

Origin of the posterior primary ramus (ppr) at less than 90^{o} angle.

ib : intermediate branch

ib : lateral branch

(B)

Division of the posterior primary ramus, into the medial branch (mb), intermediate branch (ib) and the lateral branch (lb).

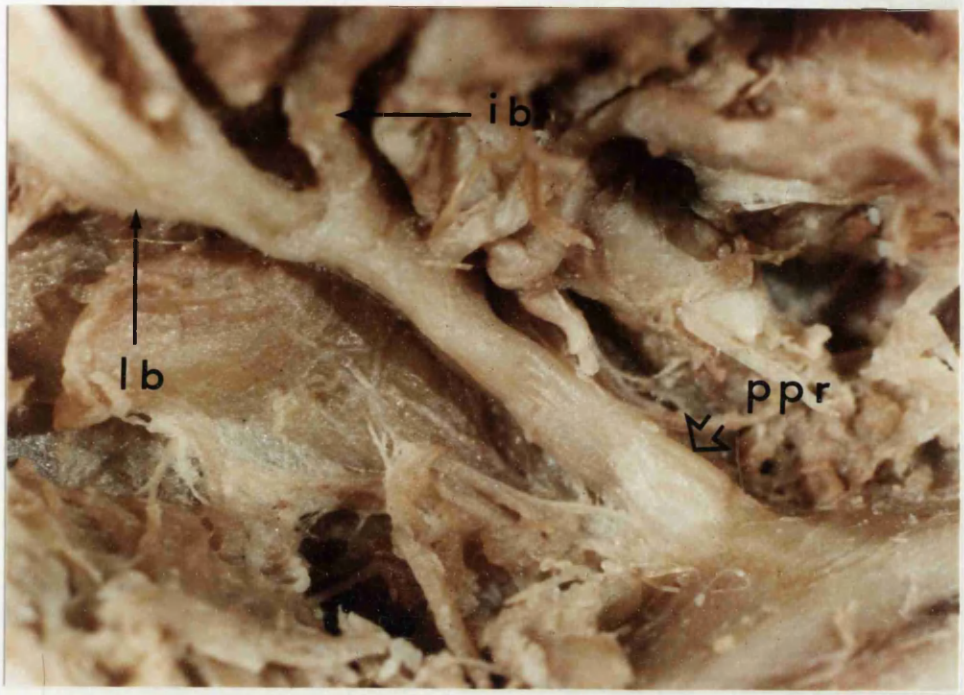
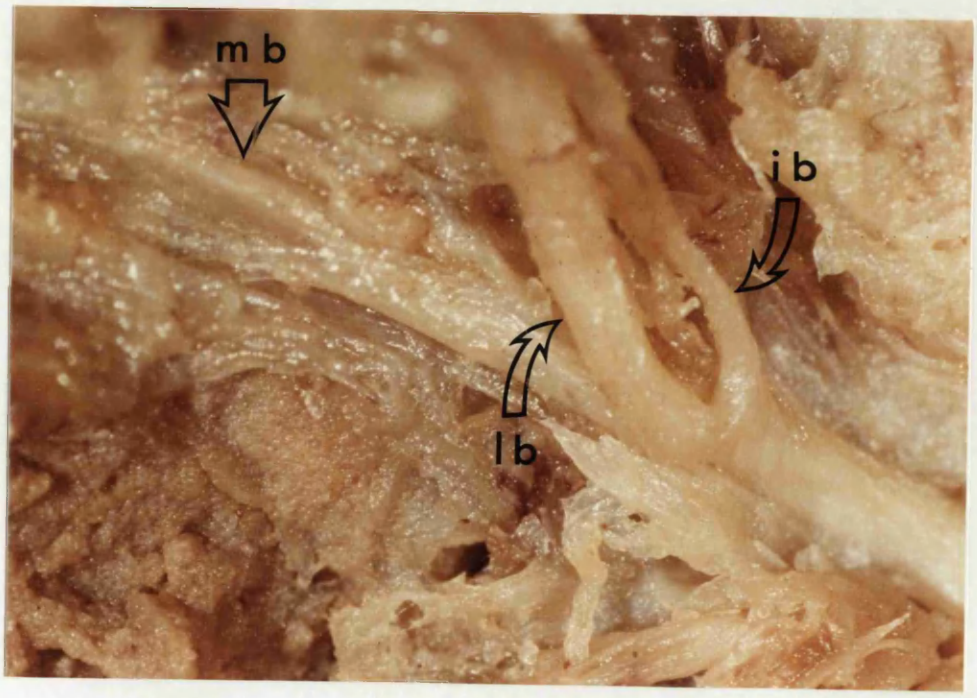


Figure 3-1 (A)



(B)

This compartment is bounded by the concave inner edge of the intertransverse ligament and the superior articular process. Our findings agree with the fascia described by Lewin (1962)

While in this compartment, and before it comes to lie above the origin of the transverse process, the posterior primary ramus divides into three branches; the medial, lateral and intermediate. The intermediate is found sometimes being in a common stem with the lateral branch.

The posterior primary ramus gives rise to several muscular branches before dividing. The first of these branches is a small nerve that passes upwards and dorsally. Nowhere in its course it is in contact with the bone.(figure 3.2a & b)
This branch was found consistently whenever appropriate care was exercised. It is about 1cm long, and very thin, like a cotton thread.
In our finding, this is a muscular branch supplying the multifidus muscle, as it ends in it well before reaching the zygapophysial joint capsule.
Just distal to this branch, and before the division of the posterior primary ramus, one or two consistent muscular branches are given off which pass directly back to the multifidus muscle as well. (figure 3.3)

FIGURE: 3.2 (A)

A very small and thin muscular branch (a) arising from the posterior primary ramus (ppr) at L3-4 level.

(B)

A muscular branch (a) runs on the fibres of the intertransversarii mediales having no contact with the bone.

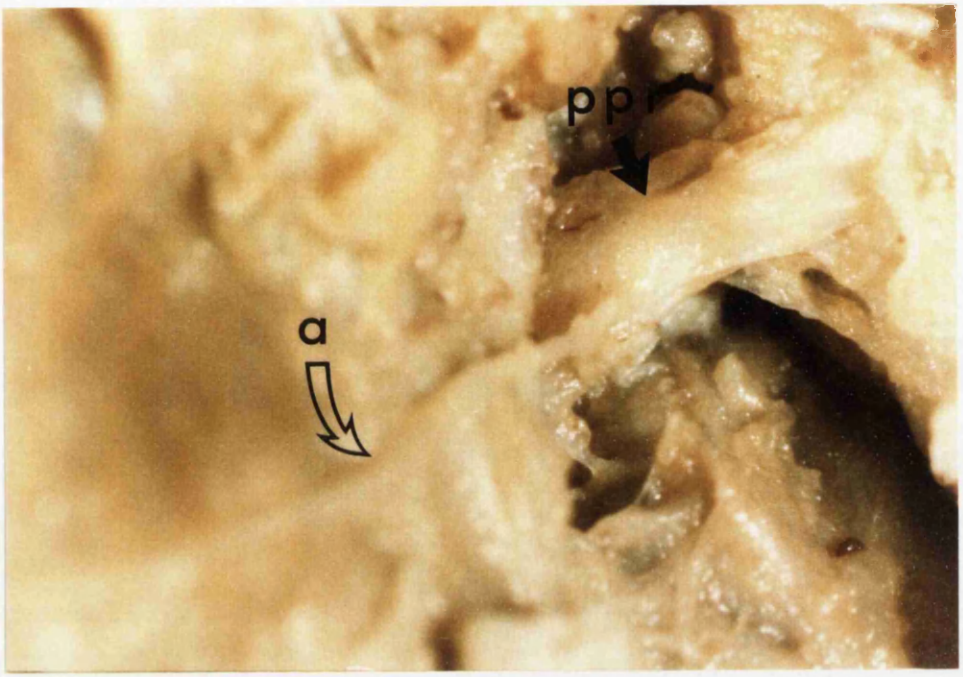
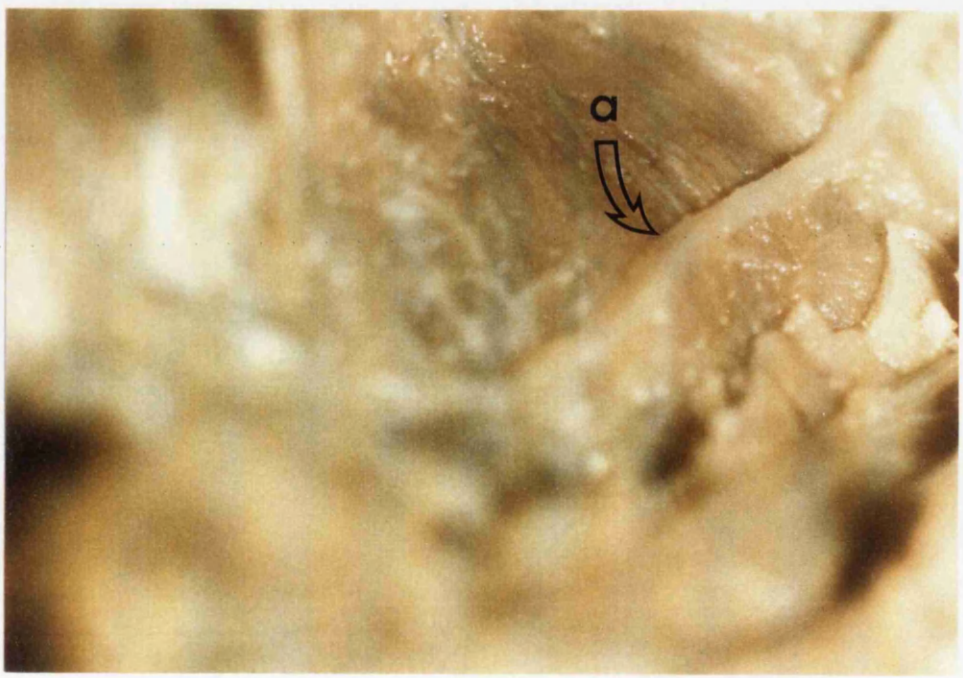


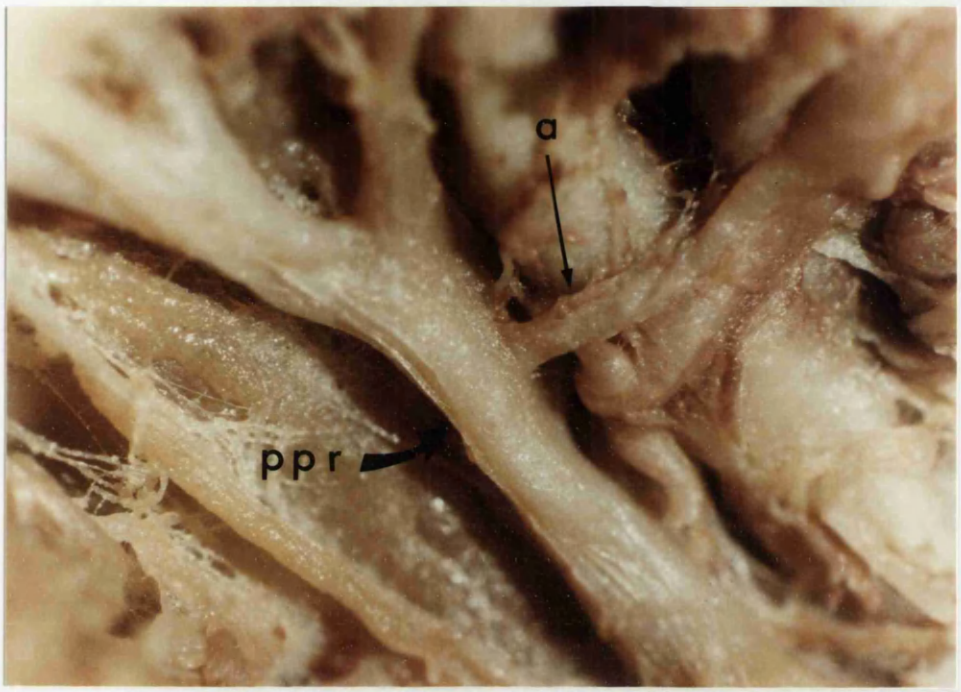
Figure 3-2 (A)



(B)

FIGURE: 3.3

A muscular branch (a) is seen originating from the posterior primary ramus (ppr) at L3-4 level.



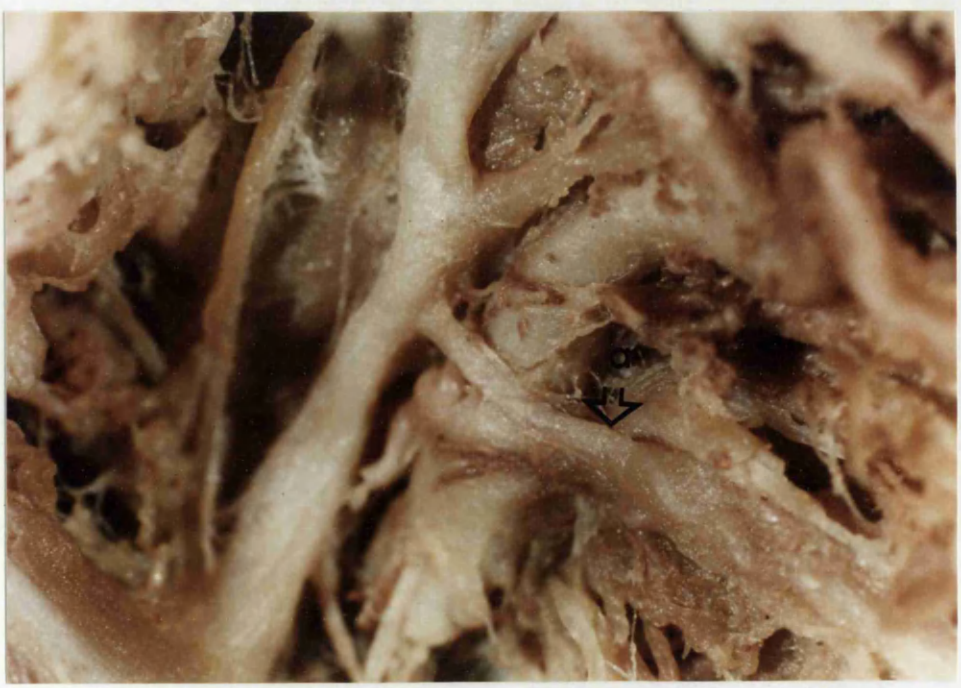


Figure 3-3

The Lateral Branch:

The lateral branch crosses on the lateral aspect of the transverse process approximately opposite the level of the accessory process, and goes to supply the iliocostalis. After innervating this muscle, it emerges from its dorsolateral surface, pierces the posterior layer of the thoracolumbar fascia and becomes cutaneous.

The Intermediate Branch:

The intermediate branch runs postero-inferiorly from the intertransverse space to be distributed to the lumbar fibres of longissimus thoracis muscle.

Just proximal to the origin of the medial branch, each posterior primary ramus gives off a tiny branch to the intertransversarii mediales. (figure 3.4)
This branch, as it arises from the most medial funiculi of the posterior primary ramus, does have an appearance of being an early branch of the medial branch.

FIGURE: 3.4

The nerve to intertransversarii mediales (nim) is seen arising close to the medial branch of the posterior primary ramus (ppr).

mb : medial branch

ib : lateral branch

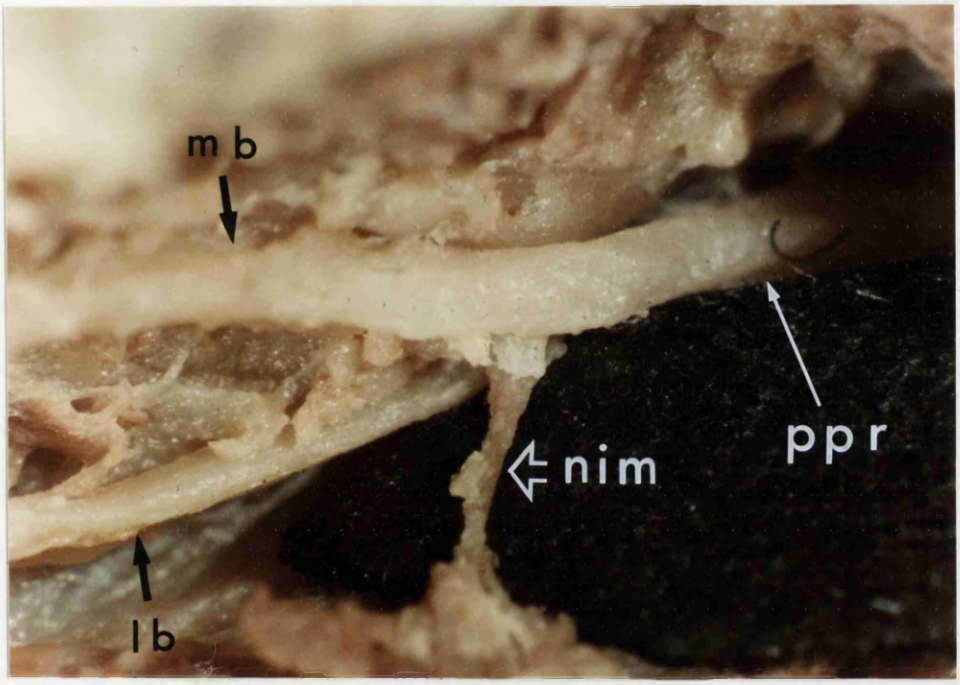


Figure 3-4

The Medial Branch:

This branch has been of particular interest to those interested in the innervation of the zygapophysial joints. This is the only branch that has received any attention from those who attempt denervation.

Each definitive medial branch of the posterior primary ramus passes posteriorly and inferiorly lying first at the junction of the root of the transverse process where it joins with the base of the superior articular process.
After a short course of about 4mm, and opposite the inferior border of the zygapophysial joint, the medial branch turns medially to enter a depression formed between the mamillary process and the accessory process.(figure 3.5 & 3.6)
These two prominences form a shallow fibro-osseous canal of 1mm to 4mm in length through which the medial branch passes. The mamillo-accessory ligament bridges these two processes. This ligament on occasions may ossify, thus transforming the canal into a bony foramen.

Upon leaving the canal, the medial branch of the posterior primary ramus runs medially and downwards across the vertebral lamina. (figure 3.7 & 3.8)
It lies deep to the multifidus, and is embedded in loose areolar and adipose tissue.
In this area, where the most difficult part of the dissection comes, the medial branch gives its articular

FIGURE: 3.5

Dorsolateral view showing the origin of the medial branch (mb) from the posterior primary ramus (ppr).
The lateral branch (lb) and the intermediate branch (ib) are also seen arising from (ppr).
tp : root of the transverse process

FIGURE: 3.6

Dorsolateral view of the proximal part of the medial branch (mb) on its course passing under the mamillo-accessory ligament (mal) which bridges between the mamillary process (mp) and the accessory process (ap).

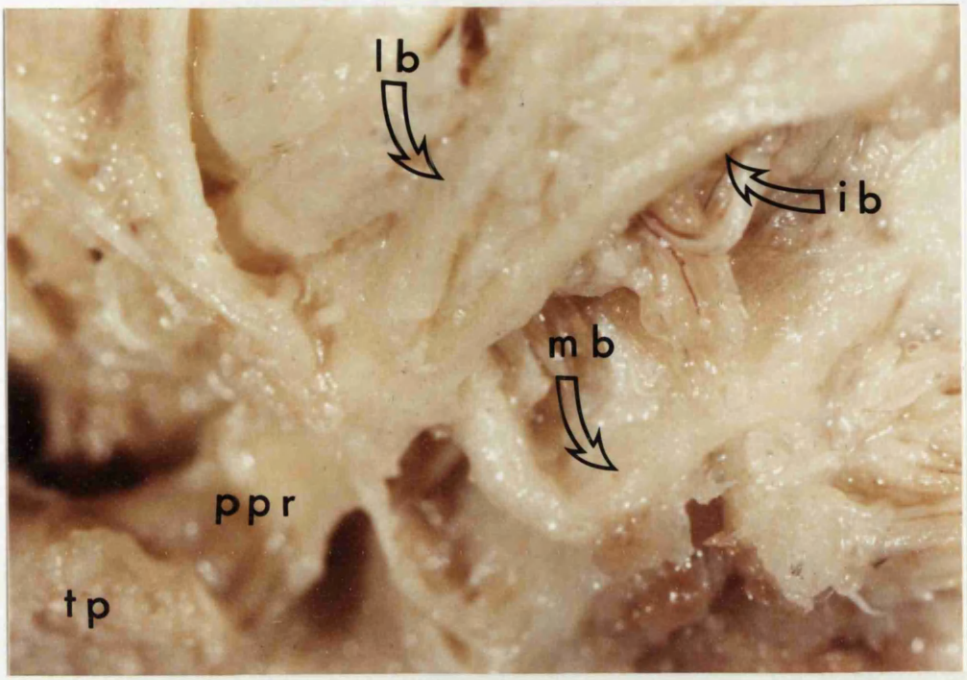


Figure 3-5

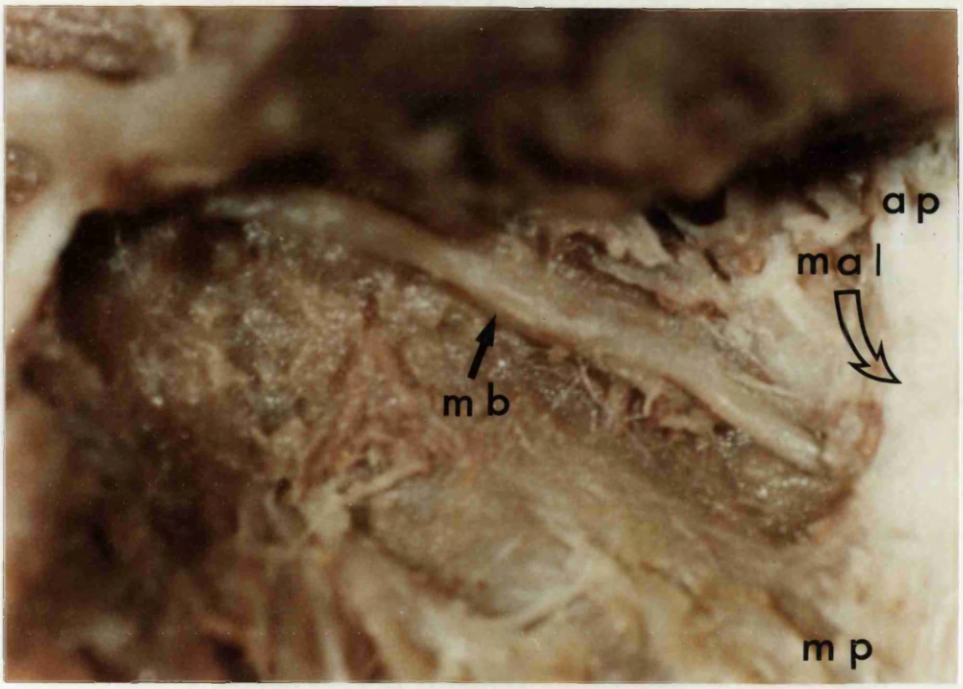


Figure 3-6

FIGURE: 3.7

Dorsal view of the course of the medial branch (mb) under the mamillo-accessory ligament (mal).

mp : mamillary process

ap : accessory process

FIGURE: 3.8

Dorsal view of the distal course of the medial branch (mb) of the posterior primary ramus.
The proximal branch (p) arises from the medial branch and innervates the adjacent zygapophysial joint (zj).

vl : vertebral lamina

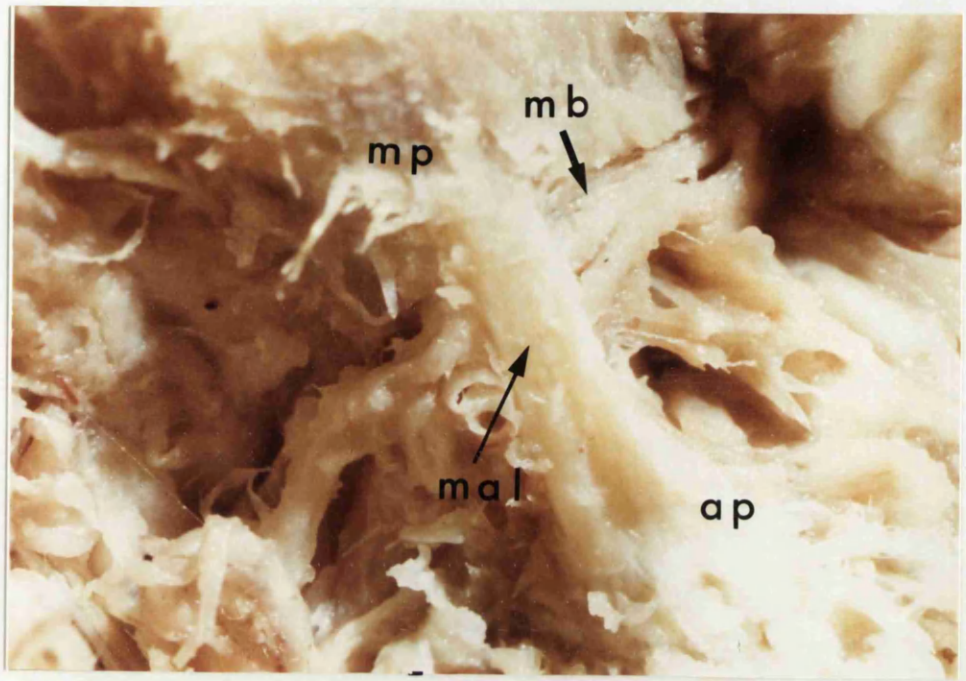


Figure 3-7

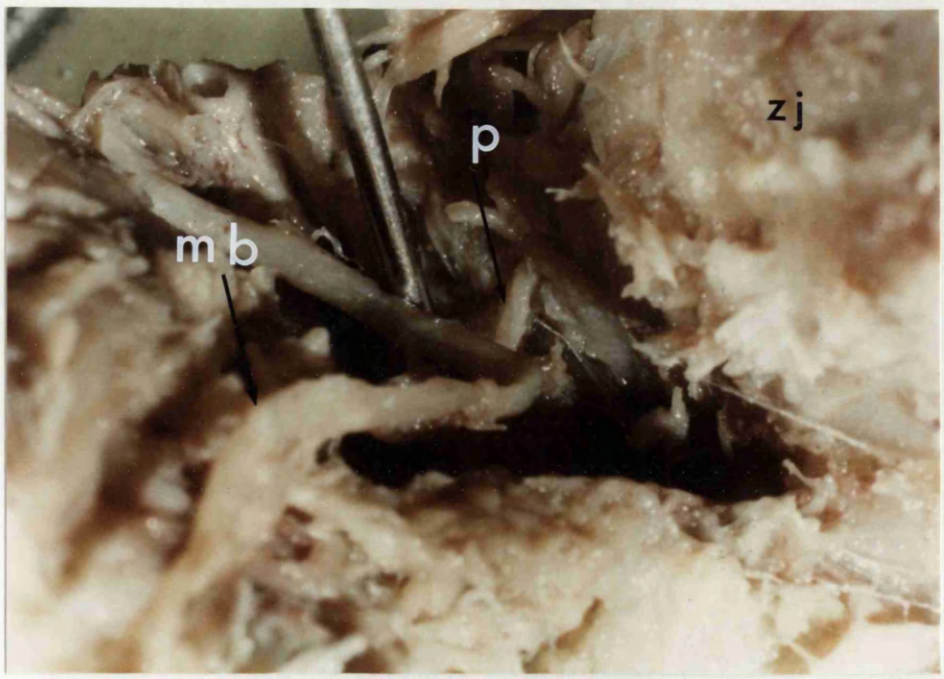


Figure 3-8

branches to the zygapophysial joints and is where an interspinous branch arises.

The first branch of the medial branch of PPR goes to the adjacent zygapophysial joint as the proximal branch, and innervates the inferior part of the joint capsule.

The second branch goes to the superior aspect of the zygapophysial joint capsule one segment lower, as the distal branch. This branch runs deep to the fibres of multifidus which cover the zygapophysial joint. (figures 3.9a & b, 3.10a & b)

The interspinous branch (figure 3.11) leaves the medial branch and weaves medially between the fascicles of multifidus to innervate the interspinous muscle and ligament.

The medial branch on its course sends a fasciculus to the under lying base of the superior articular process, proximal to the mamillo-accessory ligament. (figure 3.12)

The medial branch itself, ultimately enters the multifidus muscle through its deep surface.

In four cadavers, the medial branch of the posterior primary ramus divided into two branches that ran together along the whole course of the normal medial branch, even under the mamillo-accessory ligament, and reunited before giving the articular branches. (figures 3.13a & b,3.14a & b)

FIGURE: 3.9 (A) & (B)

The proximal branch (p) of the medial branch (mb) of the posterior primary ramus innervates the inferior portion of the adjacent zygapophysial joint.

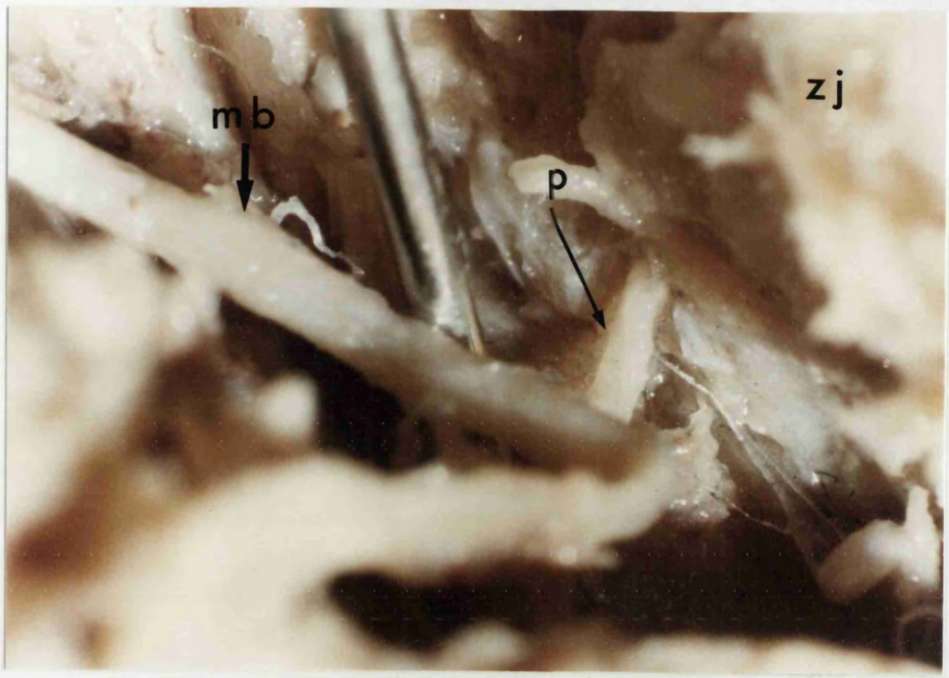
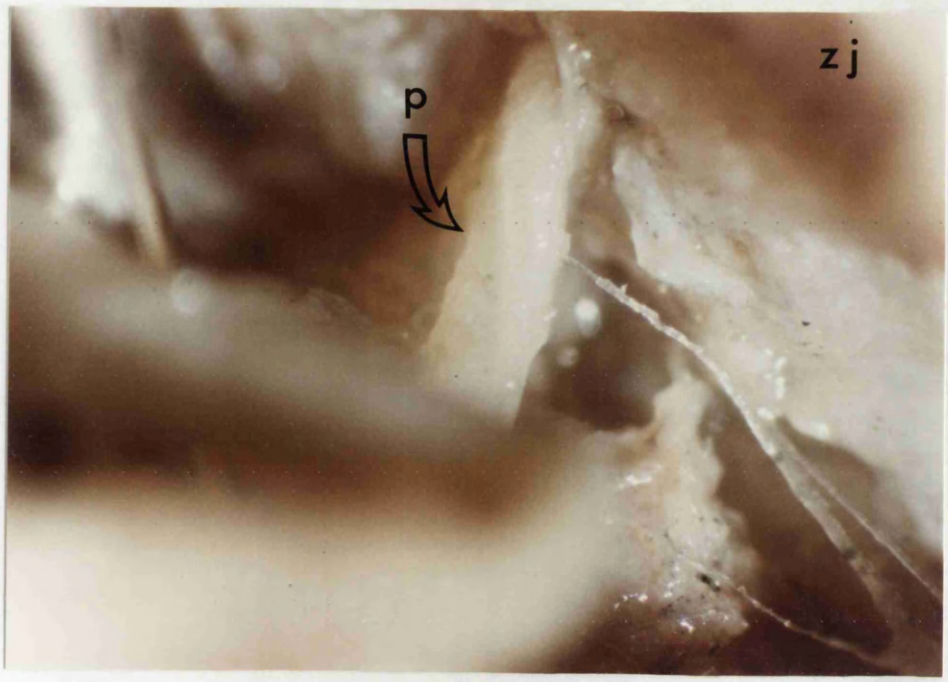


Figure 3 - 9 (A)



(B)

FIGURE: 3.10

(A) shows the proximal branch (p) of the medial branch (mb) innervating the inferior portion of the zygapophysial joint at the same level.

(B) shows the distal branch (d) arising from the medial branch (mb) running towards to zygapophysial joint one level below to innervate its superior surface.

See figure 3.18

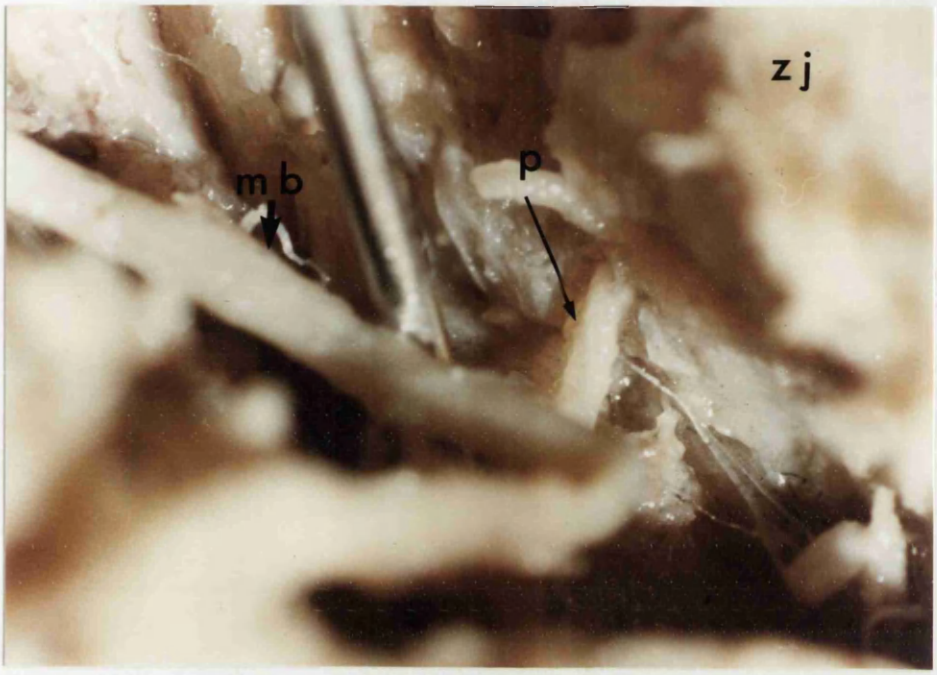


Figure 3-10 (A)

(B)

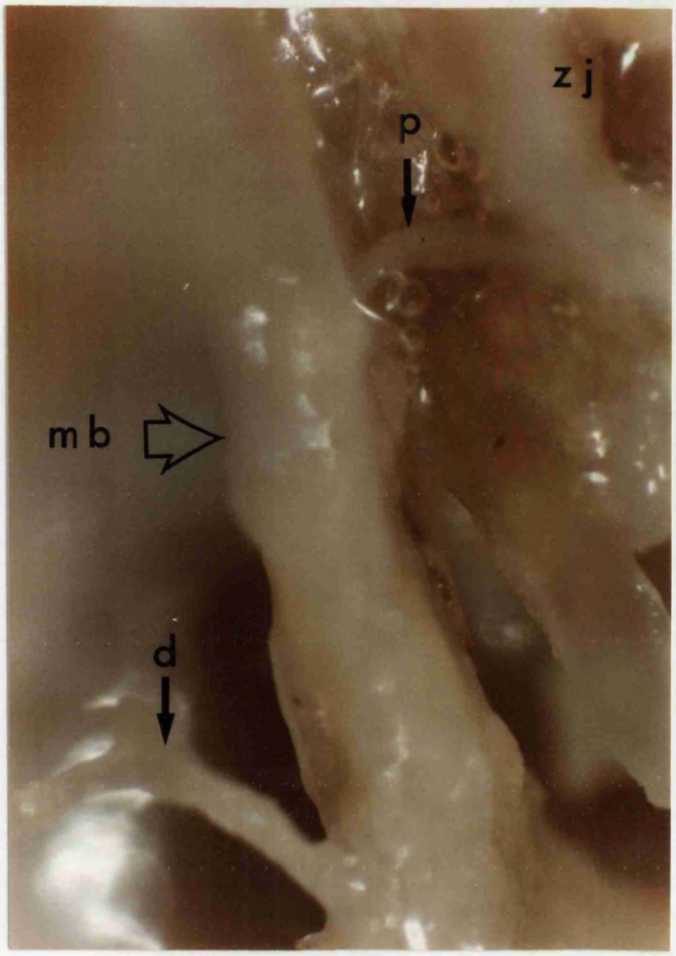


FIGURE: 3.11

Dorsal view of the interspinous branch (is) from the medial branch.
The medial branch (mb) runs to the multifidus (M) and remains wholly within its fascicles.

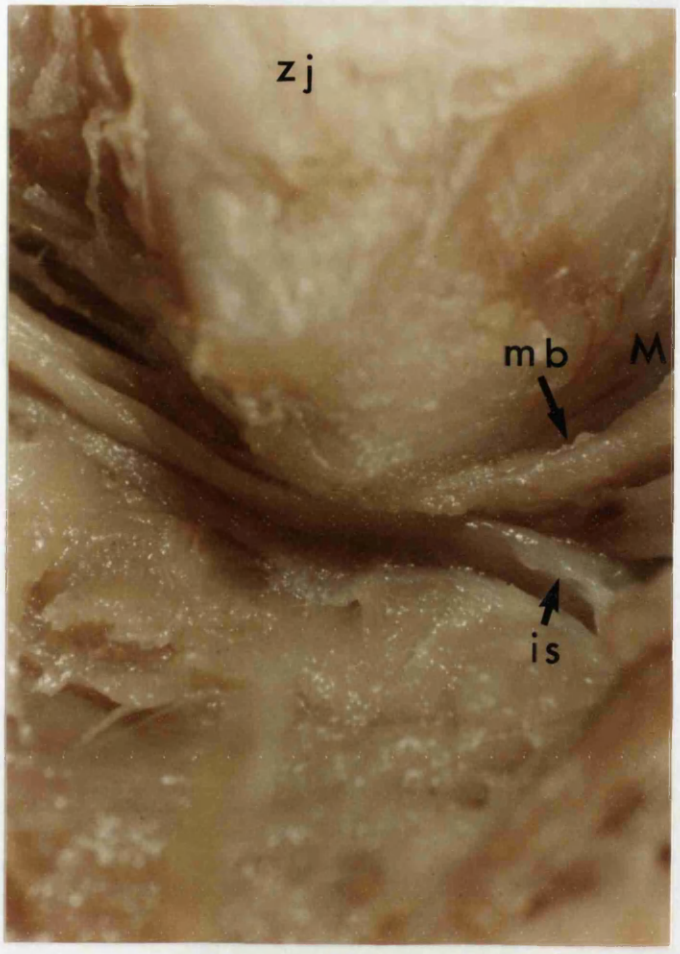


Figure 3-11

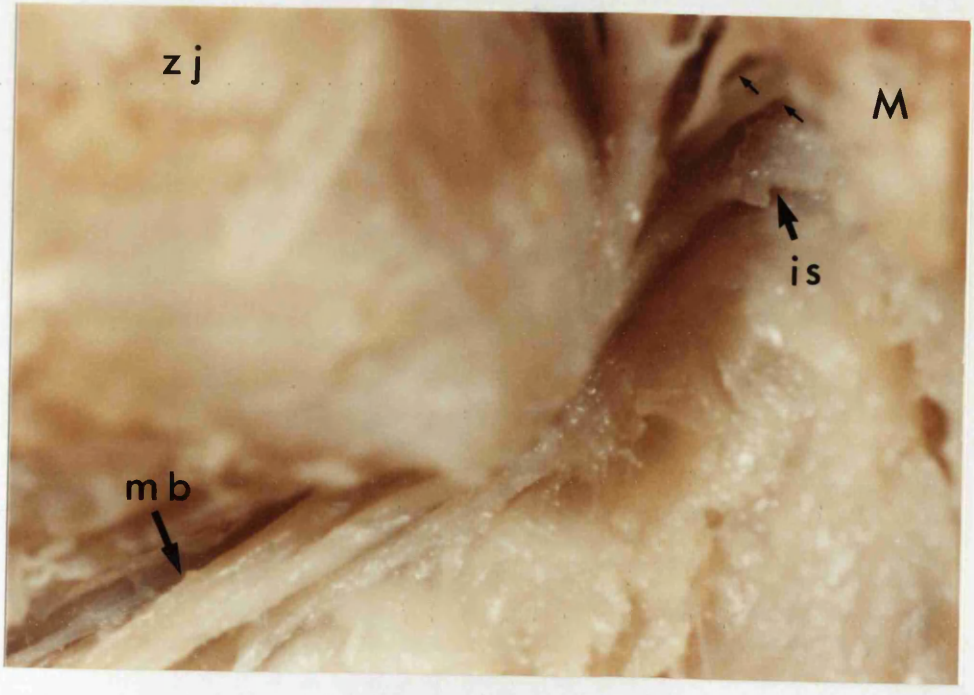


FIGURE: 3.12

The medial branch (mb) sends a fascicle (f) to the underlying base of the superior articular process on its course towards the mamillo-accessory ligament.

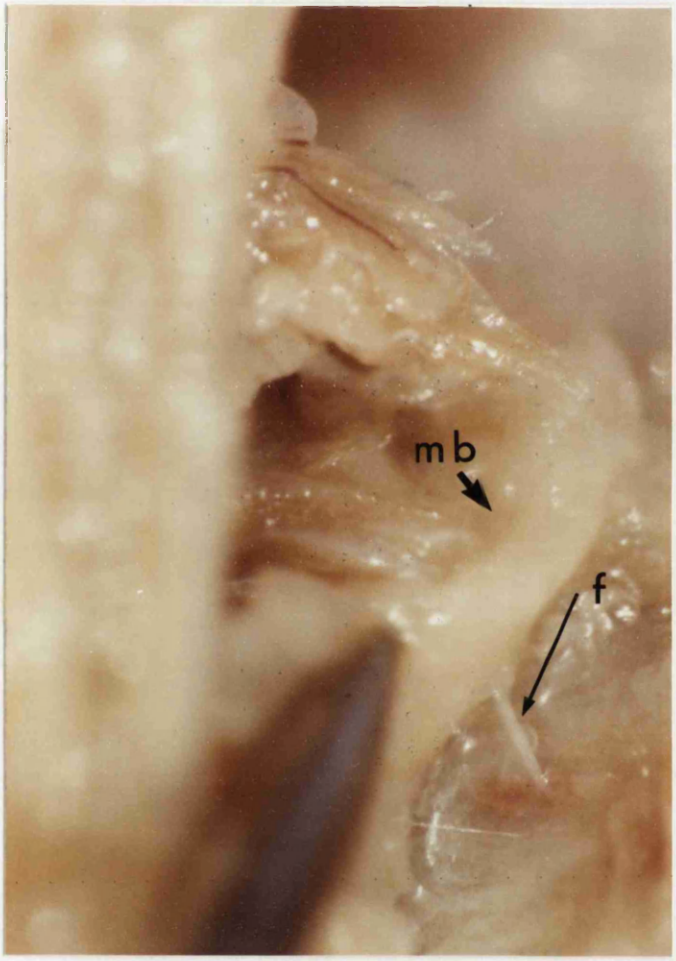


Figure 3-12

FIGURE: 3.13

(A) Dorsal view of the paired medial branch (mb) under the mamillo-accessory ligament (mal). The proximal branch (p) is also seen arising from the distal part of the medial branch.

(B) The paired medial branch (mb) seen as the mamillo-accessory ligament (mal) is removed from one side

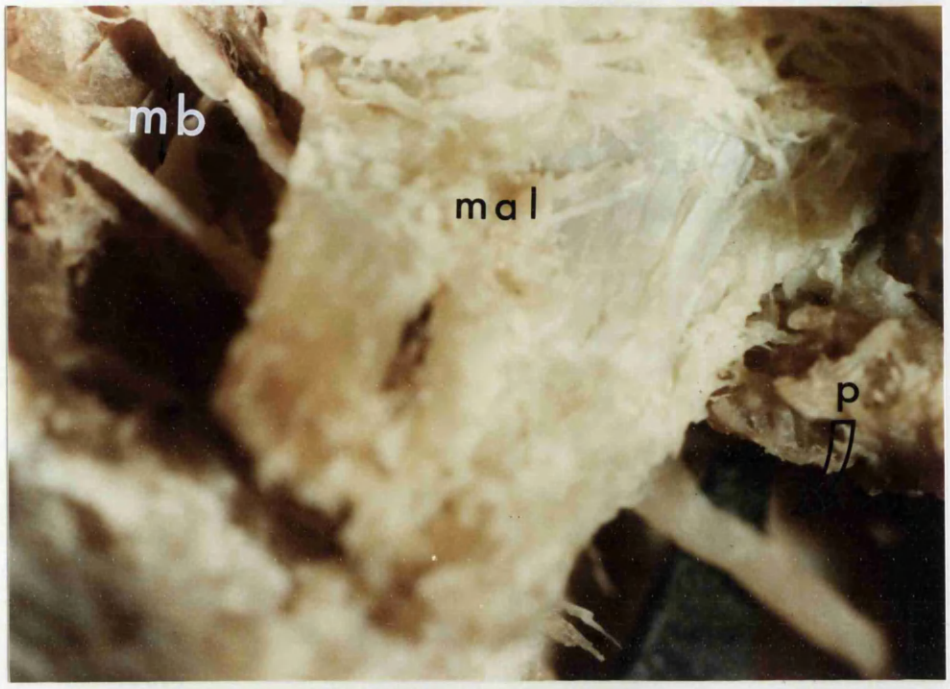
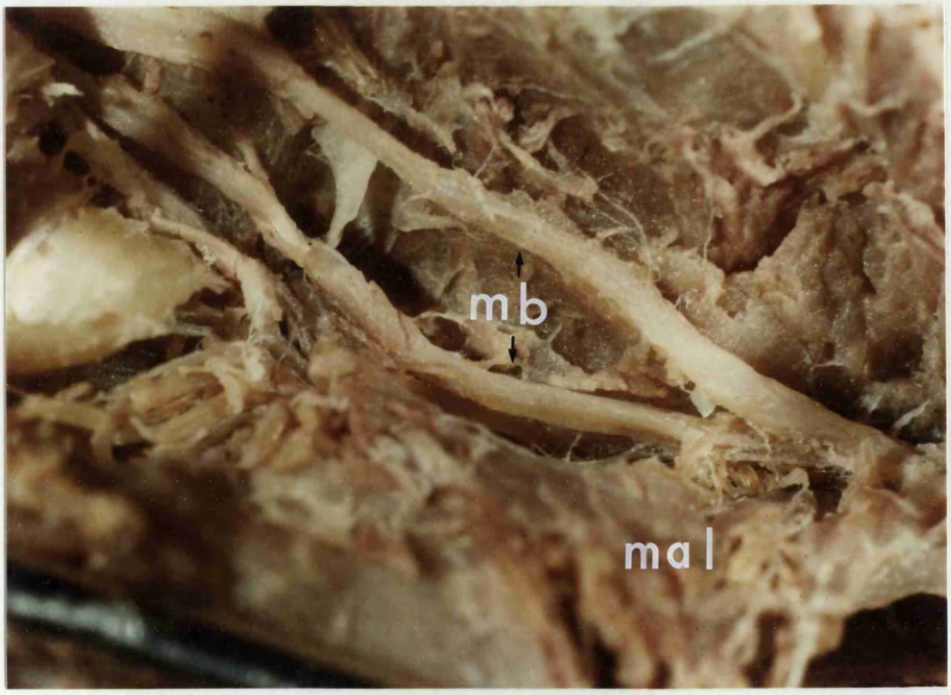


Figure 3-13 (A)



(B)

FIGURE: 3.14

(A) A closer view of the paired medial branch in the mamillo-accessory groove.

(B) The medial branch removed with its origin from the posterior primary ramus, showing the whole length of this bifurcation.

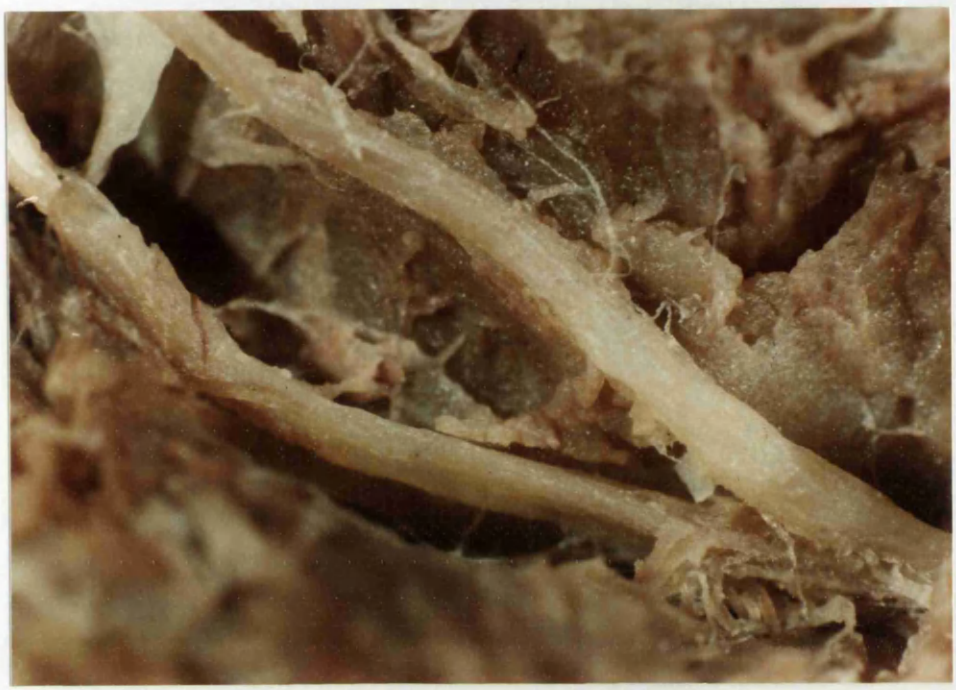


Figure 3-14 (A)

(B)

The L5 Posterior Primary Ramus:

The posterior primary ramus at L5 level, passes posteriorly and enters a long tunnel or rather a groove formed by the junction of the ala of the sacrum and the root of the superior articular process. It is therefore, considered a longer nerve than those at the higher levels. (figure 3.15a & b). Along its course, the posterior primary ramus divides into two branches; a medial and an intermediate, rather than having a lateral branch. This is because the intermediate branch innervates the longissimus thoracis which arises from the medial aspect of the dorsal segment of the iliac crest.

The medial branch curves medially around the inferior aspect of the lumbosacral zygapophysial joint, innervates it and ends in the multifidus.

3.1.2 STUDIES OF THE ZYGAPOPHYSIAL JOINTS AND THEIR RELATED STRUCTURES

A) THE CAPSULAR PART OF THE ZYGAPOPHYSIAL JOINT

The anatomy of the fibrous joint capsule and ligamentum flavum has been described and reviewed earlier.
The ligamentum flavum divides into a medial and a lateral

FIGURE: 3.15

(A) The L5 posterior primary ramus (ppr) is longer than the L1-4 posterior primary rami.

(B) Dorsolateral view showing the L5 posterior primary ramus (ppr) dividing into two branches, the medial branch (mb) and the intermediate branch (ib).

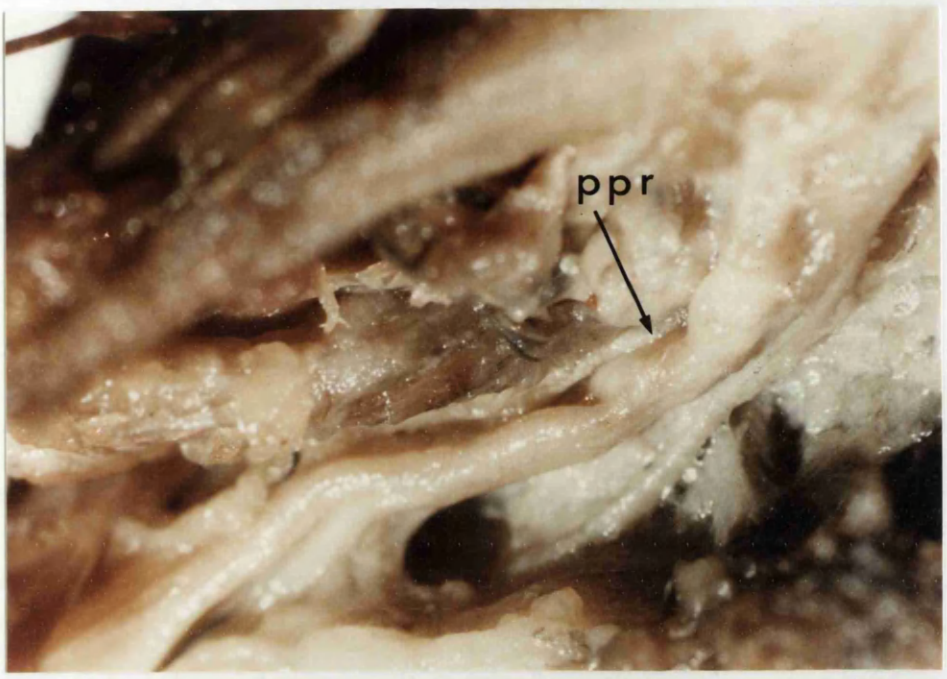
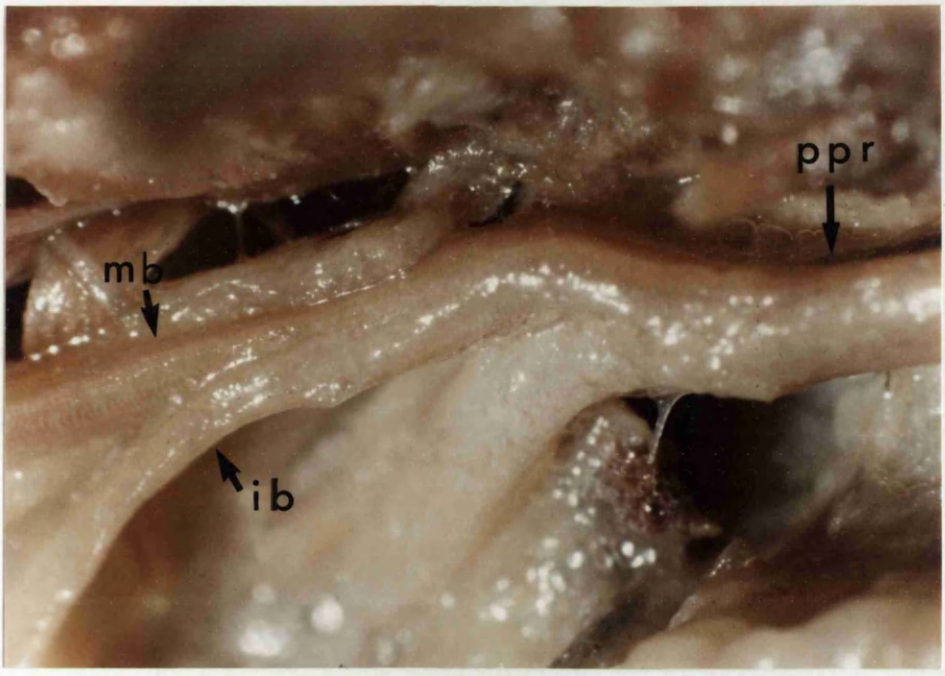


Figure 3-15 (A)



(B)

portion. The medial portion passes to the back of the next lower lamina, whereas the lateral portion passes in front of the zygapophysial joint and attaches to the anterior aspect of the inferior and superior articular processes of that joint and forms its anterior capsule. (figure 3.16)
The superior and inferior margins of the joint at the dorsal aspect are formed by a fibrous capsule. (figure 3.17a & b).

The supero-ventral and infero-dorsal poles of the joint contain adipose tissue pad, whereas the inner surface of the superior and inferior capsules project leaf-like folds of synovium that contains fat, collagen and some blood vessels known as synovial folds or menisci.

The superior surface of the zygapophysial joint capsule in innervated by the distal branch of the medial branch of the posterior primary ramus one level higher.
The inferior surface of the joint is innervated by the proximal branch of the medial branch of the posterior primary ramus of the same level. (figure 3.18 & 3.19)
The age changes noted in the articular cartilage showing increase in the vertical fibrillation of the cartilage are probably due to compressive load. Splitting of the articular cartilage parallel to the cartilage has also occurred. (figure 3.20). This supports the findings of Taylor and Twomey (1986).
The articular cartilage seen in figure 3.21, has been reflected around the bone end on the posterior aspect of the

FIGURE: 3.16

The ligamentum flavum (LF) forms the ventral capsule of the zygapophysial joint (arrow).
The vertebral bodies have been removed, to view the structures antero-posteriorly.

P : pedicle

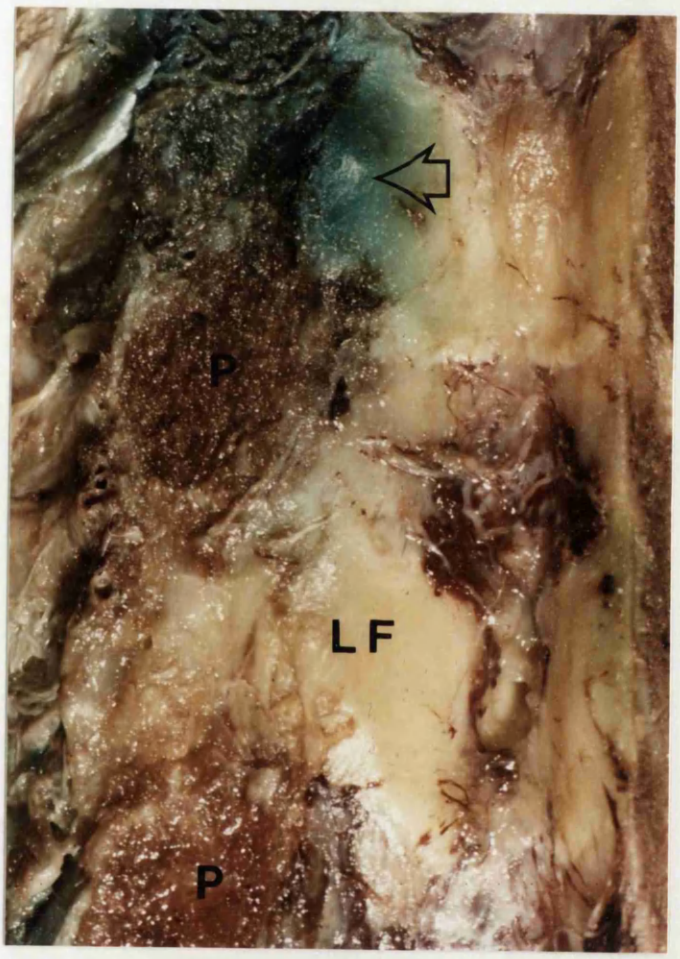


Figure 3-16

FIGURE: 3.17

(A) The ligamentum flavum (LF) forms the ventral capsule of the zygapophysial joints.

(B) The posterior joint capsule (JC) is fibrous.

SF : synovial fold

The following diagram shows the whole joint:

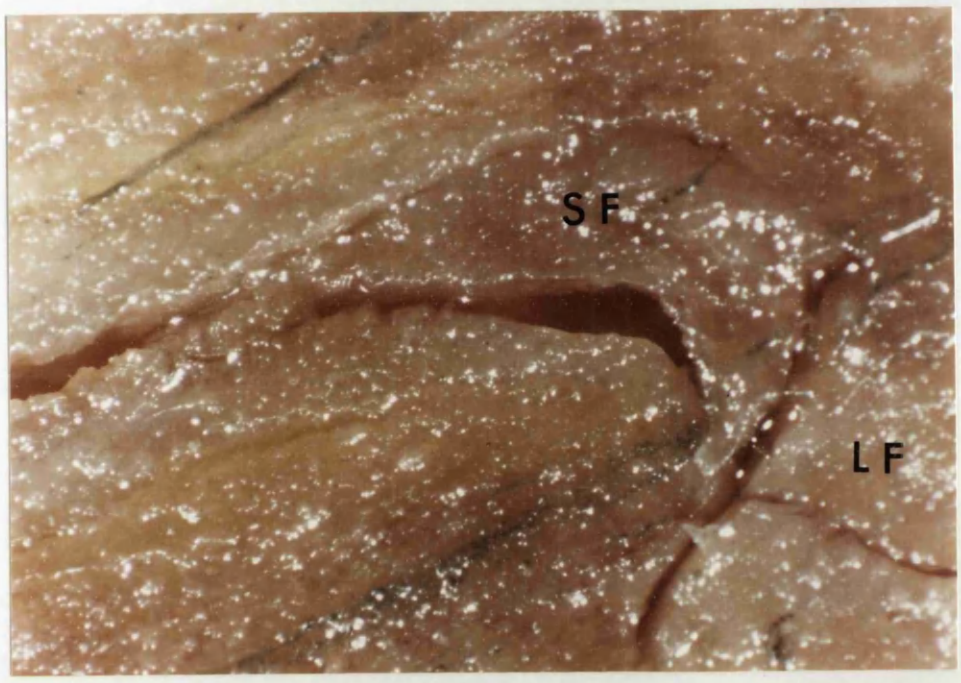
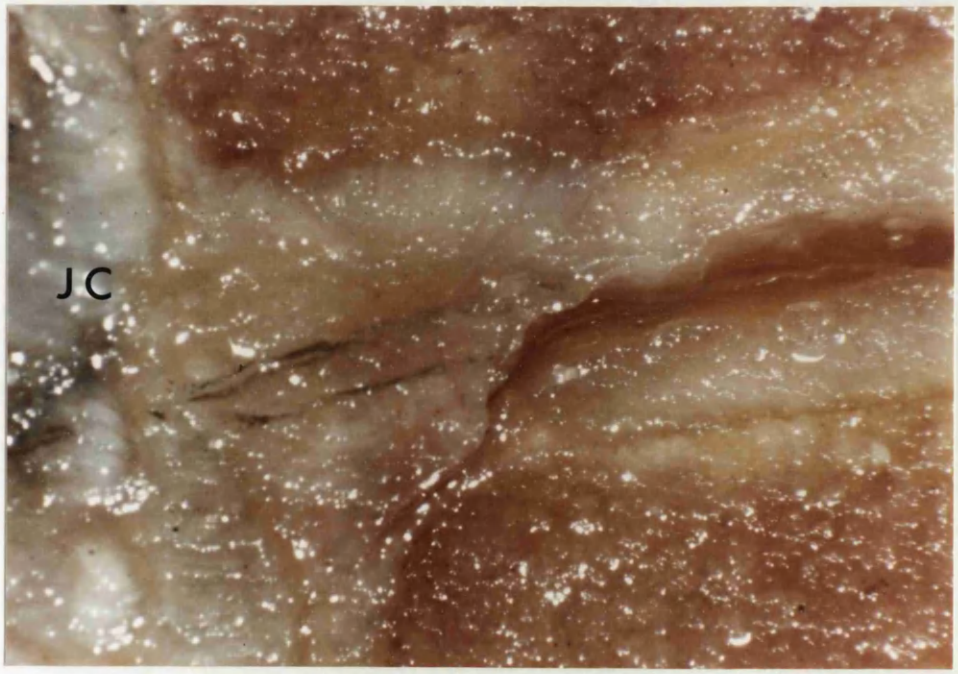


Figure 3-17 (A)



(B)

FIGURE: 3.18

The proximal (p) and the distal (d) branches are seen arising from the medial branch (mb).
The proximal branch innervates the inferior portion of the zygapophysial joint capsule at the same level, whereas the distal branch innervates the superior portion of the zygapophysial joint capsule one level lower.

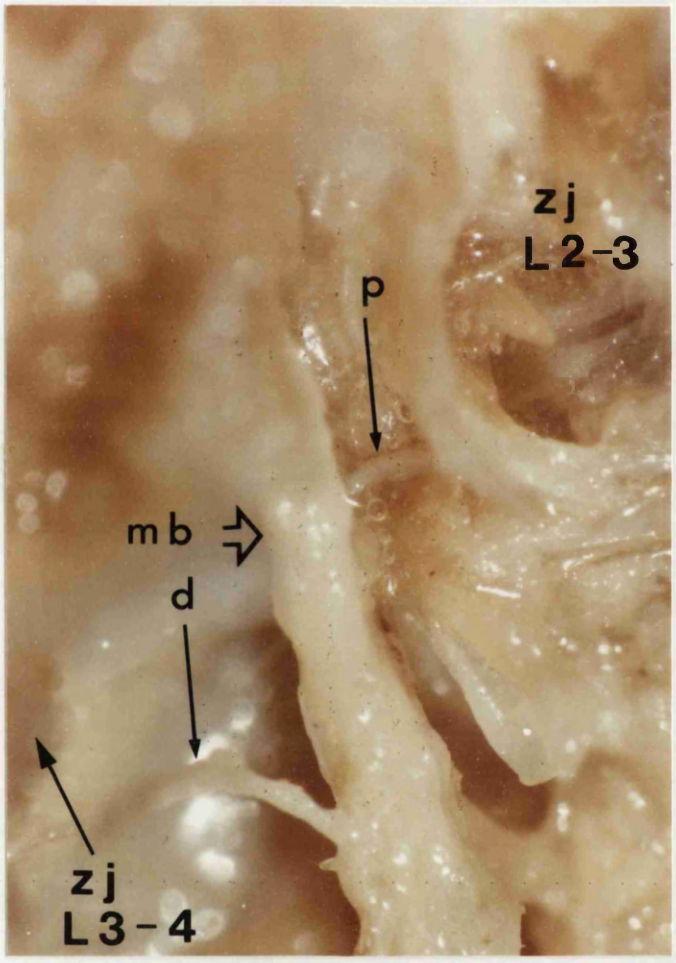


Figure 3-18

FIGURE: 3.19

Transverse section of L3-4 zygapophysial joint showing the proximal branch (arrow) approaching the fibrous posterior joint capsule (JC).
Masson Trichrome stain. Magnification X 320

FIGURE: 3.20

Transverse section of L3-4 zygapophysial joint showing vertical fibrillation in the articular cartilage of the superior articular process (SAP)
Masson Trichrome stain. Mag.X 500

IAP : inferior articular process

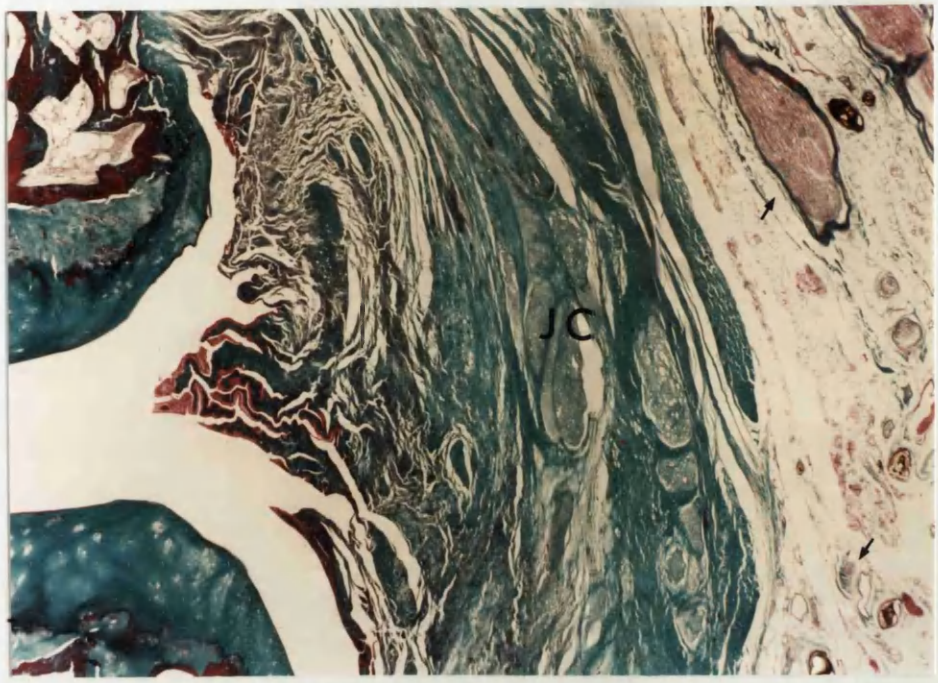


Figure 3-19

Figure 3-20

FIGURE: 3.21

Transverse section of L3-4 showing the articular cartilage being reflected around the bone at the posterior aspect of the inferior articular process (IAP).

Masson Trichrome stain. Mag.X 200

SAP : superior articular process

JC : fibrous joint capsule

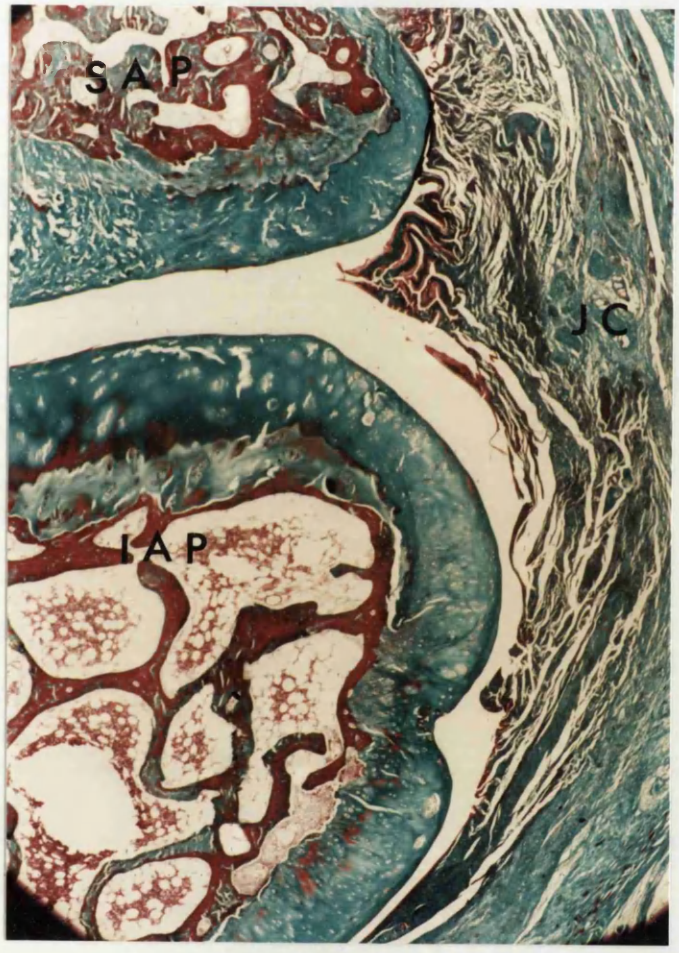


Figure 3 - 21

inferior articular process well beyond the limits of the bony contact.

This is as Hadley (1961) indicates, probably related to the pressure and friction of the joint capsule over the articular process.

B) THE SYNOVIAL FOLDS: Their Appearance and Innervation

The synovial folds project from the inner surface of the superior and inferior joint capsule. They have been seen as a constant feature of the zygapophysial joints, and are leaf-like folds extending between the articular surfaces.

Scanning electron microscopy has revealed the actual surface of these 'menisci'. (figures 3.22, 3.23,and 3.24a & b)

This specimen shows in fact, a nerve piercing through the fibrous capsule running towards the surface of the synovial fold.

FIGURE: 3.22

Photograph of the synovial fold specimen prepared for SEM, coated with gold.
The synovial fold seen as attached to the joint capsule.
Mag. X 16

FIGURE: 3.23

Specimen of the synovial fold prepared for SEM shows a nerve piercing the joint capsule to innervate the synovial fold
Mag. X 16

Figure 3-22

Figure 3-23

FIGURE: 3.24

(A) Scanning electron microscope (SEM) of the synovial fold. The synovial membrane has been washed away during preparation. A projection, possibly a nerve lies on the surface of the connective tissue of the fold.

Magnification X 30

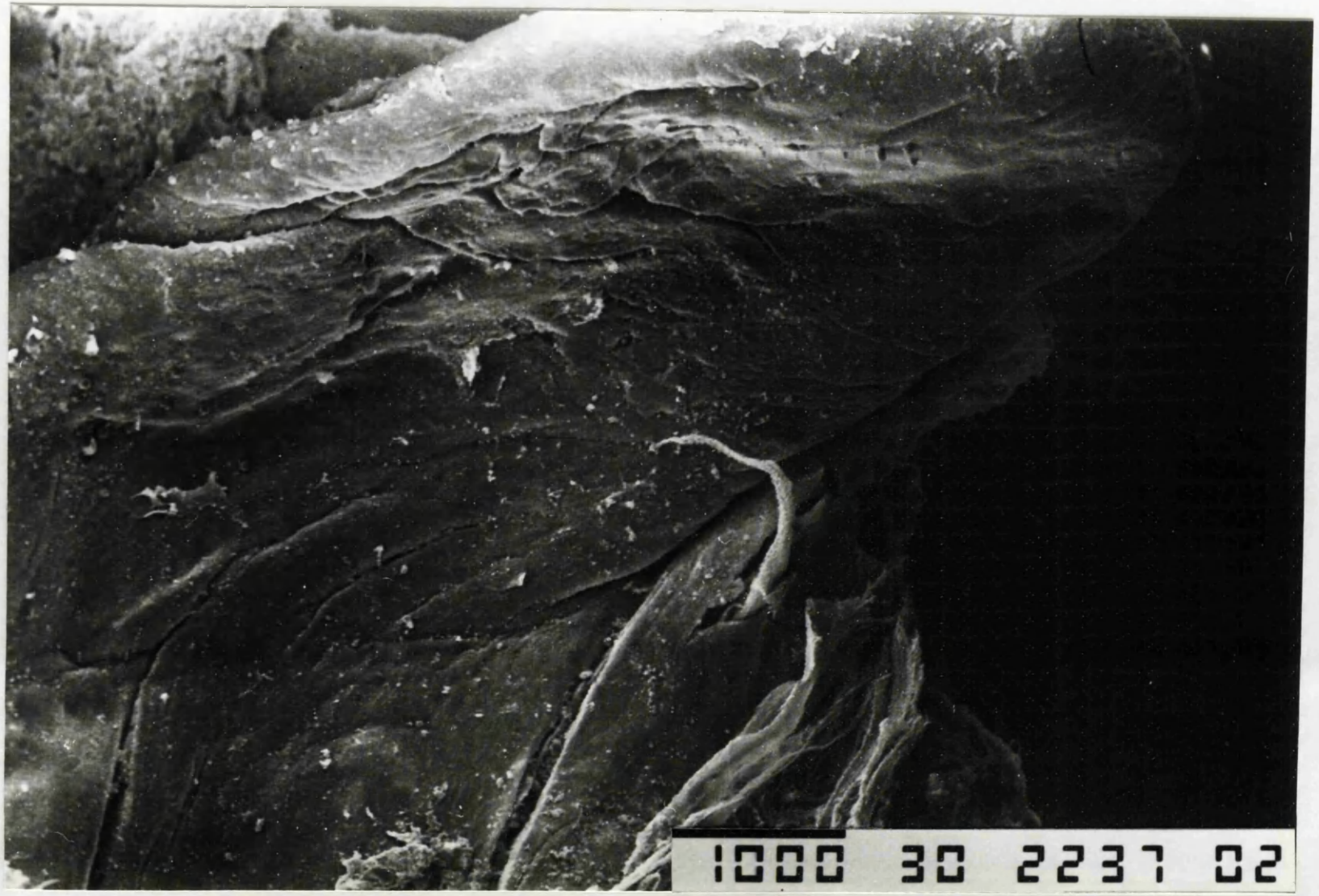
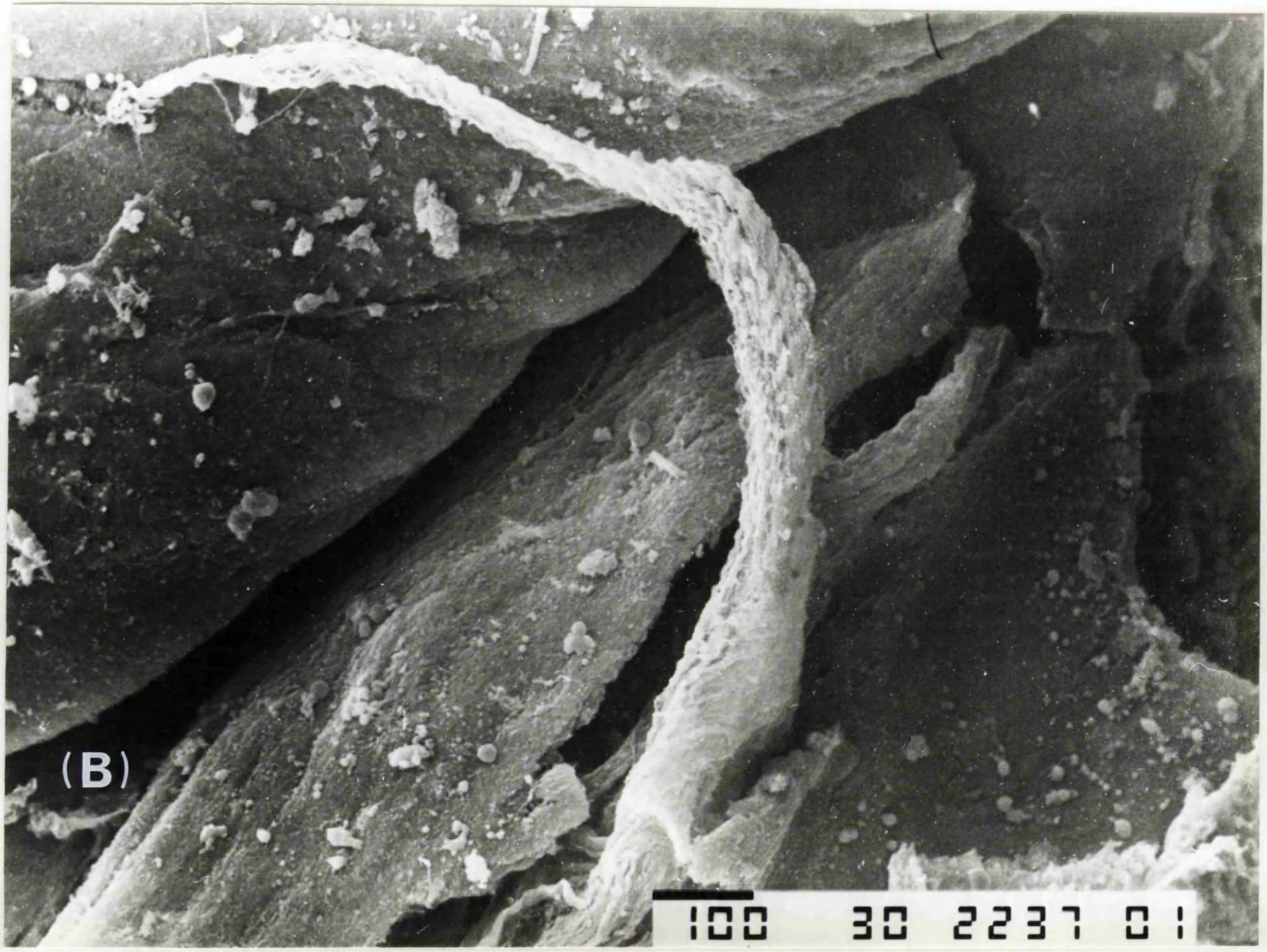


Figure 3-24 (A)

FIGURE: 3.24

(B) The "nerve" on the connective tissue surface of the synovial fold. SEM specimen.
Magnification X 200


(B)
100 30 2237 01

3.2 NERVES IN FRESH SURGICAL MATERIAL

As previously described, each surgical specimen had three parts:

a) the postero-medial fibrous joint capsule
b) the adjoining part of the ligamentum flavum
c) the synovial fold

The identification and then processing of these parts, made localisation of nerves found in the tissues much easier.
A typical specimen of the synovial fold attached to the capsule of the zygapophysial joint confirmed the existence of these folds. (figure 3.25a & b)

3.2.1 NERVES IN THE POSTEROMEDIAL FIBROUS JOINT CAPSULE

All of the specimens clearly showed defined nerve fibres.

A) Demonstration of nerves using silver impregnation

Palmgren's method for nerve fibres was adopted. Nerves were seen in the fibrous capsule of the zygapophysial joint.
Free nerve endings, encapsulated and Ruffini spray-like endings have been observed. (figures 3.26, 3.27, 3.28, 3.29,

3.30, 3.31, 3.32 and 3.33)
Nerves were found near blood vessels as well as away from them.

B) Demonstration of nerves using protein gene product 9.5 and substance P

The innervation of the synovium was judged by the presence of PGP 9.5 immunoreactivity. The extent of this innervation was considerable with nerve fibres seen throughout the depth of the tissue. (figures 3.34 & 3.36)
Substance P immunoreactivity was also seen in this tissue. Overall, the distribution of SP immunoreactive fibres was similar to the population of fibres which were detected by the PGP 9.5 antiserum, although less numerous. (figure 3.35). Routine histology does not show any nerves in the synovium, (figure 3.37), although nerves are seen very close to the joint capsule.

FIGURE: 3.25

(A) & (B) Fresh surgical specimens of the posterior zygapophysial joints in the lumbar region showing the synovial folds (arrows) immersed in Zamboni's fluid.

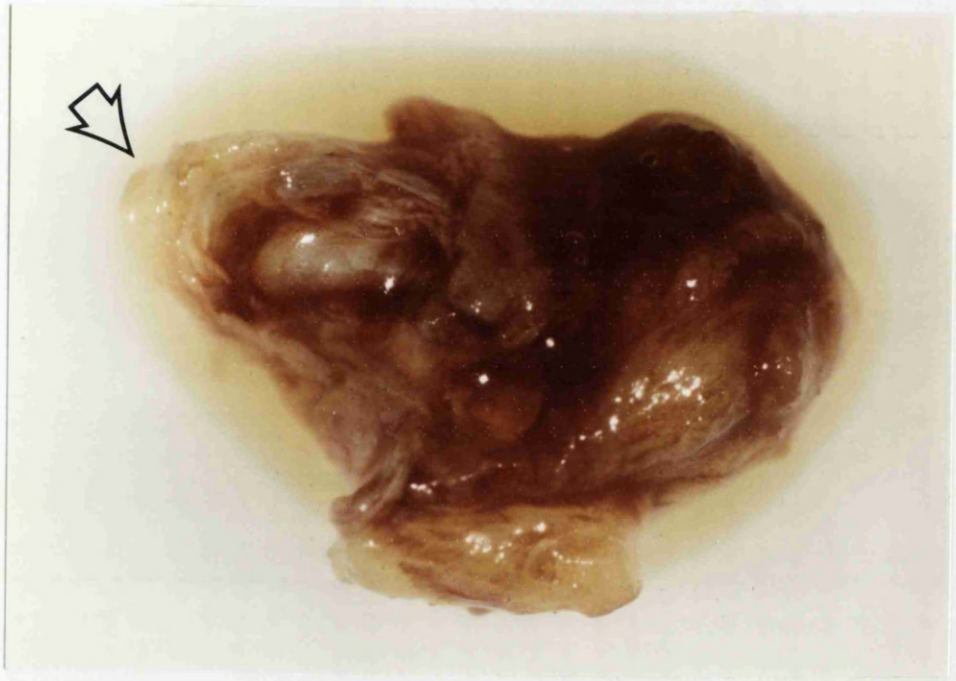
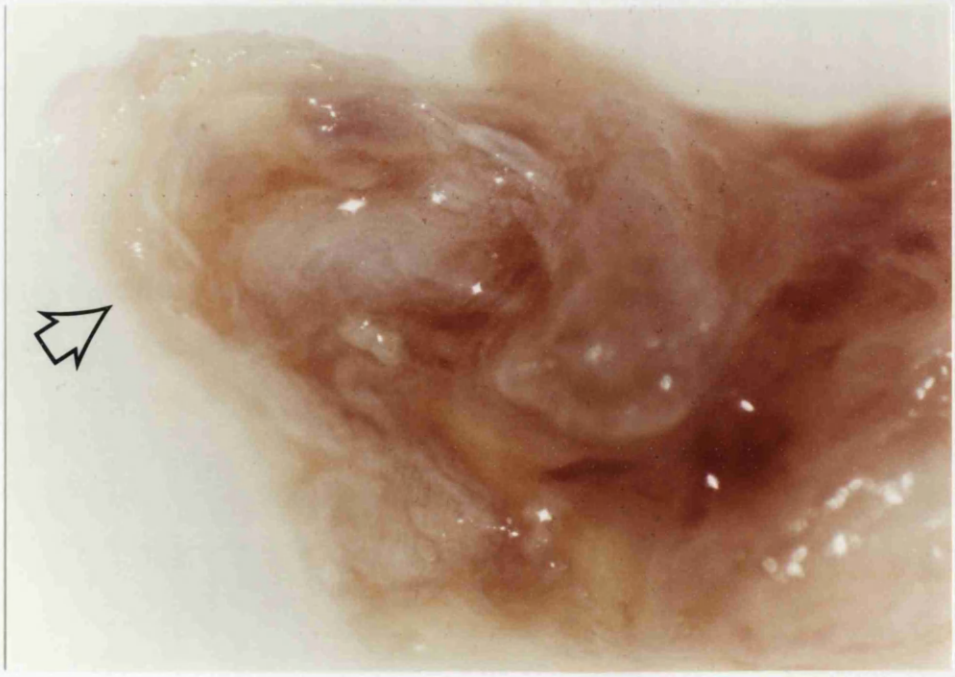


Figure 3-25 (A)



(B)

FIGURE: 3.26

Nerve endings in the synovium of the zygapophysial joint surgical material, stained with Palmgren's method for nerve fibres. Mag. X 800

FIGURE: 3.27

Arrow indicating nerve fibres as above.
Mag. X 1250

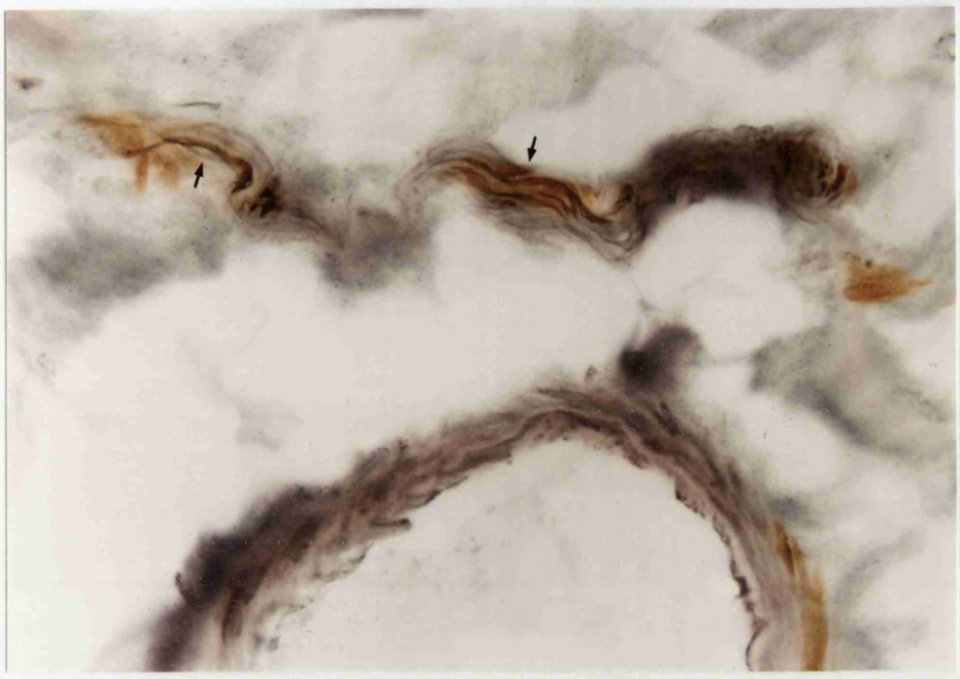


Figure 3-26

Figure 3-27

FIGURE: 3.28

Nerve fibres seen in the synovium away from blood vessels. Stained with Palmgren's silver staining.
Mag. X 1250

FIGURE: 3.29

Palmgren's silver stain showing nerve fibres in the fibrous zygapophysial joint capsule.
Mag. X 800

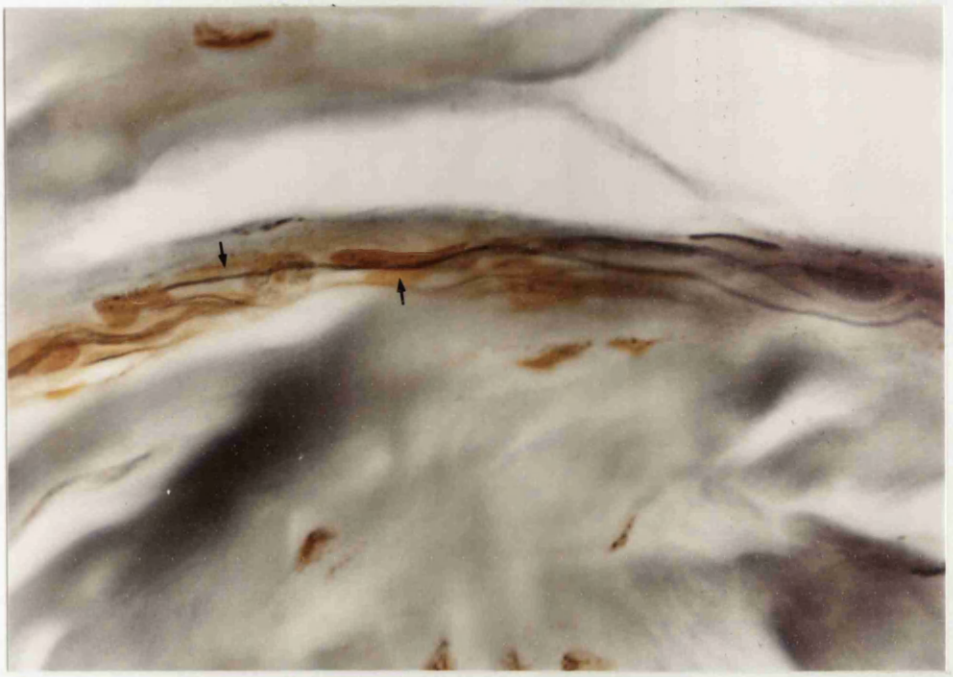


Figure 3-28

Figure 3-29

FIGURE: 3.30

Nerve fibres in the zygapophysial joint capsule.
Palmgren's silver stain. Mag. X 1250

FIGURE: 3.31

Free nerve endings in the synovium of the zygapophysial joint capsule.
Mag. X 1250

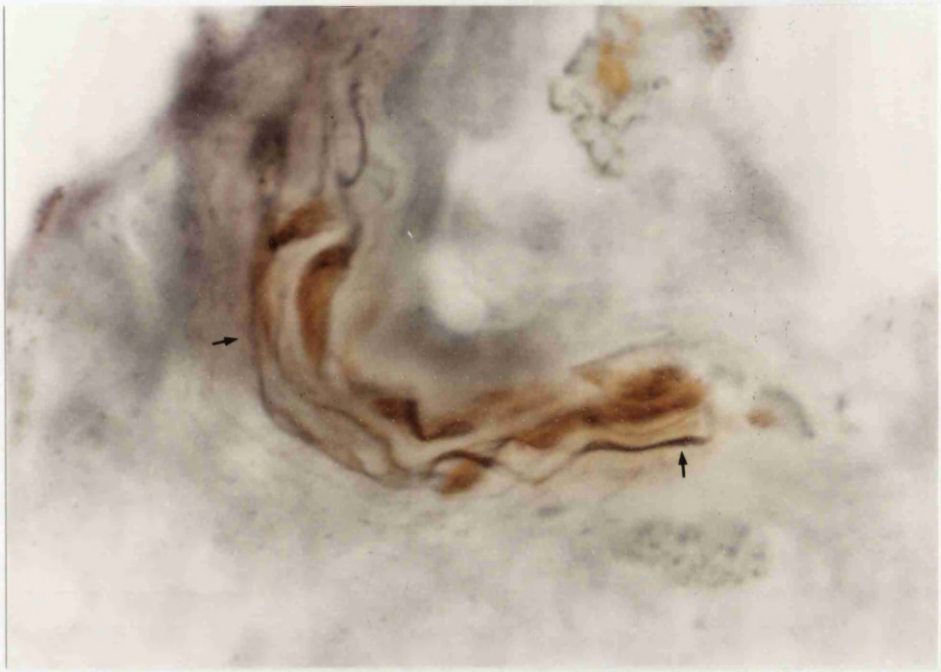


Figure 3-30

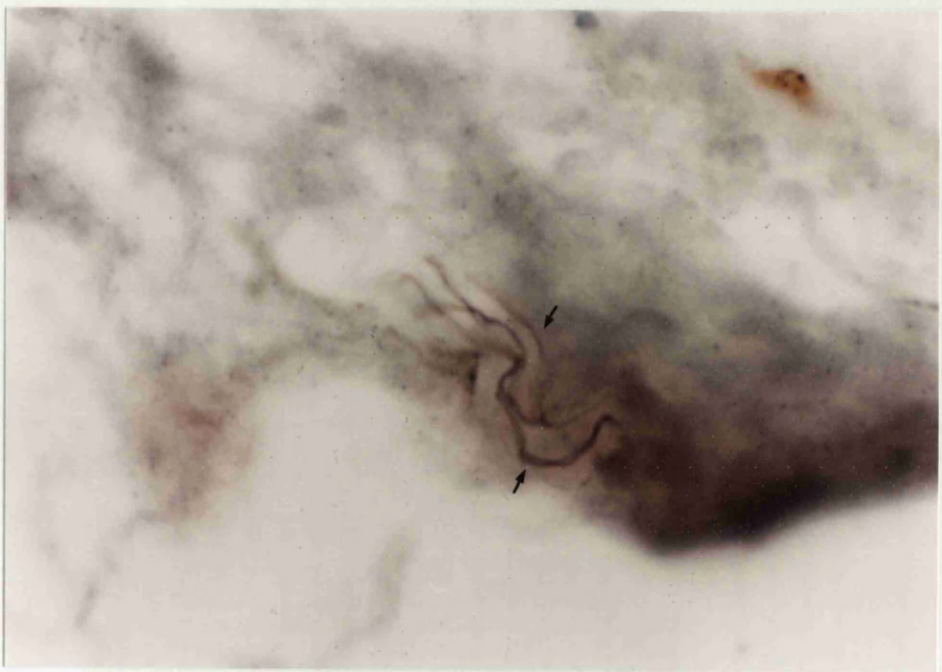


Figure 3-31

FIGURE: 3.32

Encapsulated nerve endings in the zygapophysial joint capsule, stained with Palmgren's silver stain. Mag. X 1250

FIGURE: 3.33

Spray - like ending in the synovium of the zygapophysial joint capsule, stained with Palmgren's method for nerve endings. Mag.X 1250

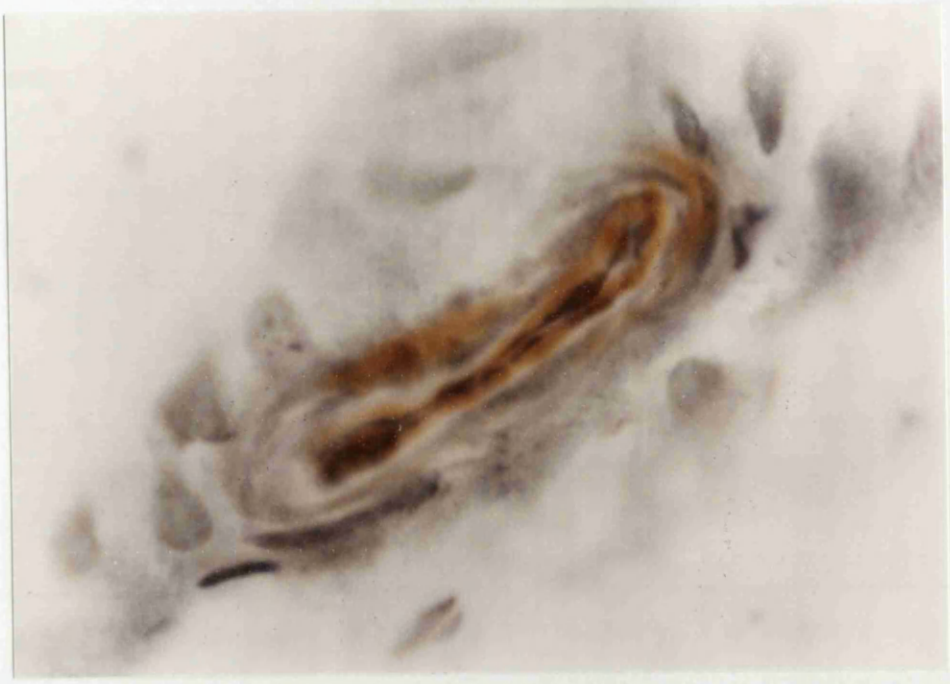


Figure 3-32

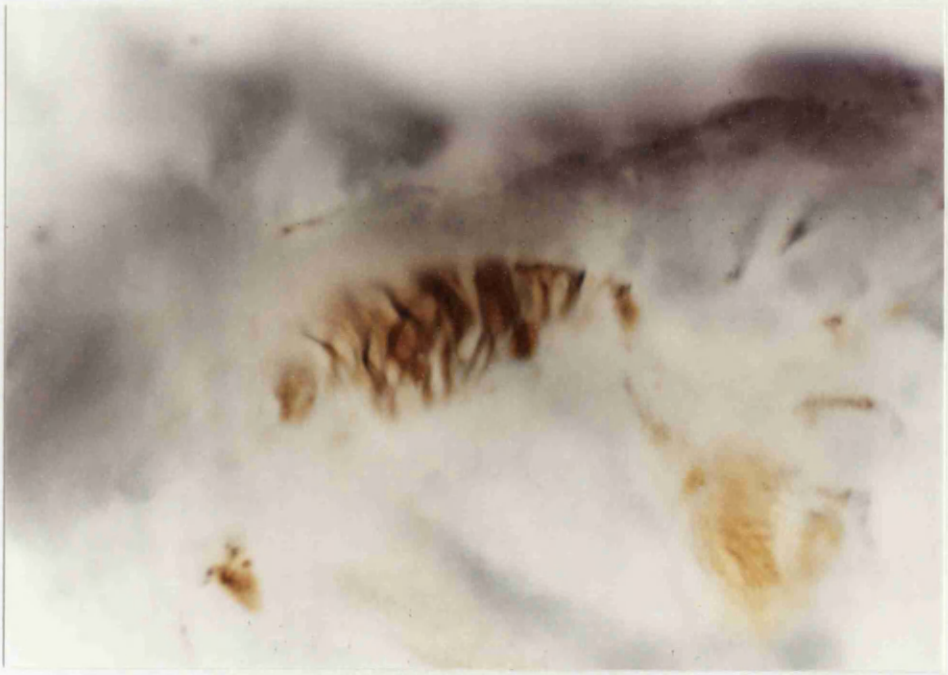


Figure 3-33

FIGURE: 3.34

Zygapophysial joint capsule showing nerves immunoreactive to PGP 9.5. Mag.X 480

FIGURE: 3.35

Numerous SP-immunoreactive fibres seen in the zygapophysial joint capsule.
Mag.X 480

Figure 3-34

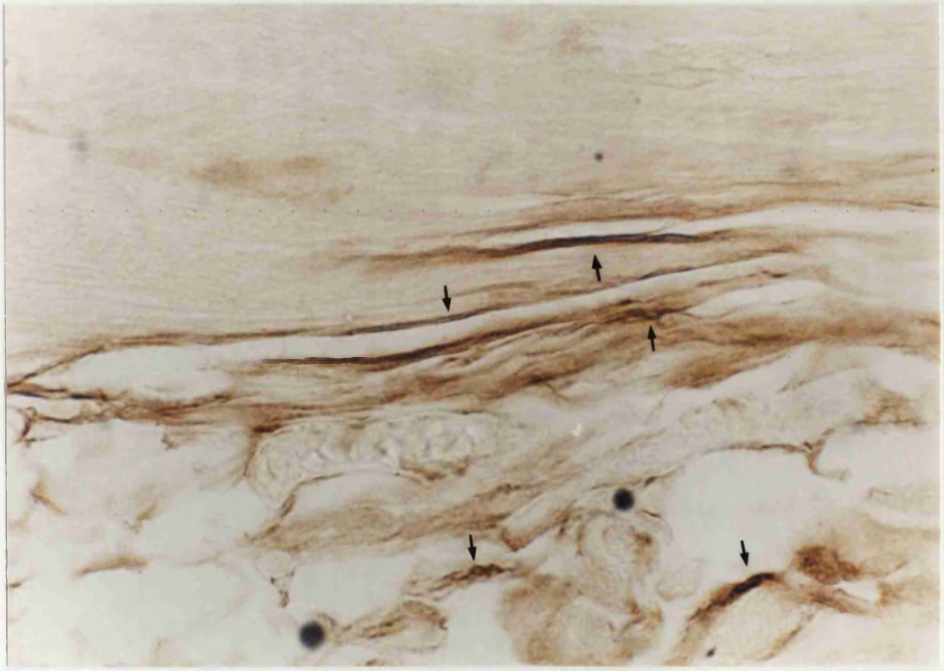


Figure 3-35

FIGURE: 3.36

PGP 9.5 immunoreactive nerve fibres in the dense fibrous tissue of the zygapophysial joint. Magnification X 480

FIGURE: 3.37

Horizontal section of L3-4 zygapophysial joint stained with Masson Trichrome, showing the proximal branch of the medial branch of the posterior primary ramus approaching the fibrous joint capsule. Mag.X 26

Figure 3-36

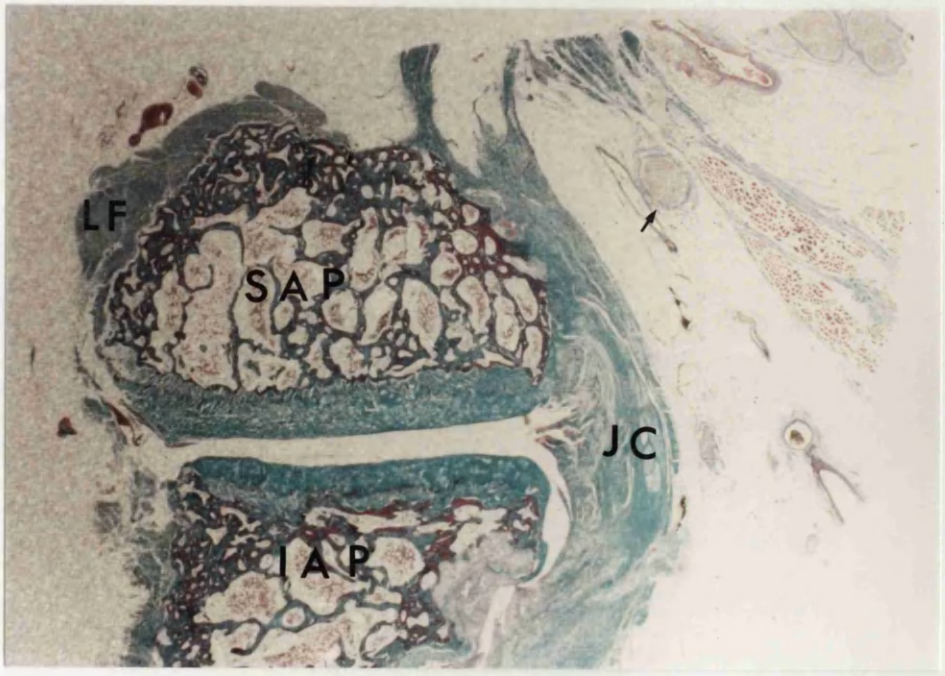


Figure 3-37

3.3 THE MAMILLO-ACCESSORY LIGAMENT

A) Gross Anatomy

The mamillo-accessory ligament is a fibrous band about 1-2mm thick, which bridges between the mamillary process and the accessory process. Heylings (1992) claimed that this ligament was not seen below L3 level. Our findings reveal that this ligament is found at all levels, on each lumbar vertebra.

The mamillo-accessory ligament has also been seen to be related to the medial branch of the posterior primary ramus at each level. The ligament at a given segment is related to the medial branch of the next rostral segment.
The medial branch of the posterior primary ramus passes under this ligament.
In one of our 28 dissections, a pair of the medial branch of PPR was seen passing under this ligament, bulging of the nerve proximal to the mamillo-accessory ligament was observed, at L2 level, suggestive of entrapment neuropathy. (figure 3.38a & b)

FIGURE: 3.38

(A) & (B) Bulging of the medial branch of the posterior primary ramus at L2 level proximal to the mamillo-accessory ligament (mal)

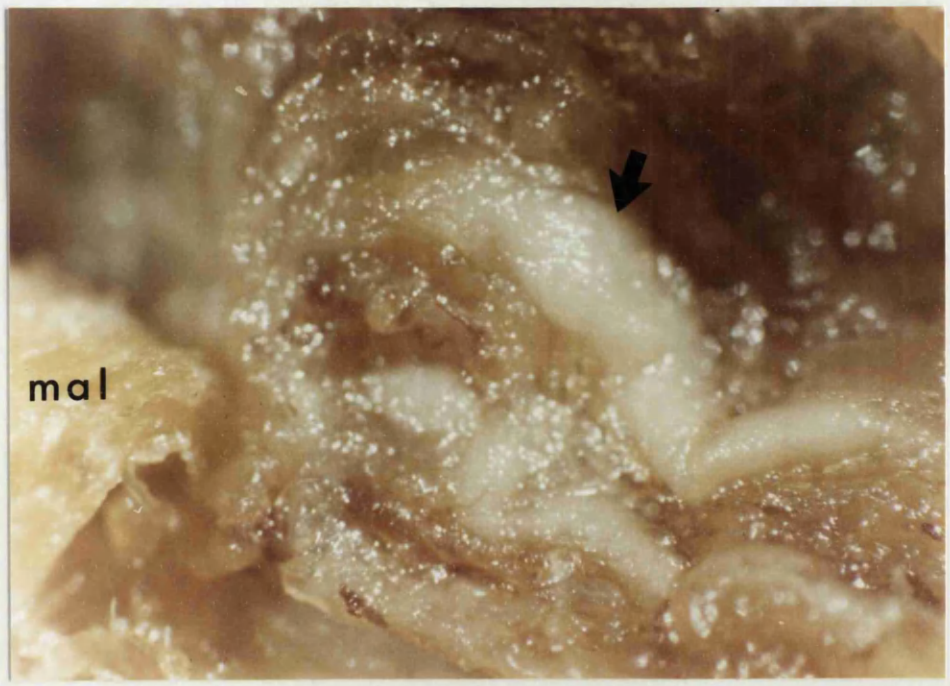
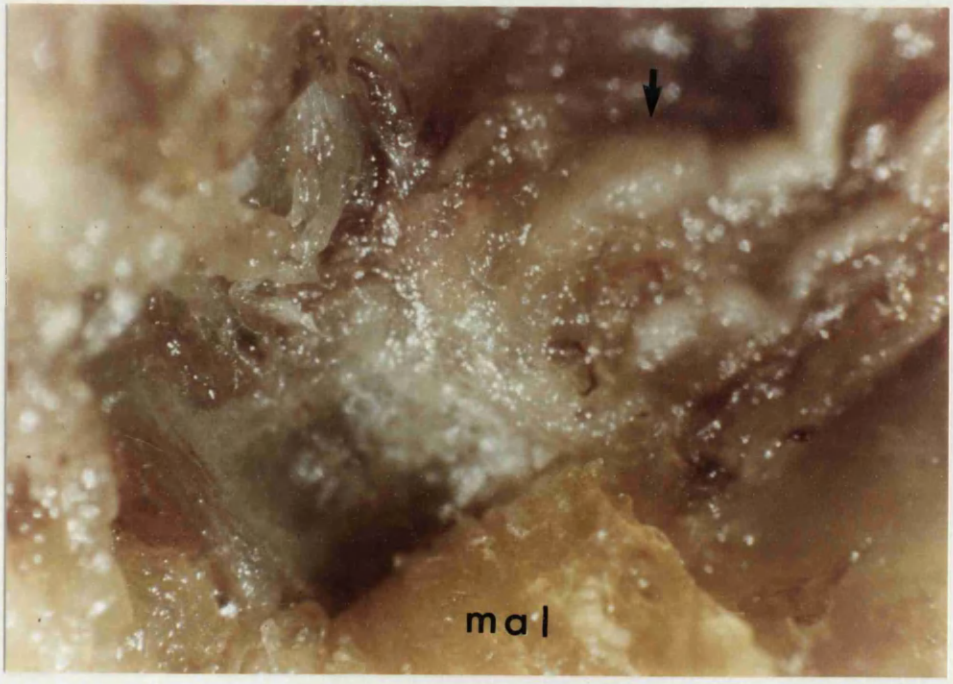


Figure 3-38 (A)



(B)

B) Ossification

The mamillo-accessory ligament shows a variable degree of ossification at each vertebral level. (figures 3.39a & b, 3.40a & b and 3.41a & b).

Ossification is maximal at L5 level, where over 11% of the ligament is completely ossified. (figure 3.42 and table 3.1)

Although it has been claimed that ossification of the mamillo-accessory ligament has been only in the presence of osteoarthritic changes, our study on 224 skeletal specimens reveals that the foramina may be formed without any osteoarthritic changes. (figure3.41a)

The size of the mamillo-accessory foramen varied from 0.6mm to 6mm in width.

Blood vessels passing under the mamillo-accessory ligament sometimes create confusion as being another nerve, therefore histology comes in to confirm the structures. (figure 3.43a & b)

FIGURE: 3.39

(A) Ossification of the mamillo-accessory ligament at L5 level, without any obvious osteoarthritic changes.

(B) Ossification of the mamillo-accessory ligament, that bridges between the mamillary process (mp) and the accessory process (ap), which leads to the formation of the mamillo-accessory foramen. Here a large foramen is formed.

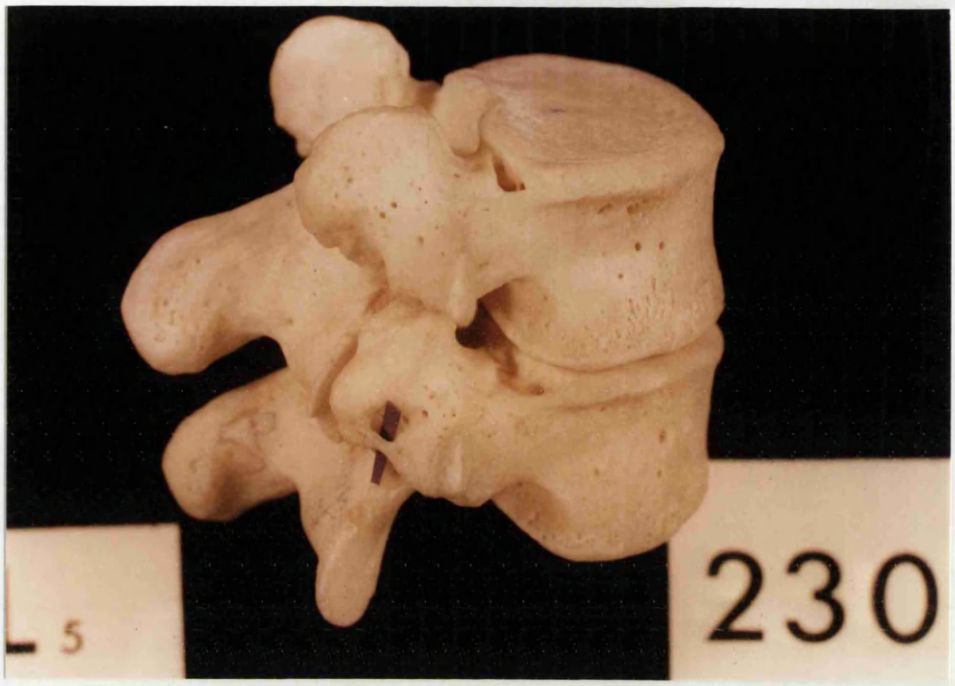
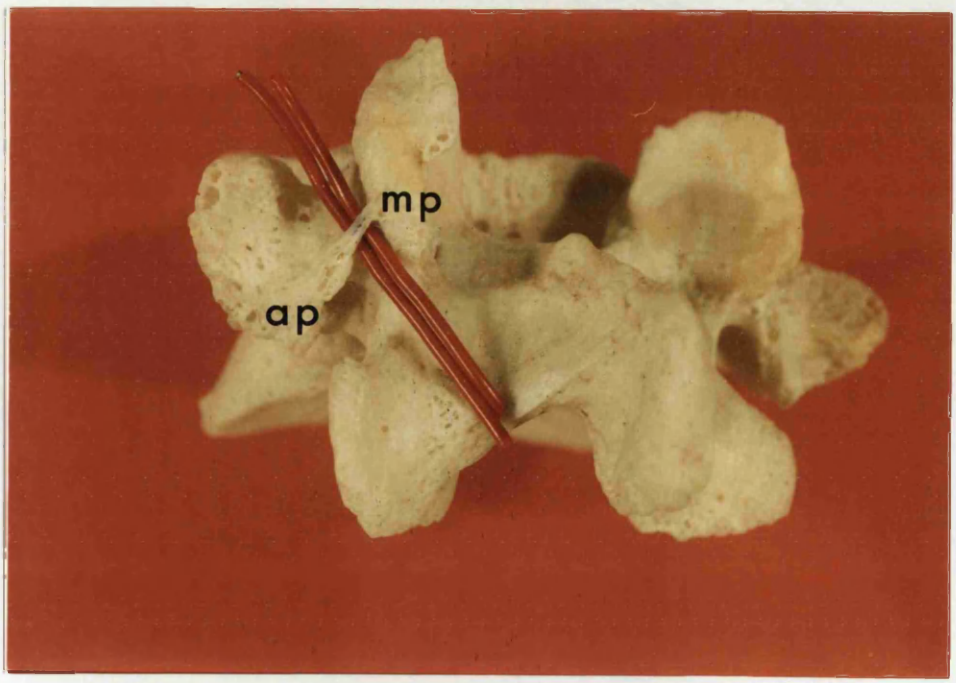


Figure 3-39 (A)



(B)

FIGURE: 3.40

(A) The mamillo-accessory foramen seen as 0.5 mm in width.

(B) Measurement of the diameter of the mamillo-accessory foramen. This was achieved by using linseed oil "Putty" and micrometer.

Figure 3-40 (A)

(B)

FIGURE: 3.41

(A) The mamillo-accessory foramen seen without any osteoarthritic changes.

(B) Precise measurement of the mamillo-accessory foramen was done, by measuring the size of the linseed oil "Putty" used for this purpose, using micrometer.

Figure 3-41 (A)

(B)

THE EXTENT OF OSSIFICATION OF THE MAMILLO-ACCESSORY LIGAMENT

Level of Vertebra	No. of spec. studied at each level	Open Notch Lt. No.	Open Notch Lt. %	Open Notch Rt. No.	Open Notch Rt. %	1/2 Circle Notch Lt. No.	1/2 Circle Notch Lt. %	1/2 Circle Notch Rt. No.	1/2 Circle Notch Rt. %	3/4 Circle Notch Lt. No.	3/4 Circle Notch Lt. %	3/4 Circle Notch Rt. No.	3/4 Circle Notch Rt. %	M.A. Foramen Lt. No.	M.A. Foramen Lt. %	M.A. Foramen Rt. No.	M.A. Foramen Rt. %
L1	224	195	87	207	92.4	29	12.9	17	7.6								
L2	224	167	74.5	192	85.7	56	25	32	14.3					1	0.4		
L3	224	103	46	137	61.1	117	52.2	85	37.9					4	1.8	2	0.9
L4	224	99	44.2	121	54	108	48.2	92	41.1	5	2	5	2	12	5.3	6	2.7
L5	224	96	42.8	114	50.9	96	42.8	84	37.5	14	6.2	11	4.9	18	8	15	6.7

Table 3-1

FIGURE: 3.42

A graph showing the incidence of complete ossification of the mamillo-accessory ligament in different population.

Chinese population

From: Ninghsia Medical College (1978)

Australian population

From: Bogduk (1981)

European population

From: Maigne et al. (1991)

Eastern population

See table 3.1

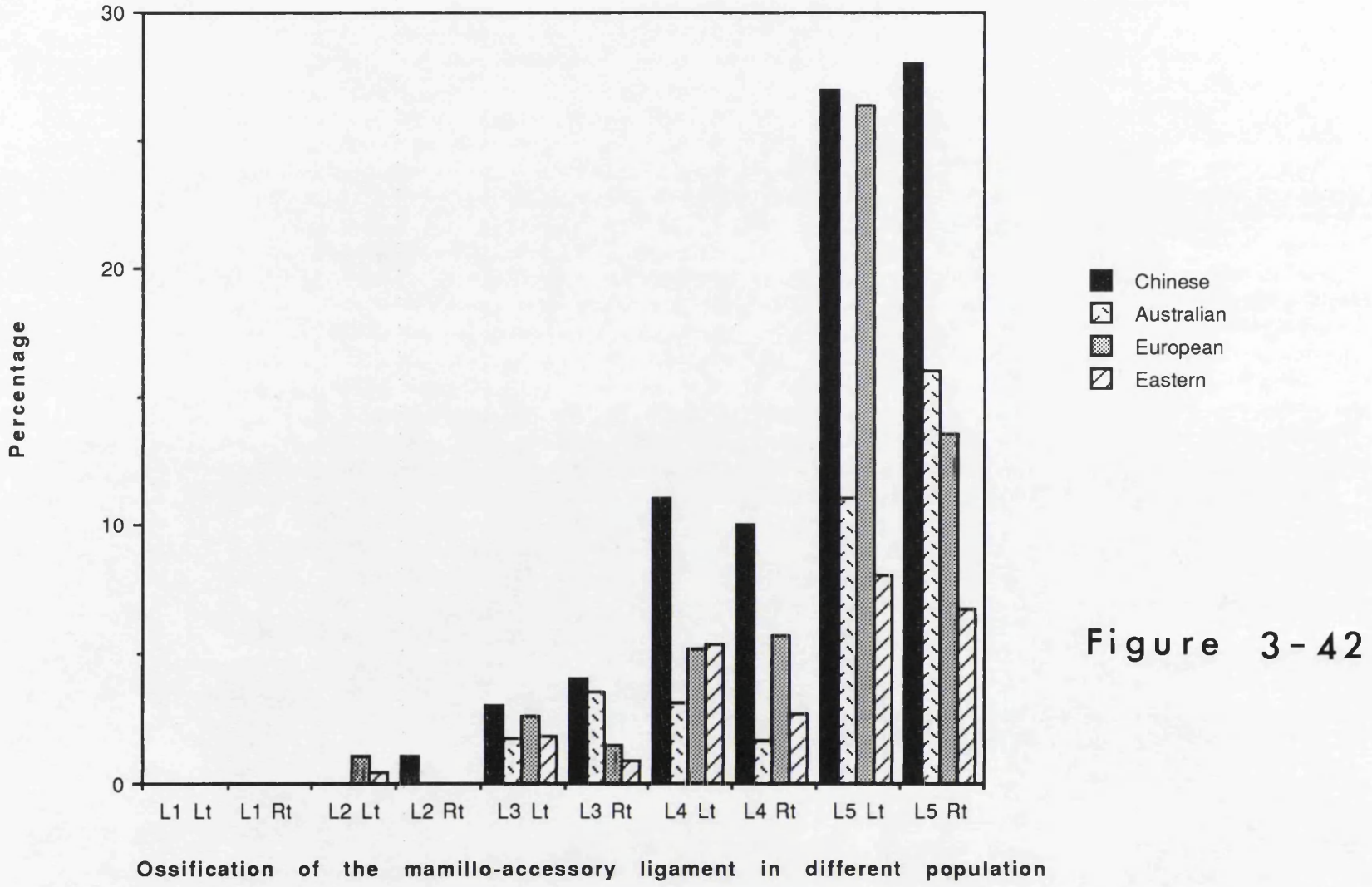

30
20
10
0
Percentage
L1 Lt
L1 Rt
L2 Lt
L2 Rt
L3 Lt
L3 Rt
L4 Lt
L4 Rt
L5 Lt
L5 Rt
Ossification of the mamillo-accessory ligament in different population
Chinese
Australian
European
Eastern

Figure 3-42

FIGURE: 3.43

(A) Cross section of the blood vessel (bv) seen in (B), that confuses with a nerve.

(B) The medial branch (mb) of the posterior primary ramus passes under the mamillo-accessory ligament (mal) which bridges between the mamillary process (mp) and the accessory process (ap). Blood vessel (bv) is also seen passing under this ligament.

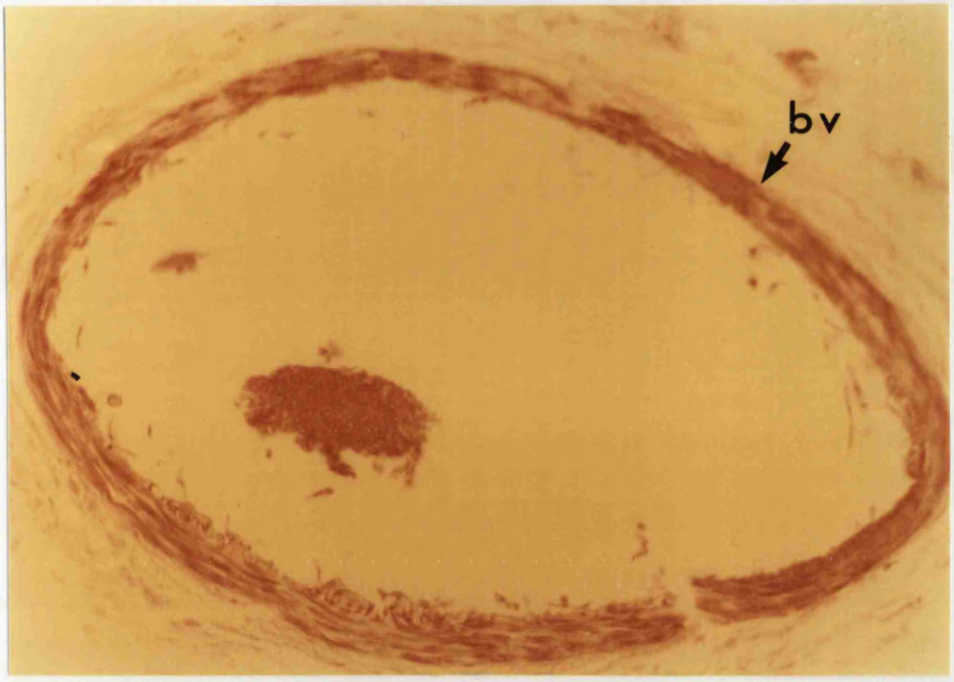
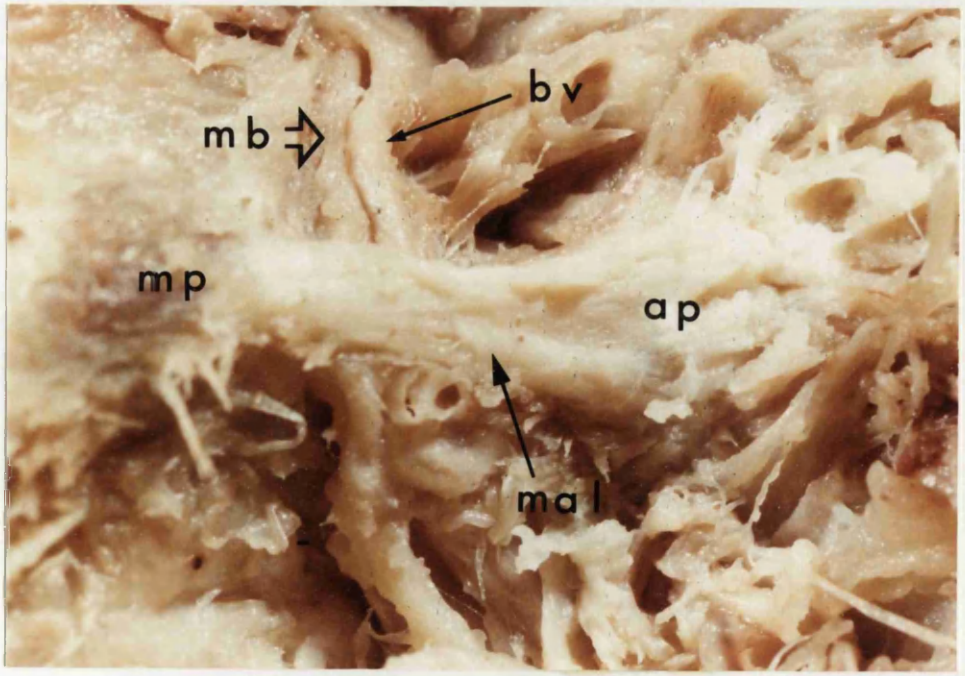


Figure 3-43 (A)



(B)

DISCUSSION

CHAPTER IV

DISCUSSION

ANATOMICAL ASPECTS

4.1 THE POSTERIOR PRIMARY RAMI

The traditional description of the posterior primary rami is having two branches (Bradley, 1974; Edgar and Ghadially, 1976; Giles, 1989; Williams et al., 1989).

The triple branching pattern with medial, lateral and intermediate has been observed in the cat (Bogduk, 1976; Carlson, 1978), monkey and dog (Bogduk, 1974). The lateral, intermediate and medial branches are specifically distributed to the iliocostalis, longissimus and the multifidus respectively.

In our dissection, the posterior primary ramus divided into three branches, having the intermediate branch sometimes sharing a common stem with the lateral branch. (figure 3.1a) This suggests that this pattern is present in man as well as other species.

Distribution of the lateral branches of the posterior primary rami were found to be in accordance with the previous descriptions, mentioned in the standard textbooks of Anatomy.

Bogduk (1980a), in a study of the morphology of the erector

spinae muscle, observed that the lumbar portions of the longissimus thoracis and iliocostalis lumborum are separated by a parasagittal aponeurosis - the lumbar intermuscular aponeurosis. Therefore, the fact that each of these muscles is innervated by a separate branch from the posterior primary ramus, provides further logical reason for not regarding the lumbar erector spinae as a common muscle mass. A close and careful dissection in the present study reveals that the intermediate branch is separate in origin from either the medial branch or the common stem with the lateral branch.
Moreover, the exclusive distribution of this branch to the lumbar fibres of longissimus justifies its having a separate name.

The posterior primary ramus of L5 has different length and branching pattern described only by Bogduk (1980a) in the past. Our study supports his work.

Since the iliocostalis does not attach to the fifth lumbar vertebra, therefore, it seems justified the absence of the lateral branch at this level, which is comparable to the lack of an L7 lateral branch in the cat (Bogduk, 1976), monkey and dog (Bogduk, 1974).
The iliocostalis is attached only at L1 to L4 vertebrae (Bogduk, 1980b).

The medial branches have been said to be freely

"anastomosing" within the multifidus (Pedersen et al., 1956; Edgar and Ghadially, 1976). Our findings agree with Macintosh et al. (1986), in observing that the medial branch remained wholly within the fascicles of the multifidus which it entered. (figure 3.11)

Traditionally, the multifidus muscle is described as a transverso-spinal muscle (Hollinshead, 1982; Williams et al., 1989) arising from the sacrum and the mamillary processes and pass to the spinous processes one to four, or two to four segments rostral.
If interpreted in this traditional manner, then the fascicles of the multifidus seem to have an overlapping innervation.

Pedersen et al. (1956), Edgar and Ghadially (1976), have in fact claimed that the multifidus receives an overlapping segmental nerve supply.
If the spinous processes are interpreted as the origin of the fasciculi, then all those fibers arising from a given vertebra receive a unisegmental innervation (Macintosh et al., 1986).

Pedersen et al. (1956), and Bogduk (1980c) have claimed that noxious stimulation of the zygapophysial joints evokes reflex activity in the paraspinal muscles and ipsisegmental muscles of the lower limb.
Therefore, considering that the multifidus fibers that act

on a particular vertebra, receive the same segmental nerve supply as the joints of that vertebra. It could well be then that the zygapophysial joint pain would be associated with the abnormal activity in the relevant portion of the multifidus.

The medial branches of the posterior primary rami in the lumbar region end in the multifidus which they innervate (Bogduk et al., 1982; Macintosh et al., 1986).
Gray's Anatomy (1989) states," medial branches run near the vertebral articular processes to end in the multifidus "
Our findings support the above claim, thus confirming that the medial branches of the posterior primary rami end in the multifidus, whereas Rothman and Simeone (1992) illustrate that the medial branch of PPR supplies the skin. 'see figures 4.1, 4.2 & 4.3'

Our present study confirms the presence of articular branches only to the rostral and caudal aspect of each lumbar zygapophysial joint.
Each zygapophysial joint capsule is therefore, innervated by the medial branch of two adjacent posterior primary rami. This supports the work of Lewin et al. (1962), Bradley (1974), Bogduk (1979), and Giles (1989).

Despite a careful search, it was not possible to substantiate the claims of Wyke (1981) and Paris (1983), that each zygapophysial joint is innervated from not less

FIGURE: 4.1

Illustration showing the distribution of the branches of the posterior primary ramus in the lumbar region, at L3 level.

From: Rothman and Simeone (1992)

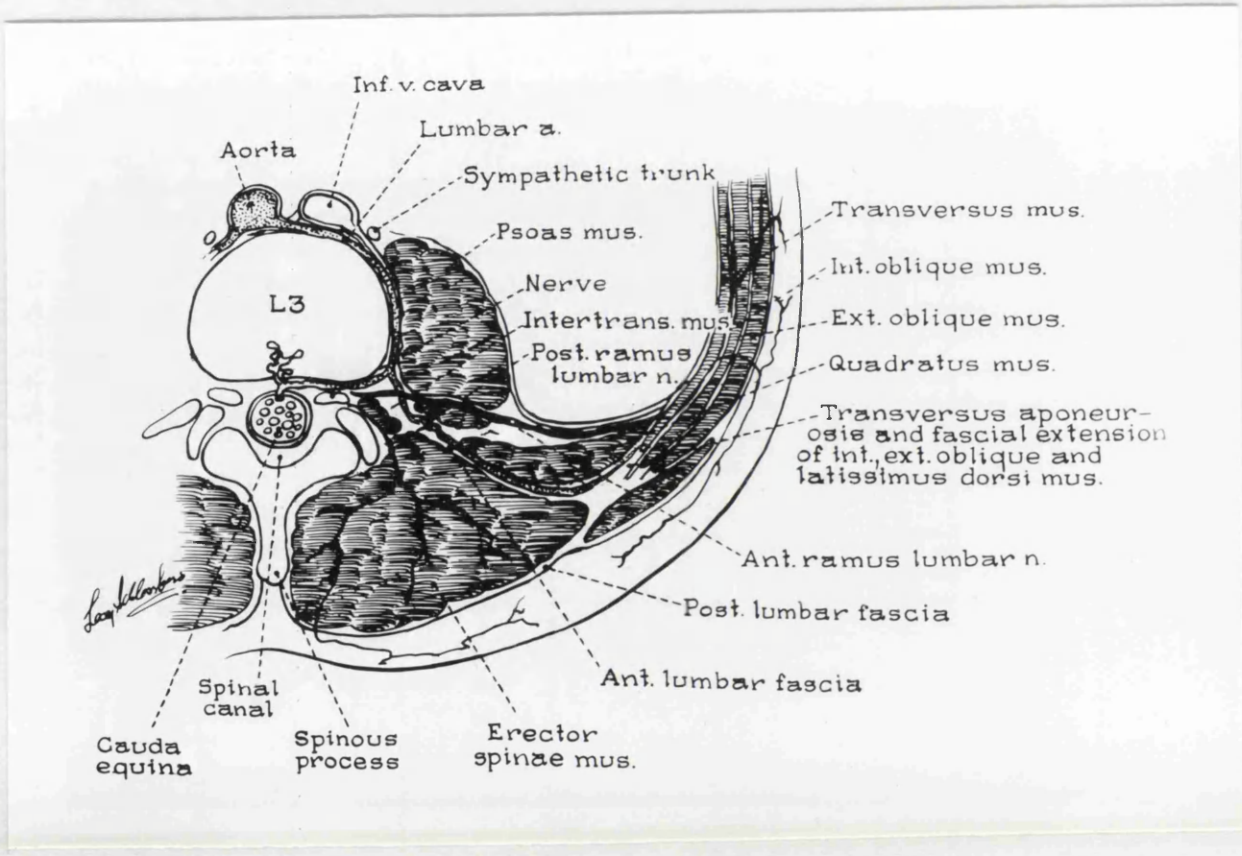

Inf. v. cava
Lumbar a.
Aorta
Sympathetic trunk
Transversus mus.
Psoas mus.
Int. oblique mus.
Nerve
L3
Intertrans. mus.
Ext. oblique mus.
Post. ramus lumbar n.
Quadratus mus.
Transversus aponeurosis and fascial extension of int., ext. oblique and latissimus dorsi mus.
Ant. ramus lumbar n.
Post. lumbar fascia
Ant. lumbar fascia
Spinal canal
Cauda equina
Spinous process
Erector spinae mus.

Figure 4-1

FIGURE: 4.2

A cross sectional view of the innervation of the lumbar spine.

dr : dorsal ramus

zj : zygapophysial joint

m : medial branch

l : lateral branch

i : intermediate branch

M : multifidus

LT : longissimus thoracis

IL : iliocostalis lumborum

From: Bogduk and Twomey (1991)

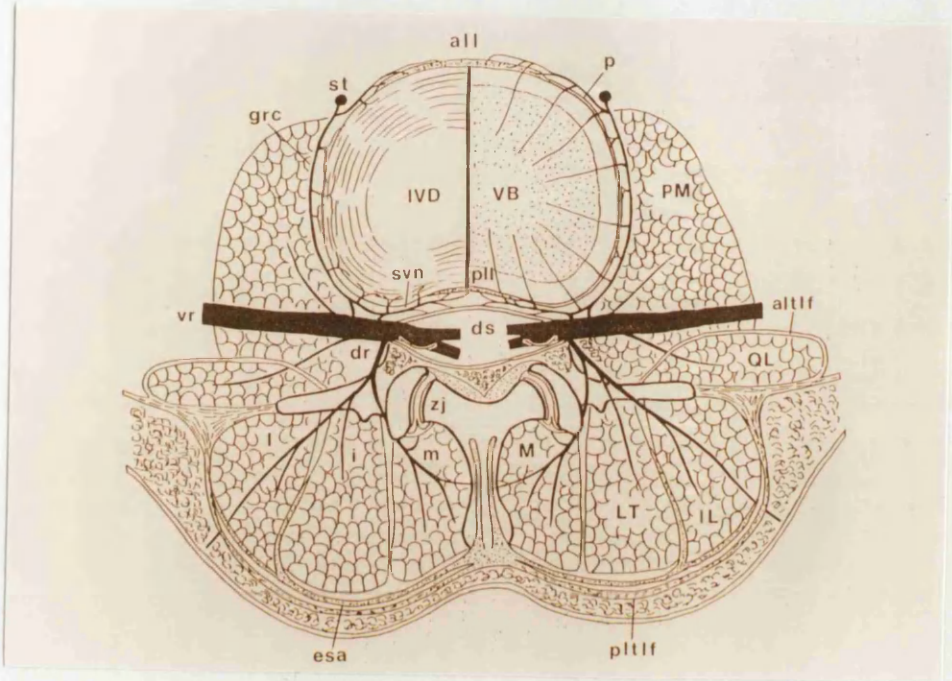

all
st
p
grc
IVD
VB
PM
svn
pll
altlf
vr
ds
dr
QL
zj
l
i
m
M
LT
IL
esa
pltlf

Figure 4 - 2

FIGURE: 4.3

A transverse section of the lumbar region at L3 level with freehand superimposed drawing showing the posterior primary ramus (ppr) and its branches.

mb : medial branch

ib : intermediate branch

ib : lateral branch

zj : zygapophysial joint

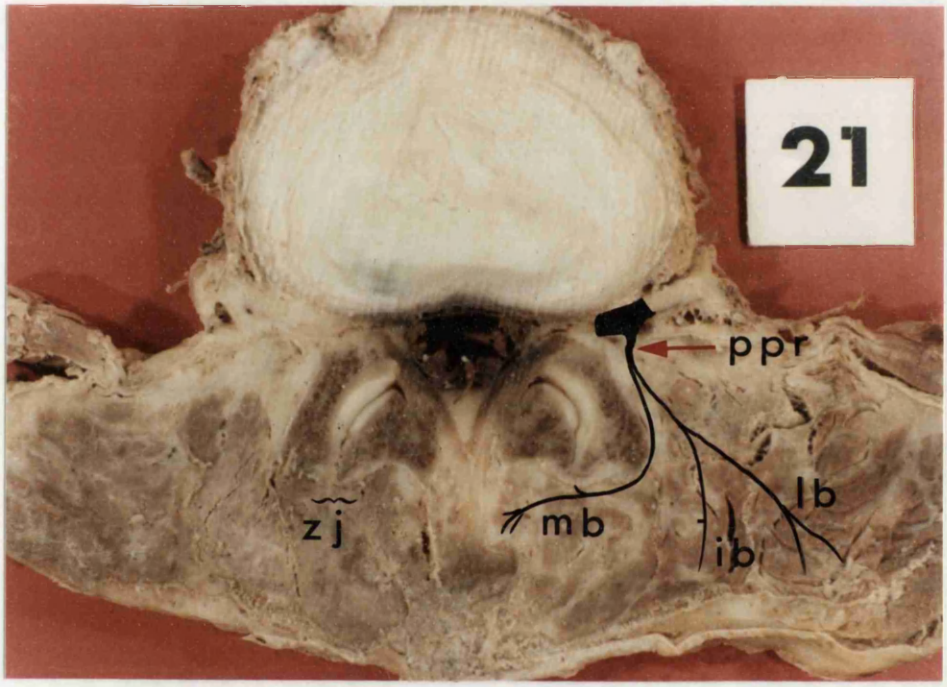


Figure 4-3

than three roots, or Ninghsia Medical College (1978) or Auteroche (1983) that anastomoses take place between any branches.

Unlike Vadeboncoeur et al. (1986), we did not find any evidence indicating that the zygapophysial joints on one side of the spine receive innervation from the contralateral posterior primary ramus.

There was also no trace of any branches ascending to the zygapophysial joint above the level of origin of the posterior primary ramus.

4.2 INNERVATION OF THE ZYGAPOPHYSIAL JOINT CAPSULES

Our study reveals that the medial branch of the posterior primary ramus is the major, if not the only source of innervation of the lumbar zygapophysial joint capsules.
It descends obliquely on the fibrous capsule of the zygapophysial joint reaching to its inferior aspect and giving branches. At this point, it lies directly superficial to the communication between the fat-filled inferior recess and the synovial cavity .
Within the capsule, the nerve breaks up into large numbers of diffusely ramifying branches containing sensory fibres.
Our study supports the work of several other investigators

who have concluded that each zygapophysial joint capsule is innervated from two spinal nerves (Bradley, 1974; Mooney and Robertson, 1976; Bogduk, 1979; Lucas, 1983; Giles, 1989).

We found that the superior portion of the joint capsule is innervated by the distal branch of the medial branch of PPR arising one level higher.
The inferior portion of the joint capsule is innervated by the proximal branch, arising from the medial branch of the posterior primary ramus that emerges from the intervertebral canal at the same level. This gives an overlap of innervation.

However, Wyke (1981) and Paris (1983) claim that each zygapophysial joint is innervated from at least three successive posterior rami.
This claim has been confirmed neither by Giles (1989), nor by us, despite careful dissection and search.

We also confirm the conclusion of Giles (1989) that no branches were found ascending to the zygapophysial joint above the level of origin of the posterior primary ramus.

No branches were found crossing the mid-line to provide innervation from the contralateral posterior primary ramus. This supports the work of Giles (1991).

Our investigations reveal that the zygapophysial joint

capsule is richly innervated, contains Substance P immunoreactive nerves, and thus support the work of Giles and Harvey, (1987), El-Bohy et al.(1988). Electrophysiologic studies by Yamashita et al. (1990) suggest the presence of nociceptive nerves.

The small myelinated nerve fibres that innervate the zygapophysial joint capsule, are considered to conduct nociceptive sensations (Nathan, 1977; Guyton, 1992).
Giles and Taylor (1987) reported that they exclusively found small myelinated fibres in the human zygapophysial joint capsule by means of electron microscopy and considered these fibres to be involved in nociceptive function.
Our findings also indicate the presence of small diameter nerves immunoreactive for PGP 9.5 and nerves containing Substance P in the human zygapophysial joint capsule.

Finding Substance P immunoreactive fibres in the zygapophysial joint capsule strongly suggests that the zygapophysial joint can be a source of low back pain.
Substance P is a neuro-peptide generally identified with neuronal pathways associated with pain. It has been implicated as having a neurogenic inflammatory role in arthritis (Mapp et al., 1990).
Thus localization of Substance P in the zygapophysial joint capsule does indicate the possible role of this joint in low back pain.

4.3 INNERVATION OF THE SYNOVIAL FOLDS

Controversy exists in the literature regarding the innervation of the zygapophysial joint synovial folds (Mooney and Robertson, 1976; Paris, 1983).

In our present study, with the ABC staining, most of the nerves were immunoreactive when treated with antiserum to PGP 9.5. Our findings support the work of Gronblad et al. (1991a, 1991b), who have recently conducted an entire investigation on the innervation of the human synovium by immunohistochemistry.

Mapp et al. (1990), found fine nerve fibres which they believe act as sensory receptors. They also found substance P in similar location to those in the synovium.
Therefore, they also concluded that a nociceptive role of these nerves, is a likely hypothesis.

4.4 THE MAMILLO-ACCESSORY LIGAMENT

The morphology of the mamillo-accessory ligament has been rather difficult to explain.
Although it appears to be an independent ligament, its cord-like structure resembles more a tendon rather than a ligament, and that is why Bogduk (1981) interpreted it as

representing a tendon of the semispinalis musculature in the lumbar region.

According to Bogduk and Twomey (1991), the mamillo-accessory ligament consists of a light bundle of collagen fibres of various thickness, and it bridges the tips of ipsilateral mamillary and accessory processes of each lumbar vertebra. Besides not having any biomechanical significance, the mamillo-accessory ligament is not recognized by some as a true ligament, because it connects two points on the same bone (Bogduk and Twomey, 1991).

Since this ligament is not found is the cat, dog and monkey (Bogduk, 1981), it is difficult to make any comparison of it in regard to other species.

The interest of this ligament lies in its relation to the medial branch to the posterior primary ramus. As described earlier, each medial branch of PPR passes dorsally and caudally through the intertransverse space towards the superior border of the root of the subjacent transverse process, from where it continues dorsally and caudally, lying against the groove formed by the junction of the root of the transverse process with the root of the superior articular process.
Opposite the caudal border of the zygapophysial joint, the medial branch turns medially through a groove between the mamillary process and the accessory process. The nerve is

held in the groove by the mamillo-accessory ligament which bridges these two processes.

Bradley (1974), Ninghsia Medical College (1978), and Maigne et al. (1991), suggest that the medial branch of the posterior primary ramus could be entrapped under this ligament. Giles (1991), on the basis of his histological study, concluded that entrapment of the medial branch by the mamillo-accessory ligament is not likely, indicating that the nerve occupies approximately 3% of the space beneath the ligament.

Our findings reveal that in our routine dissection of 28 cadavers, in one dissection swelling was present on the medial branch as it approached the mamillo-accessory notch at L2 level. This thickening was seen proximal to the fibrous band (mamillo-accessory lig.) which is suggestive of entrapment neuropathy (Gilliatt and Harrison, 1984). 'see figure 3.38a & b)

The mamillo-accessory ligament may ossify, thus converting the mamillo-accessory notch into a bony foramen.
Manners-Smith (1908), found this foramen in fourteen specimens, between the mamillary process and the accessory, but did not know its role, and thought that it was probably vascular. It was not related then to the mamillo-accessory ligament or its ossification.
Ninghsia Medical College (1978) described the bony features

of the mamillo-accessory region in a 100 Chinese skeletal specimens, but did not relate their findings to the mamillo-accessory ligament. Bogduk (1981), Maigne et al. (1991) and our study relate the appearance of this bony foramen to the ossification of the mamillo-accessory ligament.

Maigne et al. (1991) found that the mamillo-accessory foramen was in the range of 1 mm to 5 mm in width, whereas we found it to be in the range of 0.5 mm to 6.0 mm. (figure 3.40a)

Maigne et al. (1991) relate the ossification of the mamillo-accessory ligament to the osteoarthritic changes.
We found that the mamillo-accessory foramen was formed without any osteoarthritic changes, in several cases. (figure 3.41a)

The clinical significance of the mamillo-accessory ligament relates to "Facet Denervation", and "Medial Branch Neurotomy", since this ossification can impede access to the underlying medial branch of the posterior primary ramus.

Bogduk and Twomey (1991) state that ossification of this ligament is a normal phenomenon without any pathological significance.
This ligament when ossified, can be detected by computed tomography (CT) as an apparent anomaly (Beers et al., 1984).

4.5 THE SIGNIFICANCE OF THE ANATOMICAL INVOLVEMENT IN THE CAUSATION OF LUMBAR PAIN

In numerous cases of low back pain, diagnostic uncertainty still remains, because the structures causing pain often can not be seen even by the latest diagnostic imaging procedures (Nowicki et al., 1990).

Neuroanatomical studies of the spinal soft tissues confirm the presence of nerve endings and nerves immunoreactive to substance P in the zygapophysial joint capsule (Mapp et al., 1990), which strongly suggests that the zygapophysial joint capsule can be a source of pain.

Biomechanical studies show that the lumbar zygapophysial joint capsules are load bearing structures and that these capsules can undergo extensive stretch in physiologic loading (Hakim and King, 1976; Yang and King, 1984).

Electrophysiological studies of these synovial joint capsules indicate that these joint capsules contain a variety of mechanosensitive nerve endings, including nociceptors, having identified C fibres (Cavanaugh et al., 1989).

Electrical stimulation of the posterior primary rami or mechanical stimulation of the zygapophysial joints results in reflex muscle activity (Bogduk and Munro, 1974).

Nerve fibres have been found in synovial folds of relatively young patients with no evidence of zygapophysial joint osteoarthritis, as well as in the synovial folds of older patients with some degree of osteoarthritis.
Therefore, nerve fibres seen in the synovial folds are a normal anatomical finding, not associated with degenerative joint diseases.

Although it is acknowledged that it is not possible to categorically prove the function of the small nerve fibres which are unrelated to blood vessels in vivo, their function must be speculative. Therefore, it seems reasonable to say that **mechanical nipping** of the synovial folds (Kirkaldy-Willis, 1984) or traumatic synovitis with **chemical irritation** of nerve endings (Guyton, 1992) due to the release of noxious chemical stimuli in the synovial folds, could result in pain.
Pressure on an axon,and release of pain producing substance like SP or bradykinin, due to cell damage, as most workers believe, can be responsible for causing tissue damage type of pain (Guyton, 1992).

Since the synovial folds have small myelinated fibres which are remote from blood vessels, it is suggested that a nociceptive role of these fibres is a likely hypothesis.

The immunohistochemical data clearly supports this proposal.

Injection of local anaesthetic into the zygapophysial joint cavity or its nerve supply, results in relief from low back pain (Warfield, 1988), possibly because of anaesthetizing nerve receptors in the synovial folds or in the joint capsule. Therefore, it would appear that the zygapophysial joint capsule or its synovial folds are likely sources of such pain, although innervation of the synovial folds has been denied historically (Hadley, 1964; Wyke, 1981).

Early studies of facet-joint injection with steroids and anaesthetic were quite encouraging (Carrera, 1980; Destouet et al., 1982; Murtagh, 1988). Therefore, Lippitt (1984) after using these injections, concluded that since facet blocking is simple, safe, and cost-effective, the technique should be used in the management of low back pain.

Lynch and Taylor (1986), showed that intra-articular injections were more effective than extra-articular for long term pain relief.

Lilius et al. (1989), in a controlled study of the facet joint injection, by using three types of injections; corticosteroid and local anaesthetic into the joint, the same mixture around the joint and physiologic saline into the joint, concluded that facet-joint injection is a non-specific method of treatment. On the other hand, Warfield (1988), states that "the only definitive way of making the diagnosis is by injection of local anaesthetic into the

joint or its nerve supply. Relief of pain confirms the diagnosis".

Facet-joint injections are currently used as a diagnostic and therapeutic mode of treatment.

Bradley (1974), referring to the fibro-osseous canal formed by the mamillo-accessory ligament, commented that "it seems likely that nerve entrapment could occur at this point".

Sunderland (1978) postulated that the medial branch of the posterior primary ramus, being held against the root of the zygapophysial joint by the mamillo-accessory ligament, could be irritated by subluxations or by proliferative or inflammatory conditions of the joint and thus be a source of low back pain.

In our study we found thickening of the medial branch of the posterior primary ramus proximal to the mamillo-accessory ligament, suggestive of entrapment neuropathy.
Surgical intervention could relieve pain by perhaps removal of this compression.

CLINICAL STUDY

CHAPTER V

THE EFFECTS OF FACET JOINT INJECTIONS IN THE CADAVER

5.1 INTRODUCTION

The clinical significance of the anatomy of the posterior primary rami relates to the surgical techniques designed to divide these nerves, or anaesthetise the associated pain receptors in the treatment of low back pain and sciatica.

The earliest and still one of the best papers on the injection technique was by Steindler and Luck (1938) who showed that local injection of procaine into the painful and tender posterior spinal structures gave total relief of pain together with abolition of accompanying physical signs and sciatic radiation in 70% of cases tested.
Their interest was less in the anatomical source of the pain than in a neurophysiologic explanation of their findings.

There are three types of operations considered currently:

* Facet Denervation
* Lumbar Medial Branch Neurotomy
* Facet Joint Injections

A) "FACET DENERVATION"

"Rhizolysis" - Historical Background:

With the publication of his paper on the "multiple bilateral segmental rhizolysis of segmental nerves", Rees (1971) drew attention to the role of the structures within the posterior compartment in the production of low back pain. Rees claimed success rates of 99.8% for relieving pain in more than 6,000 patients, and claimed that his pupils, had performed 20,000 operations of the same kind with the same success rate as his own. In his operation (Rees, 1975), he used a Beaver Blade Number 52 R to cut what he believed were the sensory nerves to the zygapophysial joints. Other surgeons who performed the same operation, although successful, had less impressive results (Toakley, 1973; Houston, 1975; Collier, 1979).

The anatomical basis of Rees' operation was studied by Bogduk et al. (1977), who found that the anatomy of the innervation of the zygapophysial joints was not as described by Rees.

Slightly earlier, King and Lagger (1976) with radiologic studies, had demonstrated that Rees' knife blade was too short to reach the nerves of the zygapophysial joints. Therefore, "Rhizolysis" could not denervate the zygapophysial joints. '(figure 5.1)'

FIGURE: 5.1

Mean depth of the lower three lumbar zygapophysial joints and upper two sacral foramina as measured in thirty middle-aged male patients.

From: King and Lagger (1976)

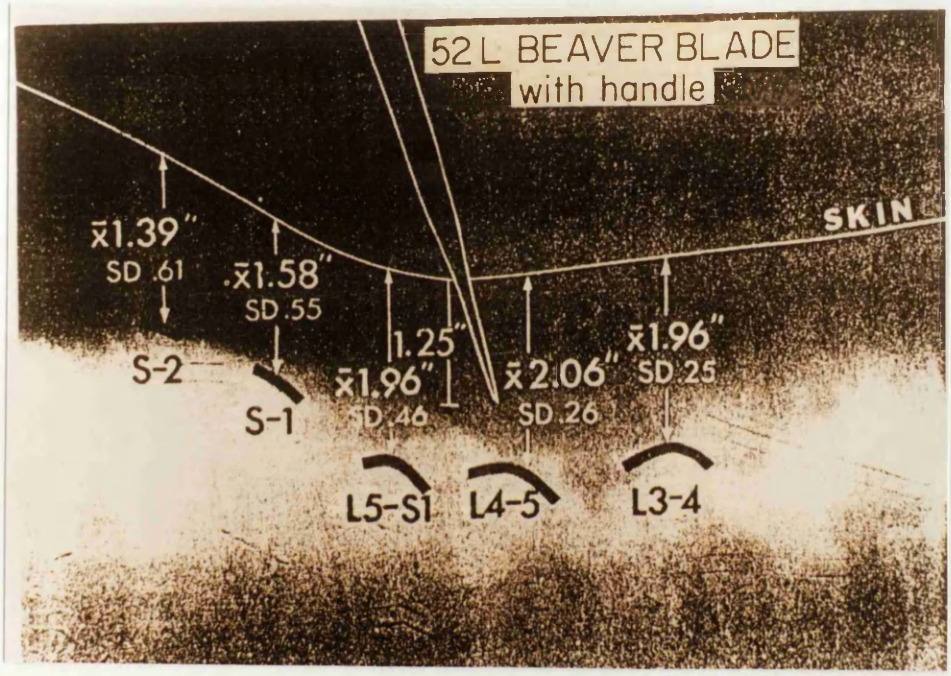

52 L BEAVER BLADE
with handle
SKIN
x̄1.39"
SD .61
x̄1.58"
SD .55
1.25"
x̄1.96"
SD .25
S-2
S-1
x̄1.96"
D .46
x̄2.06"
SD .26
L5-S1
L4-5
L3-4

Figure 5 -1

The pain relief achieved by Rees' procedure had not resulted from denervation, but more likely from a myofasciotomy of the paravertebral musculature (King and Lagger, 1976).

In spite of the technique being difficult to justify, Stuckey (1990) insists that for whatever reasons, rhizolysis works, and therefore, should be offered to more people with chronic back pain.

All of Rees' four drawings of the lumbar spine and its innervation are published in an unconventional orientation. (Rees, 1975).'see figure 5.2'

"Facet Denervation" - Development:

In 1972, Shealy performed Rees' operation on 29 patients and found that relief of pain occurred in half of those patients. But because of having a large haematoma in 20% of cases, he decided to reconsider the technique and develop a new one (Shealy, 1974,1976). Shealy like Rees, believed that disorders of zygapophysial joints could produce low back and sciatic pain, and therefore denervation of such pain-producing joints, was an appropriate form of treatment (Shealy, 1974,1976).

FIGURE: 5.2

Rees (1975)

Multiple bilateral percutaneous rhizolysis procedure.

The diagrams are printed upside down.

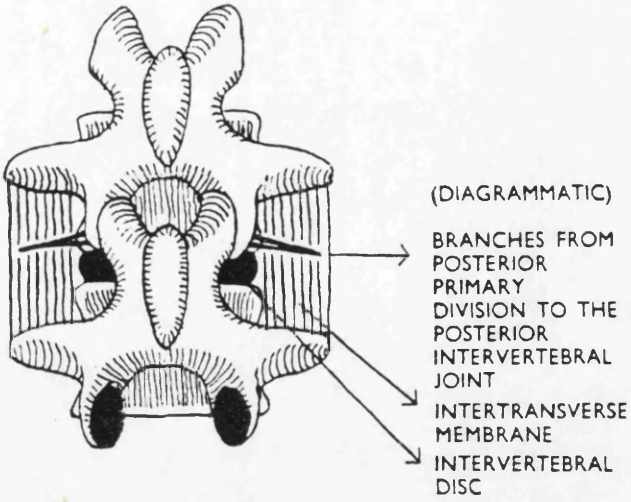


FIGURE 1: Sensory nerve supply to intervertebral discs and posterior intervertebral joints (posterior view).

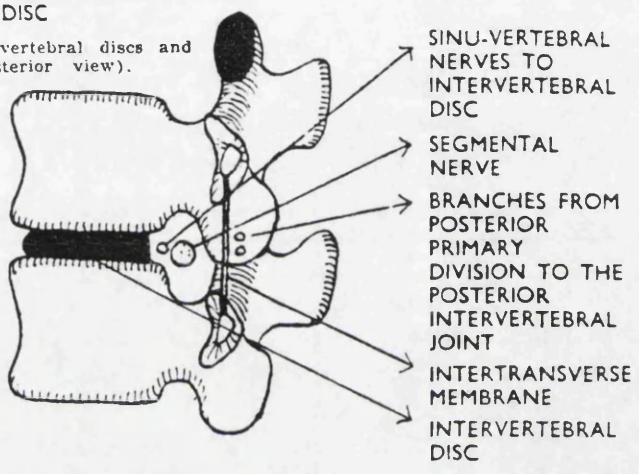


FIGURE 2: Sensory nerve supply to intervertebral discs and posterior intervertebral joints (lateral view).

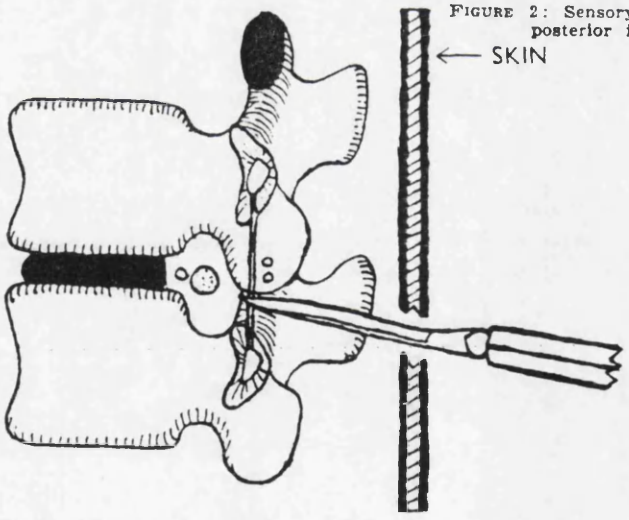


FIGURE 3: Beaver eye knife 52 L and holder (Rudolph Beaver Inc., Belmont, Mass., 02178, U.S.A.) (lateral view).

Figure 5-2

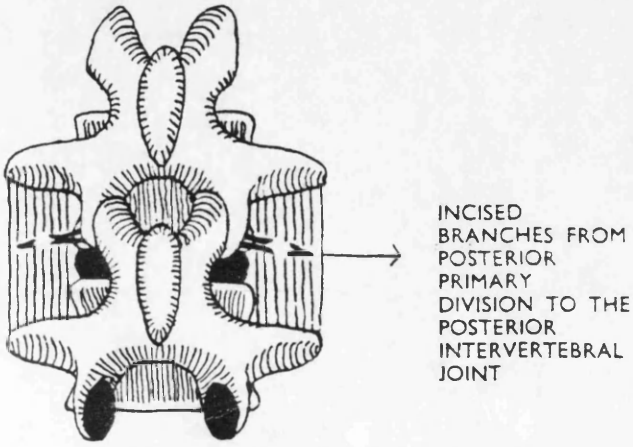


FIGURE 4: The severed nerve branches (posterior view).

In 1974, he modified Rees' technique and used a thermal-lesion marker to destroy the medial branches of the posterior primary rami to the zygapophysial joints.

The result he achieved was good or excellent in 44 out of 57 patients not previously operated on. He concluded that the majority of patients who have back or sciatic pain, do not have a "ruptured disc" (Shealy, 1975). He called his technique "Facet Denervation". 'see figure 5.3'

Shealy's illustration, unfortunately reveals a major error in the nomenclature and morphology of the nerves.

The articular branches to the lumbar zygapophysial joint do not rise over the summit of the joint as illustrated by Shealy. They in fact, approach the joint from its rostral or caudal aspect.
The nerve that most probably resembles what Shealy (1974) called an "articular branch" is the medial branch of the posterior primary ramus.

Apart from this, the illustration showing the course of the medial branch is inaccurate. The medial branch does not rise over the summit of the joint, and neither do any of its branches. Therefore, the target point is not the articular branch, but the parent medial branch, which means that other structures innervated by the medial branch would also be affected.

So it was rather a "Medial Branch Neurotomy" as described by Bogduk (1980d), than being "Facet Denervation".

Mooney (1990) indicates that Shealy has now given up the procedure.

B) Lumbar Medial Branch Neurotomy

Lumbar Medial Branch Neurotomy was devised by Bogduk (1980d) as a modification of the "Facet Denervation".
In this the target is specifically the medial branch of the posterior primary ramus.

At L1-4 levels, the target point is the dorsal surface of the transverse process just caudal to the most medial end of the superior edge of the transverse process.
At L5 level, the medial branch is not accessible. Instead the target point at this level is the posterior primary ramus proper.

Once the needle is in position, an electrode may be introduced through it and the needle slightly withdrawn to expose the electrode tip. The electrode should be resting on bone. The nerve is destroyed by a lesion made with a radiofrequency generator. (figure 5.4)
Besides denervating the joints, medial branch neurotomy

FIGURE 5.3

"Facet Denervation" technique
The three electrode positions during lesioning and the region of electrocoagulation.
From: Shealy (1976)

FIGURE: 5.4

Dorsal view of the lumbar spine illustrating techniques of lumbar medial branch blocks and intra-articular zygapophysial blocks.
Zj : zygapophysial joint
mb : medial branch of the posterior primary ramus
From: Bogduk, N. (1985) Low back pain.
Australian Family Physician, **14**(11), 1168-1171

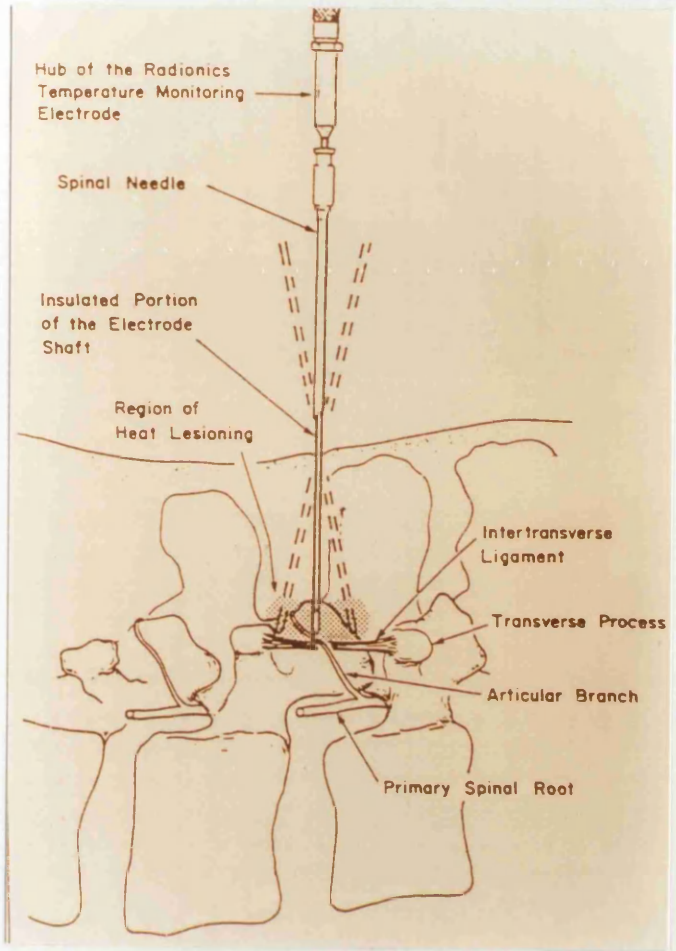


Figure 5-3

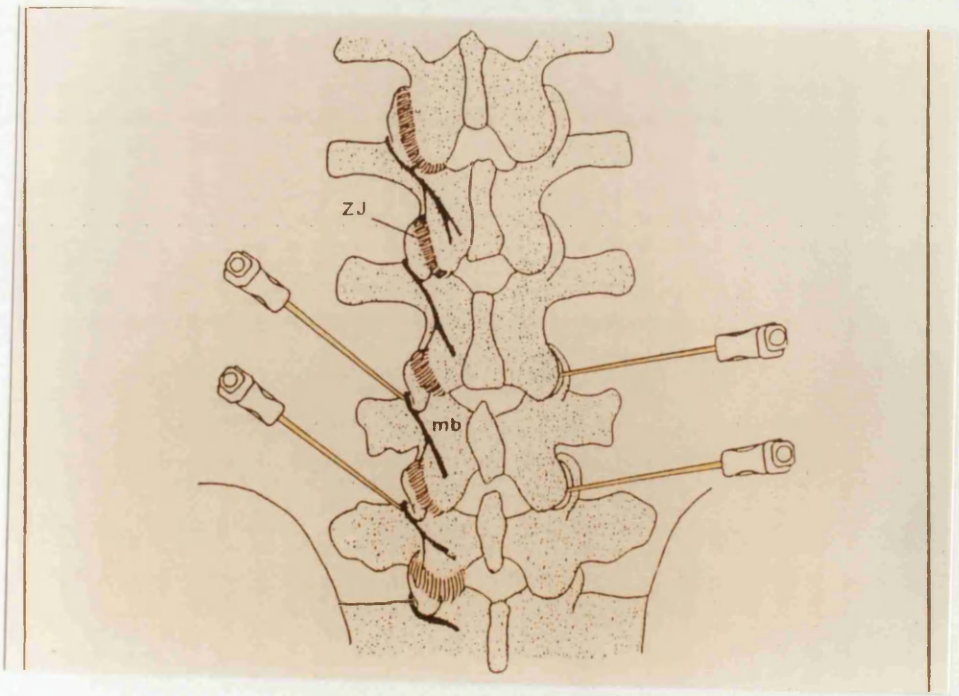


Figure 5-4

also destroys innervation to other structures innervated by the medial branch, namely the multifidus, or if at L5 level, all structures innervated by the posterior primary ramus.

C) "Facet Joint Injections"

Facet joint injections with local anaesthetic agent and steroids are, according to Mooney (1990), used to serve two main functions; as a diagnostic tool and as a device to "buy time" until a proper diagnosis is reached. It may also be a definitive treatment.

The injection in the lumbar spine is performed under fluoroscopic control or CT (Carrera, 1980; Murtagh, 1988), so that the needle position can be localized accurately.
Since the zygapophysial joint is both curved and obliquely oriented, the joint is punctured with the patient either prone or in a shallow anterior oblique position, with the injected side up. The obliquity should be limited to ensure that the most posterior portion of the joint is the part in profile. (figure 5.5)

FIGURE: 5.5

Illustration of the technique for injecting the lumbar zygapophysial joint under fluoroscopic control.

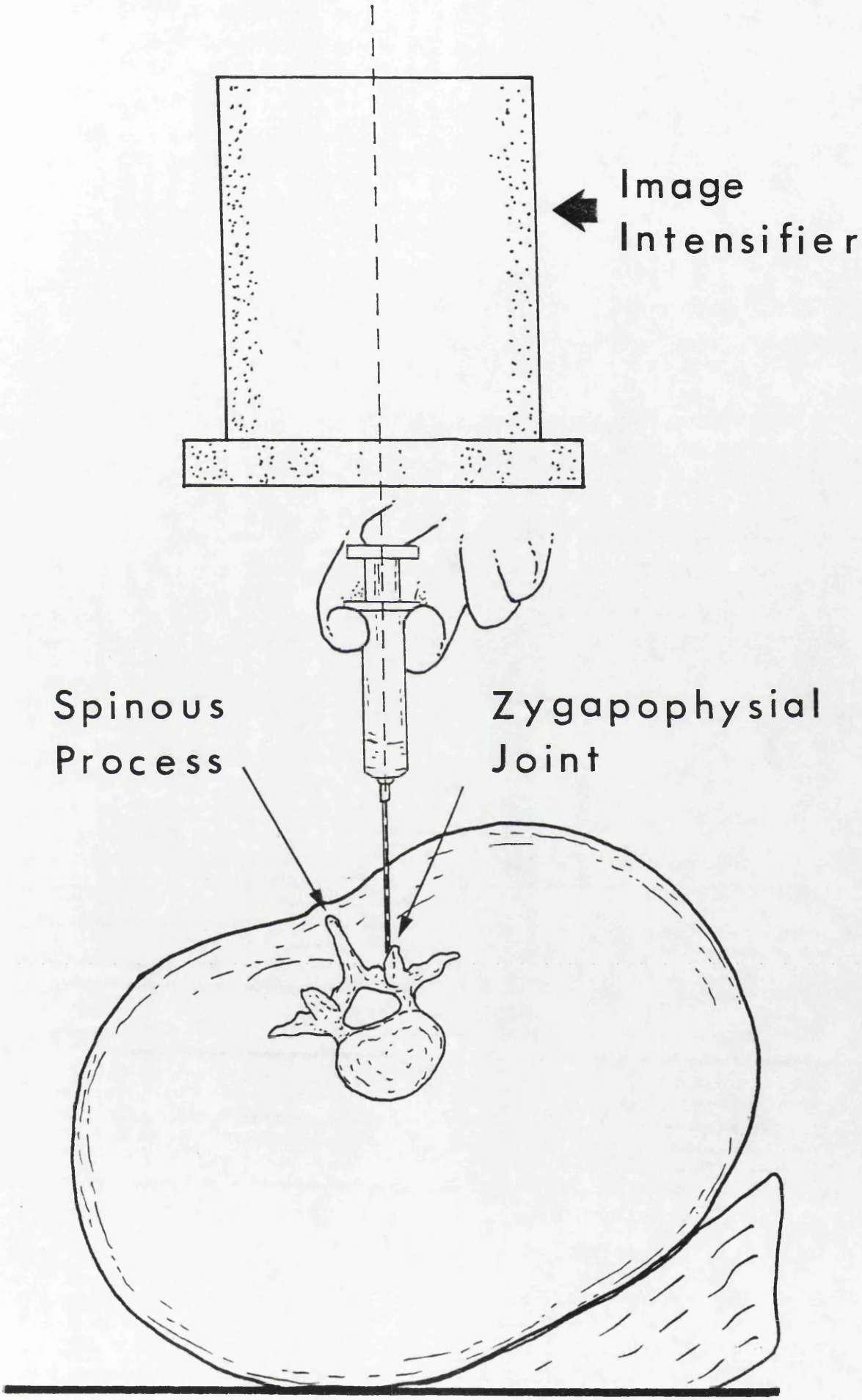


Figure 5-5

5.2 MATERIALS AND METHODS

5.2.1 CADAVERIC LUMBAR SPINES FOR FACET-JOINT INJECTIONS

A) Materials:

Two cadavers were chosen from those normally accepted for research and teaching purposes at University of Glasgow, Anatomy Department.
The cadavers were of females of the ages 57 and 64 years. Both were perfused with embalming fluid (table 2.1), within 24 to 48 hours of death.
The embalmed cadavers, as explained on page 44, are properly stored and preserved.
The selected bodies were intact and undissected, so that they presented as normal appearance as possible for the operation, and also showed normal contrast on x-ray.
The trunk was divided at T12 and S2 level, in order to include the full length of the lumbar spine. The cut ends of the specimens were covered with a sheet of opaque polythene sewn from the sides to prevent leakage.

B) Methods:

The first case was injected by a Consultant Radiologist, who used a 20 gauge 6 inches long spinal needle for this

injection. The specimen was laid on the table of the x-ray machine, in the prone position. A supporting cushion was then inserted to hold the specimen in the required oblique position.

The position was checked under fluoroscopic control, to ensure that the posterior portion of the zygapophysial joint is the part in profile. The needle was inserted and aimed towards the L2-3 and L4-5 zygapophysial joints separately. When the needle was felt to be in the desired orientation, its position was checked by injecting 0.5ml of nonionic contrast medium, and taking an x-ray at each level. The clinical injection was then simulated by 1ml of Patent Blue V, a dye regularly used by the Radiology Department.

The second specimen was injected by a Consultant Anaesthetist, also under fluoroscopic control. The attempt was aimed at L4-5 zygapophysial joint, but the dye this time was 1ml of India Ink, which we believed might minimize diffusion.

Both the clinicians found handling of the embalmed cadaveric tissue unfamiliar, and had some difficulty in finding the bony landmarks. In both the cases, the procedure took much longer than it would have in an actual patient. After the injections were given, the specimens were brought back to the Anatomy Department.

The sites of injectins were carefully identified, and a

window was opened in the skin at the site.
The dissection started from the skin of the back, moving through the deep muscles, and eventually reaching to the posterior capsule of the zygapophysial joints.
The lumbar region in both the cases was cut through the midline by a band-saw, and the vertebral bodies were removed in order to view the ligamentum flavum, and allow dissection of the posterior primary rami by ventral approach.

The specimen injected with India Ink at L4-5 level, was carefully dissected, tracing the posterior primary ramus and its branches.
The same specimen was later snap frozen. 0.5cm thick horizontal sections were cut, examined under Wild M400 photomacroscope, and photographs were taken using Vericolor III VPS film.
One of these sections was processed for histology and stained by the Masson Trichrome technique.

0.5cm thick sections were also obtained from the specimen injected with Patent Blue V, and photographed using Wild M400 photomacroscope.

Complete series of photographs were taken of the dissections using Nikon FG-20 camera, with Panagor Auto Macroconverter attached to it.

5.3 RESULTS

Although the specimens had the general appearance relevant to the actual patient's back with the skin being intact, the air shadows in the muscles made it rather difficult for the clinicians to locate the zygapophysial joints on x-ray. (figure 5.6)

The positioning of the patient for injection which normally ensures that the posterior portion of the joint is the part in profile, also presented problems. In the living, it is fairly easy to ask the patient to move slightly, but it proved to be difficult in cadavers, when cushions were used for balancing. An Image Intensifier was used every time changes were made, to ensure the correct position. (figures 5.7 & 5.8)

Fibre by fibre dissection of the injected specimens was carried out initially using the posterior approach, which revealed that the dye in both the cases had stained the deep fascia, and permeated deeper into the musculature of the back. (figure 5.9a & b)

The dye spreading in the erector spinae covered an area of about 3cm deep to the site of injection (figure 5.10a & b). Here the staining of the dye was heavy, and it gradually started fading out as we approached the posterior capsule of the zygapophysial joints. (figures 5.11, 5.12, 5.13, 5.14a & b, and 5.15)

FIGURE: 5.6

An oblique view of the zygapophysial joint at L4-5 level.

The spinal needle is inserted in the joint capsule.

(Air shadow is seen in the muscular area)

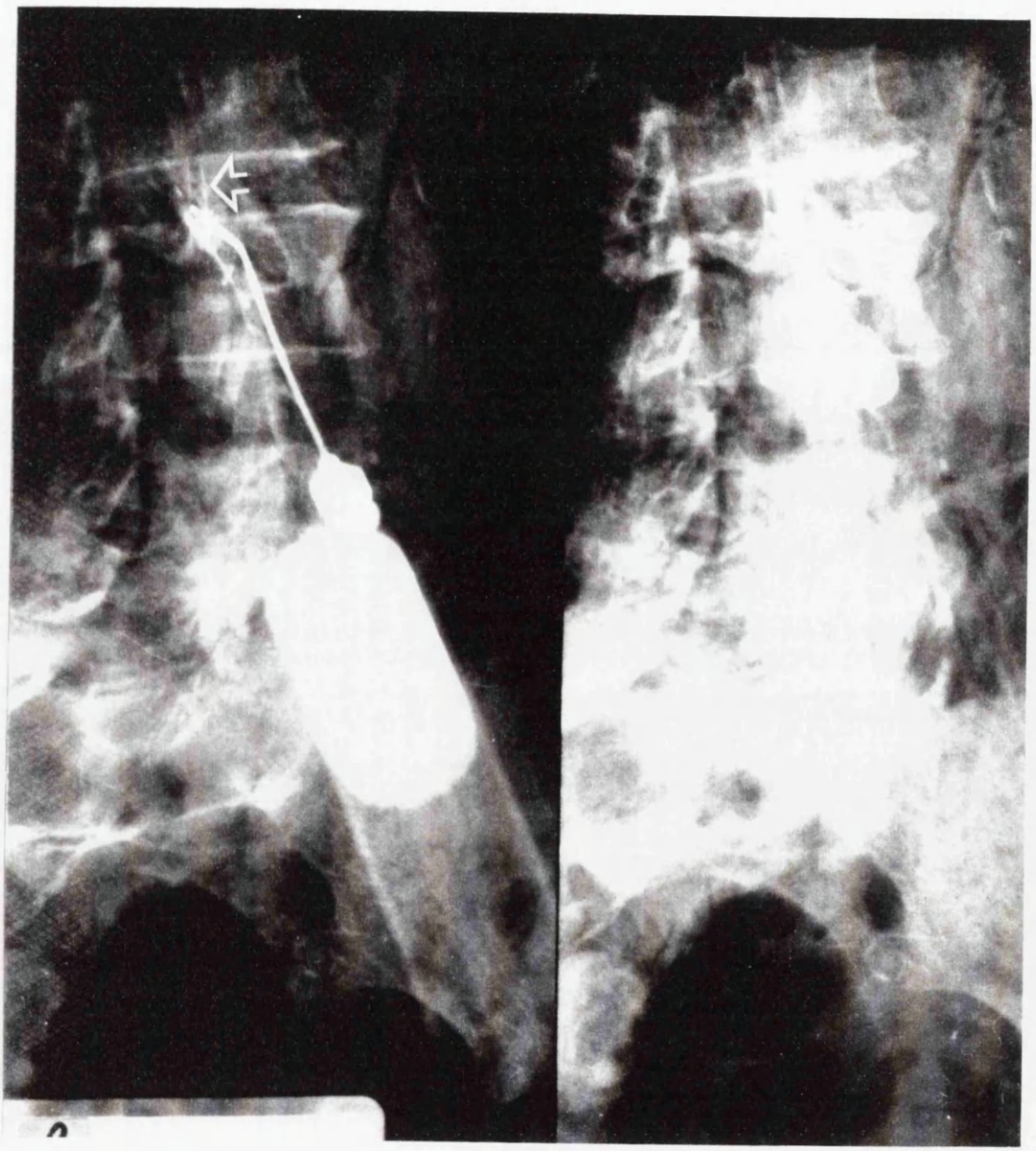


Figure 5-6

FIGURE: 5.7

An oblique view of the L4-5 zygapophysial joint illustrating the location of the spinal needle (arrow).

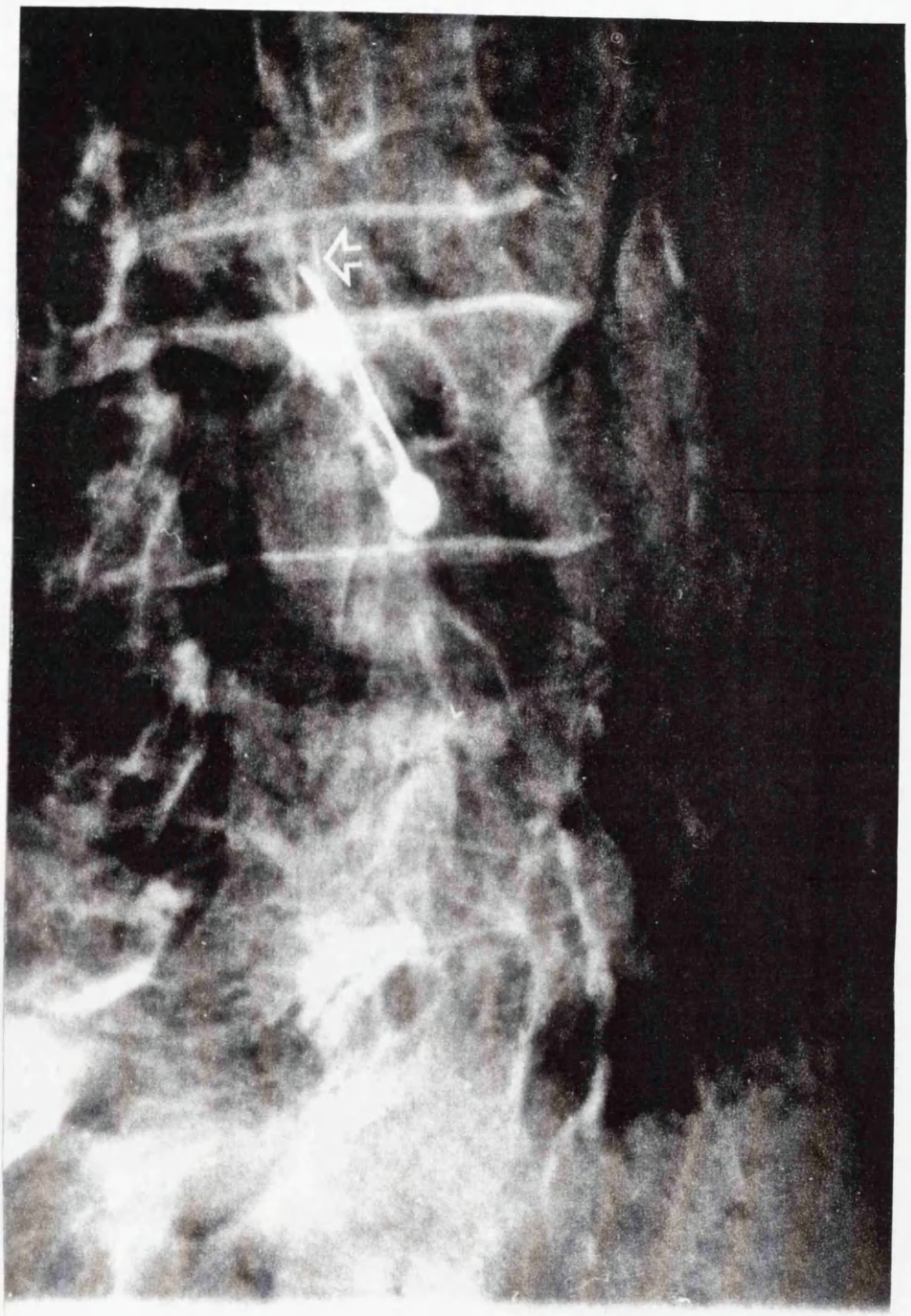


Figure 5-7

FIGURE: 5.8

An oblique view of the lumbar region showing spread of the contrast material mixed with Patent Blue V, at L2-3 zygapophysial joint (open arrow). Spread of the contrast material in the paravertebral area, confusing it with L3-4 zygapophysial joint.

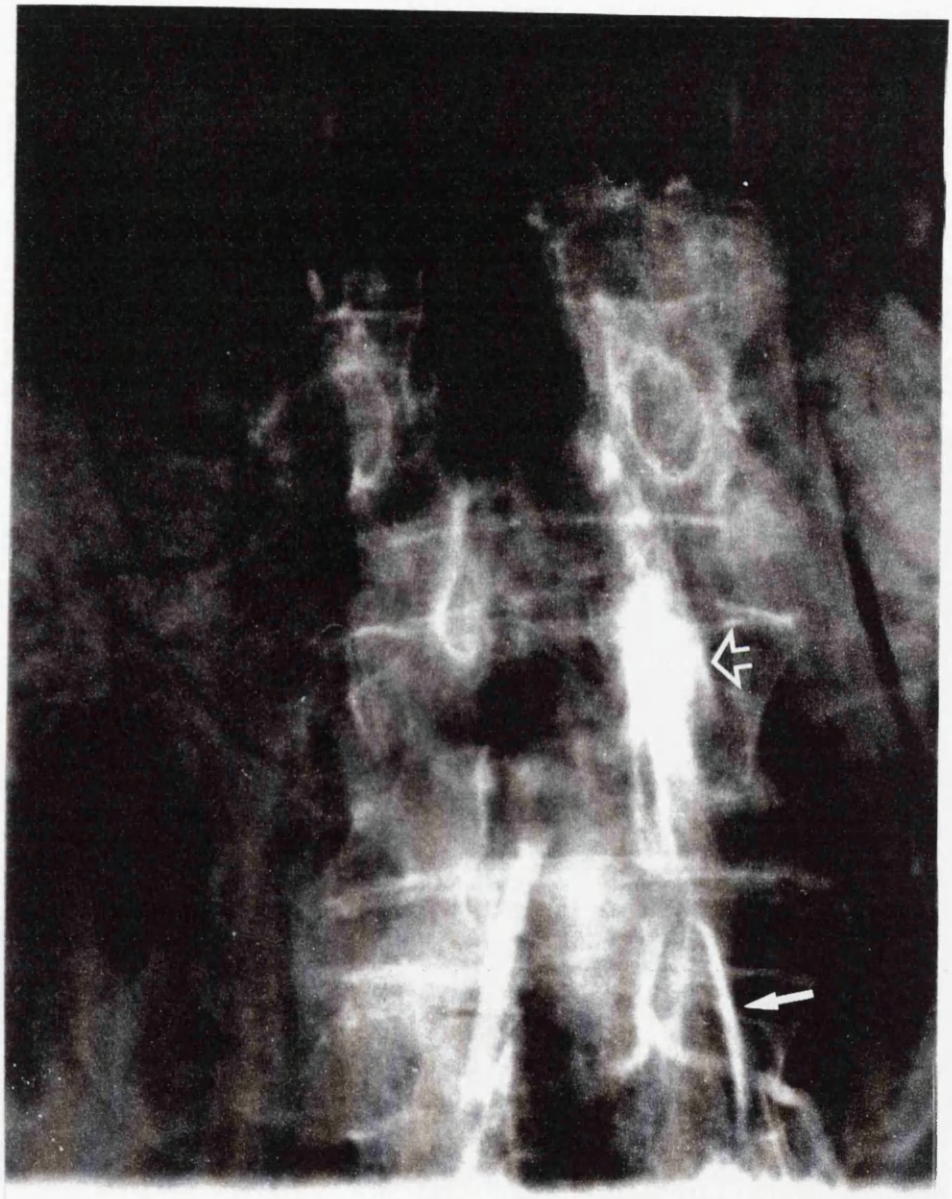


Figure 5-8

FIGURE: 5.9 (A)

Insertion of the spinal needle with Patent Blue V, at L4-5 zygapophysial joint.

(B)

Location of the spinal needle before dissecting the area.

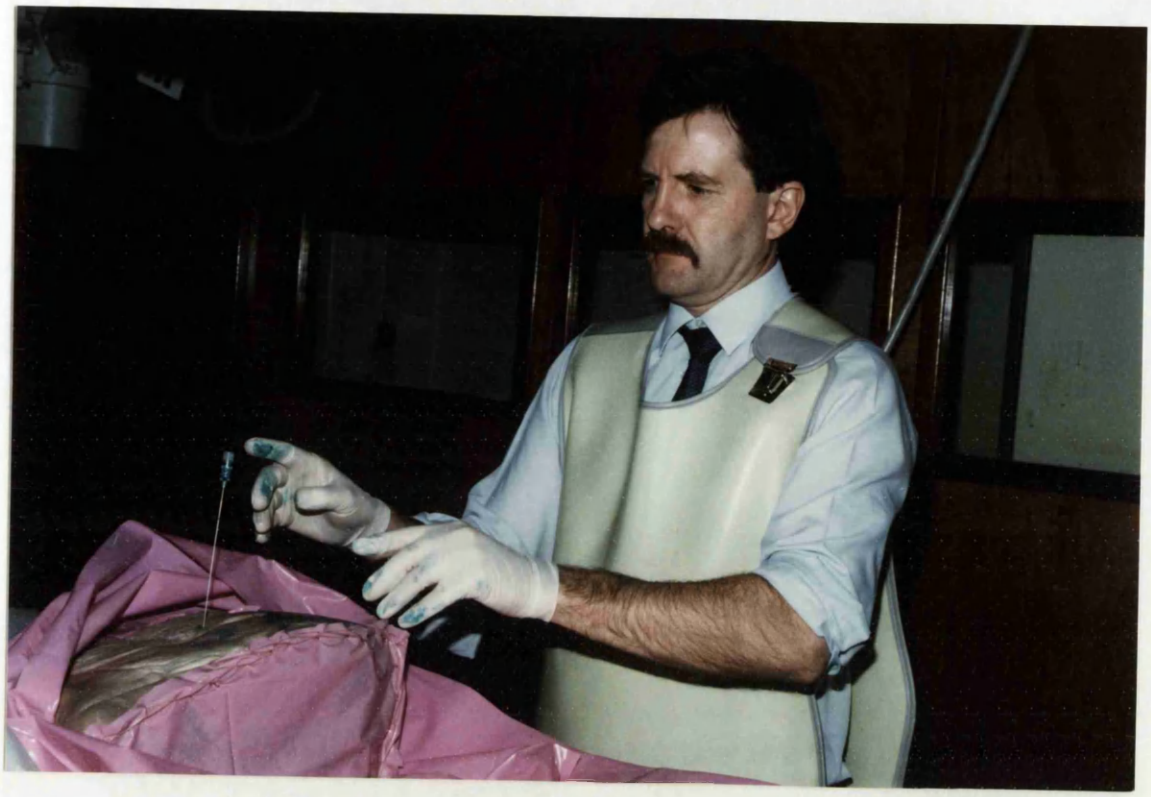
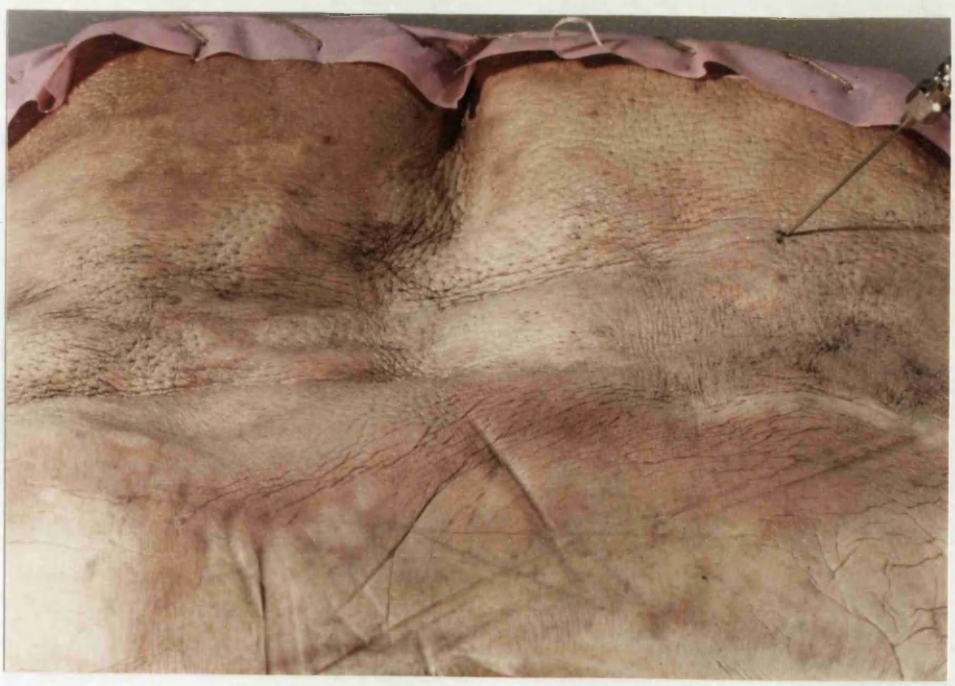


Figure 5 - 9 (**A**)



(**B**)

FIGURE: 5.10 (A)

Spread of the dye (Patent Blue V) in the paravertebral musculature. The deep stain is in the erector spinae muscle at L4-5 level. The stain is seen running along the outer surface of the multifidus muscle towards L3-4 level.
Compare with figure 5.8

(B)

Insertion of the pin shows the location of L4-5 zygapophysial joint.

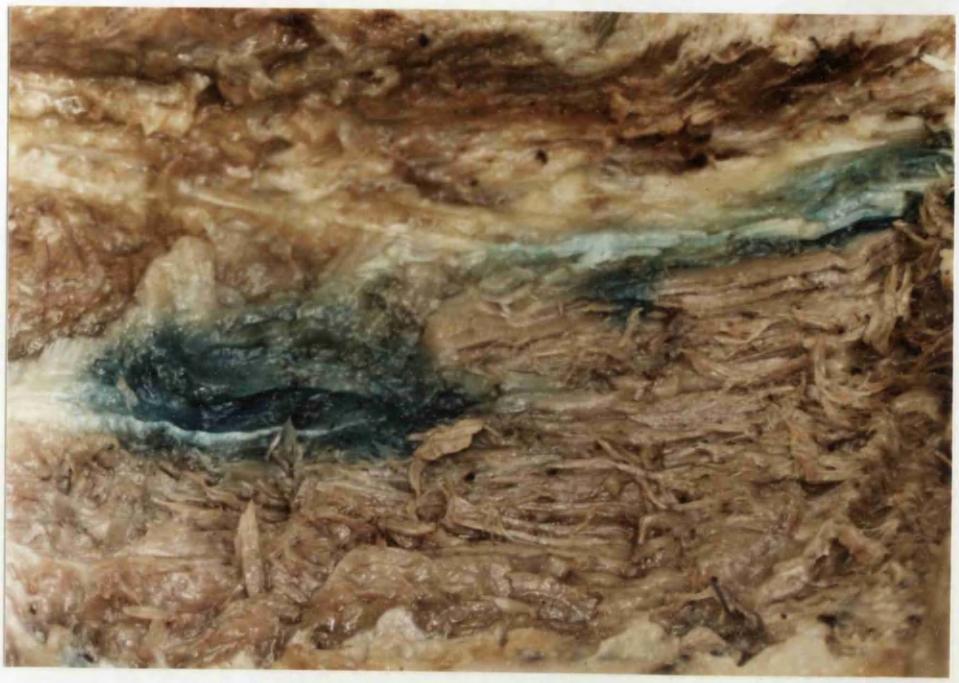
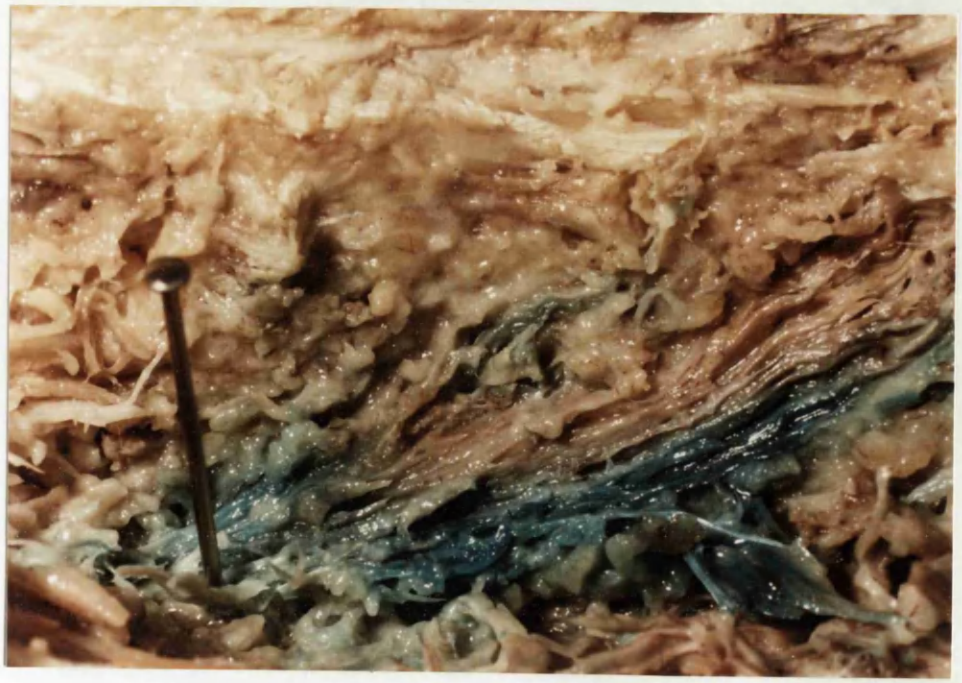


Figure 5-10 (A)



(B)

FIGURE: 5.11

Fading of the dye (Patent Blue V) is seen as we approach the zygapophysial joints.
The red pins mark the location of these joints (L4-5, L3-4, L2-3)

FIGURE: 5.12

Spread of the dye (Patent Blue V) in the epidural space and abdominal aorta.

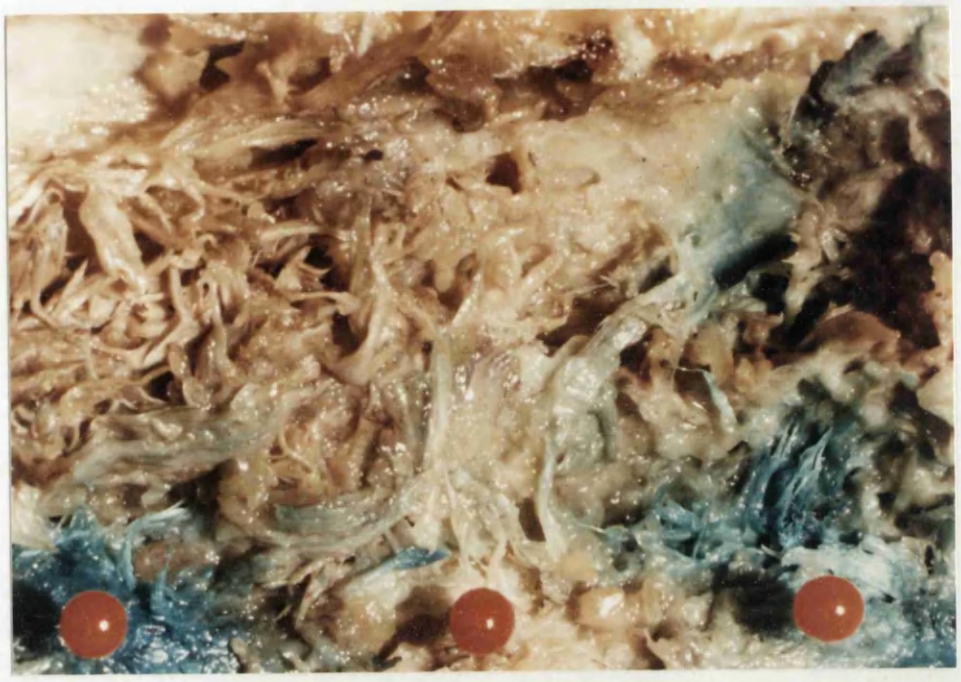


Figure 5 - 11

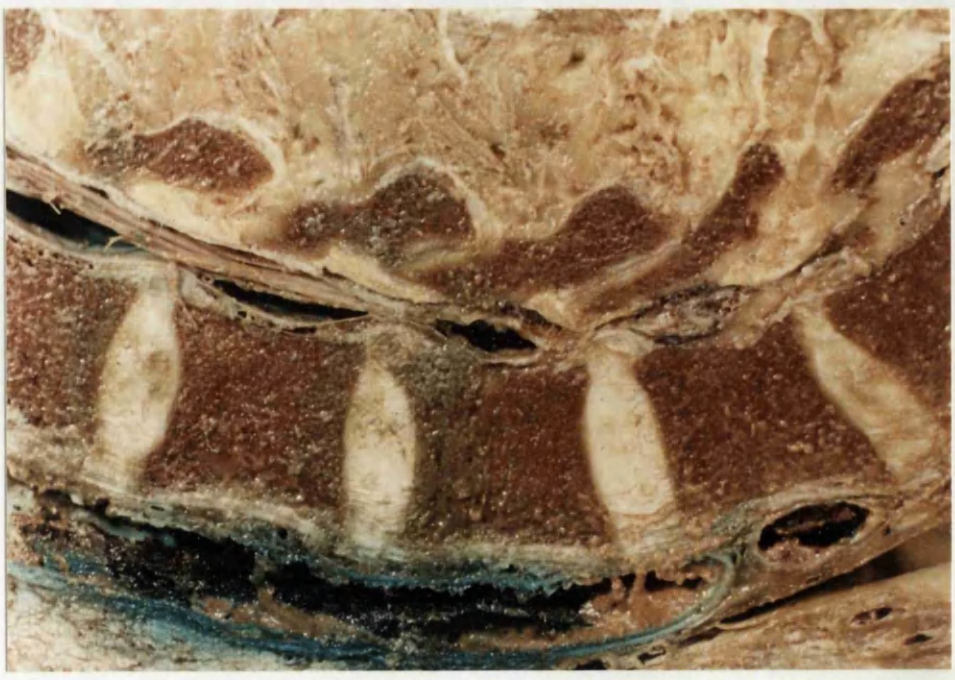


Figure 5 - 12

explain why division of the XI nerve in radical neck dissection does not always cause trapezius paralysis. On the right the XI nerve had no connection with the cervical plexus peripherally and supplied sternomastoid only. The entire supply (motor and sensory) to trapezius came from C1, C2, C3, and C4 cervical plexus branches crossing the posterior triangle. Intradurally, the spinal portion of the XI nerve emerged between the dorsal and ventral roots of C1 to C5 and connected with C2 and C3 dorsal roots. On the left a more usual pattern was found, with mixed XI and cervical plexus supply to trapezius. On this side the spinal accessory nerve emerged between the dorsal and ventral roots, but extended only as far as C3, and an unusual peripheral connection between C3, C4 and the XI nerve in the posterior triangle was found. This study provides anatomical support for the view that cervical plexus branches to trapezius may be motor and must be preserved. We are pursuing this possibility with further work.

The authors are grateful to the British Industries Neurosurgical Research Fund and Codman UK, Ltd. for their generous support. P.J. Hamlyn was supported by a Guinness Neurosurgical Fellowship.

NAVARATNAM, Visvan, Department of Anatomy, University of Cambridge, UK.

Heart valves: Design in nature.

An ideal heart valve should (1) open easily and widely to offer minimal impedance to high velocity blood flow and (2) close completely and rapidly with minimal displacement. Histologically, each valve comprises a fibrous anulus of characteristic shape, usually complex, to which are attached tough but flexible cusps or leaflets. In the aortic and pulmonary semilunar valves, each anulus resembles a 3-pronged coronet where each cusp is attached along a scallop-like line; above each scallop, the arterial wall bulges to form the sinuses of Valsalva which are crucial to the closure of the valve. Movement of the cusps at closure is supplemented by substantial contraction of the anulus. The atrioventricular valves, despite their traditional names (mitral and tricuspid), each include more than three "leaflets"; the cusp tissue is best regarded as a single funnel-shaped structure, indented along its distal border. Closure of the valves includes anular contraction as well as co-aptation of cusp tissue; during co-aptation, the cusp tissue is held fairly stiff, initially by passive stretching of the chordae tendineae and then by papillary muscle contraction.

HOLT, Edward M., Richard ALLIBONE, Department of Anatomy and Orthopaedics, Liverpool University, and the Department of Histo-Pathology, Royal Devon and Exeter Hospital, U.K.

The Coraco-Acromial ligament: clinical implications of the anatomical variants.

The coraco-acromial ligament has previously been described as 1) a broad band, 2) a triangular band, and 3) a Y-shaped ligament. Fifty embalmed human cadavers were dissected to reveal the coraco-acromial ligaments which were measured to assess their size and shape. The marked variances in the dimensions and shapes were documented and photographed. In the process of determining the shape of this ligament a further form was determined 4) a multi-banded ligament which had a wide coracoid attachment. The coraco-acromial ligament has long been implicated in the shoulder impingement syndrome. The persistence of signs and symptoms after operation may be the result of inadequate treatment of the medial aspect of the ligament, especially if the ligament is of the previously undescribed multi-banded form.

GODWIN, Yvette, Harold ELLIS, Department of Anatomy, Cambridge, UK.

An anatomical study of the symmetry of the first dorsal compartment of the wrist.

The anatomy of the first dorsal compartment has been extensively studied since it is the site of de Quervain's disease. A study of ten pairs of cadaver hands was performed to see if the distribution of septation, tendon number and insertion was bilaterally symmetrical.

Septation and multiple tendons have been implicated in causing overcrowding of the first dorsal compartment and hence involved in the pathogenesis of de Quervain's disease. This assumption arose because the description of the first dorsal compartment was oversimplified in standard anatomy text books. "Aberrant" tendons and septation were noted for the first time as surgeons decompressed diseased dorsal compartments. Such tendons were hence considered pathological. Review of the literature has shown that these variations are normal and unlikely to play a role in de Quervain's disease. De Quervain's disease tends to be a unilateral condition and this study has shown multiple tendons and septation are bilaterally symmetrical, putting further in doubt the view that anatomical variations are involved in the pathogenesis of de Quervain's.

MATTHEWSON, Murray H., Department of Orthopaedics, Addenbrooke's Hospital, Cambridge, UK.

The arthroscopic anatomy of the wrist joint.

In recent years arthroscopy has been increasingly utilized to investigate disorders of the wrist (radiocarpal) joint. The anatomy of the portals of entry and the features of the intra-articular anatomy that are visible were presented.

KING, Ann, Andrew HINE, Candice McDONALD, Peter ABRAHAMS, Departments of Radiology, Central Middlesex Hospital and University College Hospital, and Department of Anatomy and Developmental Biology, University College London.

Correlation of ultrasound with dissection of the normal psoas muscle.

Following a study on the ultrasound appearance in 144 normal psoas muscles, it was noted that in the section of fibers from the iliac crest to the fusion with iliacus muscle there was a prominent single echogenic plane in 70% of muscles. This was running obliquely in the transverse plane. There was no explanation in the anatomical literature for this finding and so we instigated a detailed dissection of the human psoas. Nine dissections have all revealed a consistent feature of intramuscular tendon formation arising three quarters of the way along from the origin towards the formation of the main psoas tendon just above the inguinal ligament. This is true for each individual muscle-belly origin from T12–L3. The origins from L4 and L5 did not show this feature, the fleshy muscular origins, when present, formed directly the main psoas tendon. The arrangement of muscle fibers, their tendency to "cork-screw" into the main tendon and the relationship with psoas minor muscle were discussed.

DIXON, Adrian K., Mark COOPER, Departments of Radiology, Addenbrooke's Hospital and the University of Cambridge, Cambridge, UK.

The anatomy of sacral edema.

A prospective study of 100 patients undergoing abdominopelvic computed tomography (CT) revealed CT evidence of sacral edema in 17. Sacral edema was clinically present in 12 of these 17 patients.

The excessive fluid in sacral edema characteristically collects in the superficial plane (between the superficial and deep layers of subcutaneous fat), at the point where this plane blends with the lumbar fascia. In gross examples of sacral edema the two layers of fat in this region may become quite separated. The maximal location of this fluid tends to be situated over the lower lumbar spine rather than the sacrum. Accordingly the term sacral edema may be something of a misnomer; either lumbar or lumbosacral edema would seem preferable terms.

Modern CT systems provide exquisite detail of the fascial planes within adipose tissue. These are accentuated by edema. The controversial relationships between the superficial and deep fascial planes in the trunk to those in the inguinal and perineal regions (Camper, Scarpa and Colles) were discussed.

DE SILVA, Suzete A.A., Ian D. LEWIS-JONES, C. Vyvian HOWARD, Dick van VELZEN, Departments of Human Anatomy and Cell Biology and Fetal and Infant Pathology, University of Liverpool, UK.

Ureteric differentiation and its innervation.

Increased knowledge on the development of the urinary tract has improved understanding of possible mechanisms causing congenital urinary tract malformations. Ultrasonography has revealed the antenatal natural history of urinary tract abnormalities. Contradictions remain with regard to the treatment and pathogenesis of these conditions of unknown etiology. "In-vitro" experiments have demonstrated early ureteric innervation and specific proteins were found to be expressed in growing stromal cells. Although this suggests that a defect at a cellular level during the differentiation could result in ureteric malformations, the developing nervous system remains to be defined "in vivo." The authors present preliminary immunohistochemical and histomorphological studies on the innervation of the developing ureter. Preliminary results indicate different phases of ureteric development, with changes occurring dependent on differentiation of the myo-epithelium complex and its innervation. The possibilities for abnormal development during the phases of induction, differentiation, and maturation of the ureter and the influence of its mesenchymal microenvironmental components were discussed. This work was supported by a grant from the Alder Hey Kidney Research Fund.

LATIF, Nasir A., John SHAW DUNN, Dept. of Anatomy, University of Glasgow, Glasgow, UK.

Innervation of the lumbar zygapophyseal joints.

The lumbar zygapophyseal joints are a recognized source of low back pain, but there is still controversy about their innervation, which affects diagnosis and treatment.

1. Presentation at the summer meeting of the British Association of Clinical Anatomists, Department of Anatomy, University of Cambridge, July 17th, 1992.

Innervation of the lumbar zygapophysial joints

Clinical Anatomy, **6**(1), 58-59 (1993)

2. Accepted for presentation at the summer meeting of the British Association of Clinical Anatomists, Liverpool Medical Institute, Mount Pleasant, Liverpool.
July 16th, 1993

The mamillo-accessory ligament - a possible site of nerve entrapment.

Recommendations:-

1. In cases of idiopathic low back pain the mamillo-accessory notch should be imaged as a possible site of compression of the medial branch of the posterior primary ramus .

2. When injections are given into the zygapophysial joint for diagnostic purposes, the volume of the injection should be limited to 1-2 ml to minimize extravasation, in the interest of precision of diagnosis. In therapeutic injections, a larger volume, with its attendant extravasation might of course be beneficial.

3. If an injection into the zygapophysial joint were to fail to give relief from pain, it would be reasonable to carry out injections of one joint above and one below. This is the range within which pain is likely to radiate.

4. Medial branch neurotomy is less specific than facet joint injection, and may cause harmful denervation of adjacent structures.

6. Immunohistochemistry revealed Substance P immunoreactive nerve fibres in the capsule and synovial folds of the zygapophysial joints. These nerves are thought to be involved in pain reception.

7. Intra-articular synovial folds can project between the surfaces of the hyaline cartilage. The tips of these folds may become pinched between the two cartilage surfaces.

8. The mamillo-accessory ligament bridges between the mamillary and accessory processes of each lumbar vertebra and encloses the medial branch of the posterior primary ramus in a fibro-osseous tunnel.

9. The mamillo-accessory ligament ossifies in over 11% of the lower lumbar vertebrae and thus becomes a foramen. The mamillo-accessory ligament may be a site of entrapment of the medial branch of posterior primary ramus, and thus lead to low back pain.

10. Experiments on facet joint injections in the cadaver suggest that the injection often spreads from the zygapophysial joints into the paravertebral musculature and the epidural space.

SUMMARY

The main conclusions arising from this study are summarized as follows:

1. The posterior primary rami of spinal nerves L1-4 form three branches; medial, lateral, and intermediate.

2. The intertransversarii mediales are innervated by a branch that arises near the origin of the medial branch of the posterior primary ramus.

3. The posterior primary ramus of L5 is much longer than the others and forms two branches only, medial and intermediate.

4. Each medial branch of the posterior primary ramus innervates two adjacent zygapophysial joints and ramifies in the multifidus.
   The zygapophysial joints on one side of the spine are not innervated from the contra-lateral side.

5. With silver staining the synovial folds of the zygapophysial joints are found to have nerve fibres weaving between the fat cells.

Our study supports the findings of Moran et al. (1988) who injected varying quantities of methylene blue as intra-articular injections in a fresh intact cadaver lumbosacral spine, at different levels.

Currently there is no strict scientific procedure to identify the zygapophysial joints responsible for significant pain in patients who have low back symptoms. Therefore, the specificity of facet joint injection as a test to discover the source of suspected zygapophysial joint pain is important because furtther procedures like joint denervation or spinal fusion, are often based on the result of this test (Raymond and Dumas, 1984).

Having said that, there is a group of people who claim high rate of success with facet joimt injections and recommend them for frequent use (Lau, 1986), whereas there groups who question the efficacy of these injections (Moran et al., 1988), and those who state that lumbar facet joint injections should not be used for patients suffering from low back pain, because these imjections are not predictive of either surgical or nonsurgical success (Esses and Moro, 1993).

The volume of the lumbar zygapophysial joint is estimated to be 1 to 2 ml (Glover, 1977). Large volumes of fluid used inevitably extravasate because the volume of the joint cavity is very small. Such extravasation was observed in the epidural space. But we also found that leakage of the dye in both cases took place in the deep musculature of the back. The fibrous capsule is thick dorsally and laterally, but ventrally where it is replaced with ligamentum flavum, it is in direct contact with the adipose tissue in the superior recess. Here the dye leaks. That is apparently why it was seen on the surface of the ligamentum flavum.

Moran et al. (1988) injected varying quantities of methylene blue as intra-articular injections at different levels in a fresh intact cadaver lumbosacral spine, and found that when large volumes of fluid are injected into the zygapophysial joint, extravasation occurs. This extravasation was noted in the epidural space rather than the paravertebral tissue. In our experiment, the possible explanation of muscle stain is either the injection in the muscle happened by accident when locating the joint, or extravasation occurred when the needle was pulled from the joint proper.

Such leakage may lead one to question whether the relief obtained was necessarily due specifically to anaesthetisation of the zygapophysial joints and not some other tissue.

muscle.

Muscle injections into myofascial trigger points (TPs), described by Simons and Travell (1983) are known to relieve pain, and this may be an additional factor in the anaesthesia achieved.

Local anaesthetic might reach the spinal ganglion via the epidural space, but the results described here show that the tracer did not stain the medial branch of the posterior primary ramus, so that there is no evidence a traditional block of the medial branch. The injections may therefore work by cutting off pain impulses at their origin, in the tissue of the joint, rather than by blocking the articular nerves.

In clinical practice, one group of people claim a high rate of success with facet joint injections and recommend them for frequent use (Lau, 1986), whereas another group questions the efficacy of these injections (Moran et al., 1988), or by stating that these injections are not predictive of either surgical or nonsurgical success (Esses and Moro, 1993).

The specificity of facet joint injection as a test to discover the source of suspected zygapophysial joint pain is important because further procedures like joint denervation or spinal fusion, are often based on the result of this test (Raymond and Dumas, 1984).

joints of the lumbosacral spines in the unfixed cadaver. They also found extravasation which spread in the epidural space.

The reason for extravasation almost certainly lies in the volume of fluid used. Estimates of the joint cavity vary from 1-2 ml (Glover, 1977). Thus a larger injection may well tear the capsule and leak out. The fibrous capsule is thick dorsally and laterally, but in front it is replaced by the ligamentum flavum. Here the capsule is in direct contact with the adipose tissue in the superior recess, and it is here that the leak occurs. This is apparently why dye is seen on the surface of the ligamentum flavum.

Our findings differ from Moran's in that we found deep staining of the paravertebral muscles. A possible explanation is that the injection into the muscle happened by accident when locating the joint, or extravasation occurred along the needle track when the needle was pulled from the joint proper.

The injection experiments show that even in the cadaver, it is possible to fill the joint cavity with a fluid equivalent to local anaesthetic. This will reach the synovial membrane, the capsule itself, and the ligamentum flavum, all of which are likely to contain pain receptors, as has been shown.

The extravasation of dye suggests that local anaesthetic also might diffuse into the surrounding structures, especially in the epidural space, but also perhaps into the

from the normal injection. It might also show a tendency to separate out or partition from the other constituents of the injection in the semi-permeable compartments of the cadaver, as fixatives may do (Young, 1935).

There are problems in the injected tissue as well.
The tissue is stiff after embalming. Tissue fluid is replaced by fixative, and the tissue pressures are altered. There is no circulation and no movement - factors which are probably involved for example in the movement of lymph.
These objections mean that the results of this kind of experiment must be interpreted with care.

However, the method is widely used, for example in studying the problems of paravascular anaesthesia of the lumbar plexus (Patel et al., 1988), or of injection of the back (Moran et al., 1988). Attempts to fill a specific cavity are perhaps open to less objections than studies of the diffusion of the injection through different tissue planes.
The results of both our injections showed that tracer had reached the zygapophysial joint cavity, but there was extensive extravasation in the epidural space.
There was also staining in the deep musculature of the back, but the nerves supplying the zygapophysial joint were unstained.
Moran et al. (1988) carried out somewhat similar experiment, injecting varying quantities of methylene blue into the

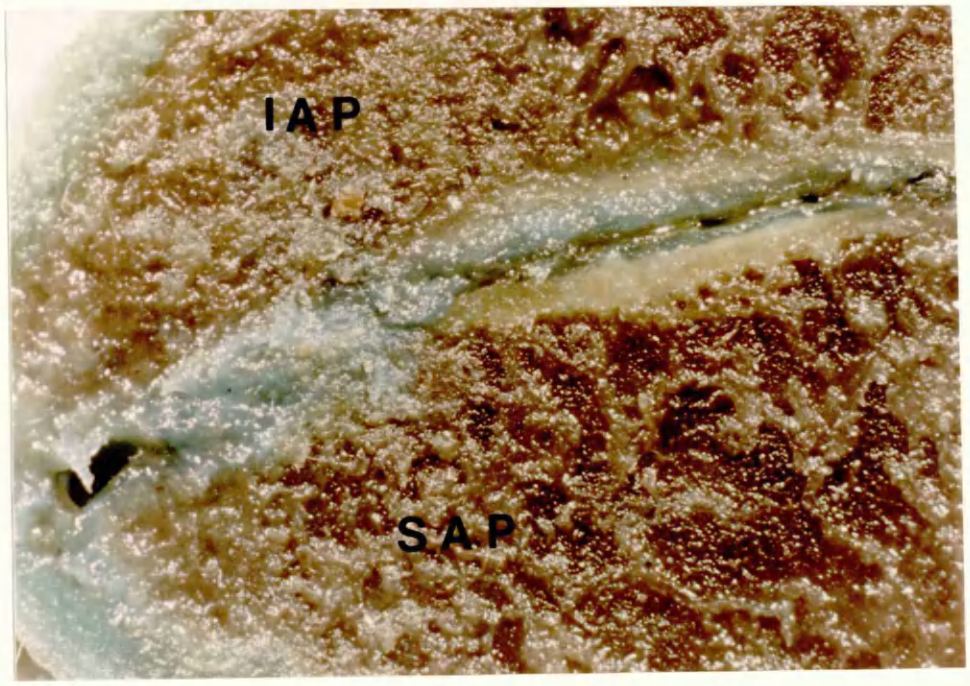


Figure 5-20

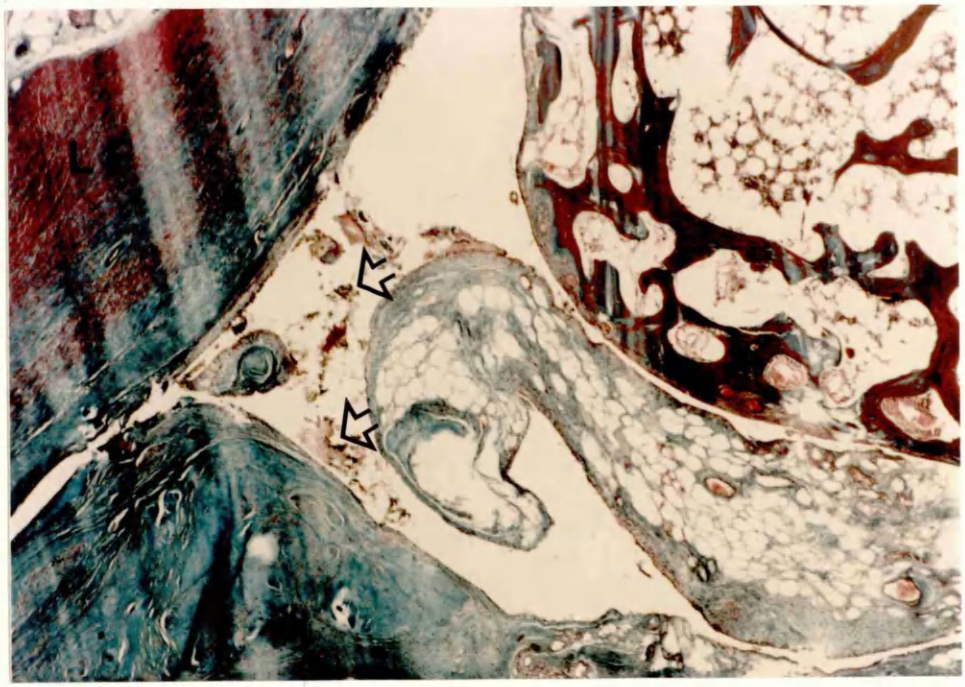


Figure 5-21

FIGURE: 5.20

Horizontal section of L2-3 zygapophysial joint showing the dye (Patent Blue V) in the joint cavity.

SAP : superior articular process

IAP : inferior articular process

FIGURE: 5.21

A transverse histological section of L4-5 zygapophysial joint showing India Ink in the joint cavity (arrows), stained with Masson Trichrome. Magnification X 500

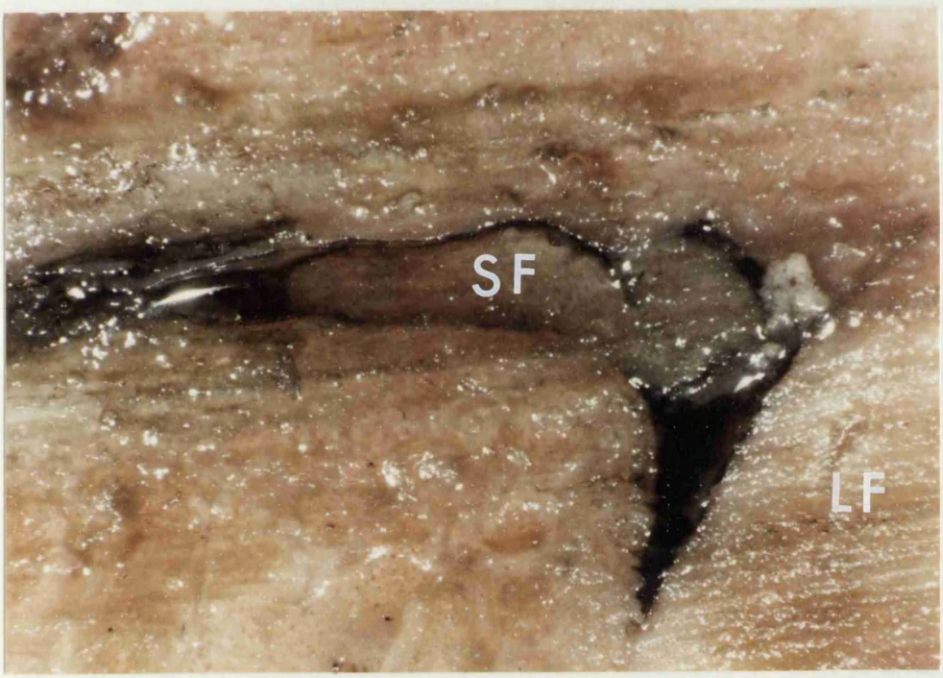


Figure 5-19

FIGURE: 5.19

A horizontal section of L4-5 zygapophysial joint showing India Ink in the joint cavity.

LF : ligamentum flavum

SF : synovial fold

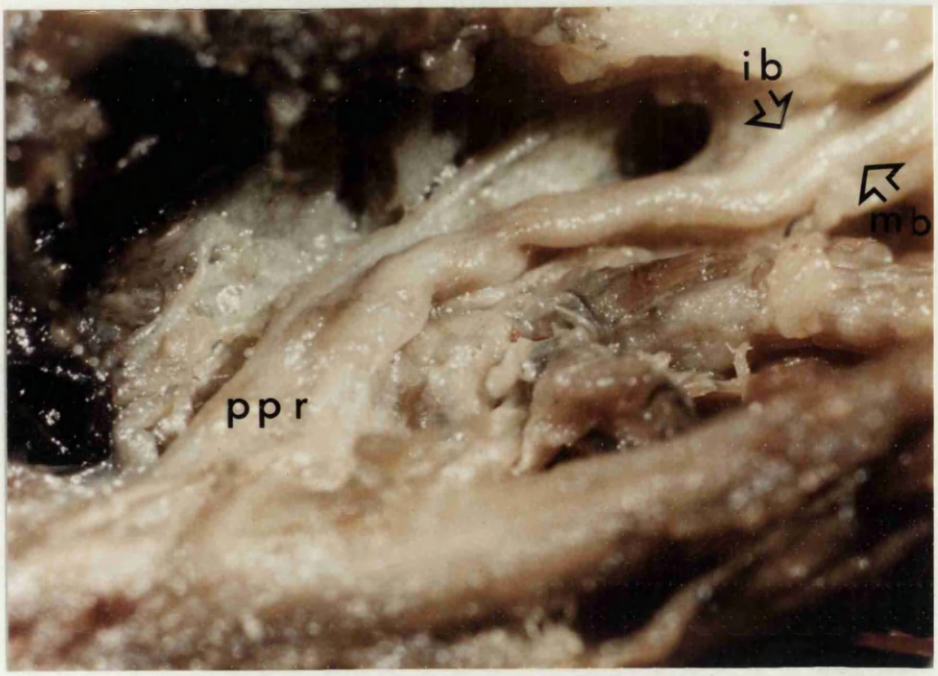


Figure 5-17

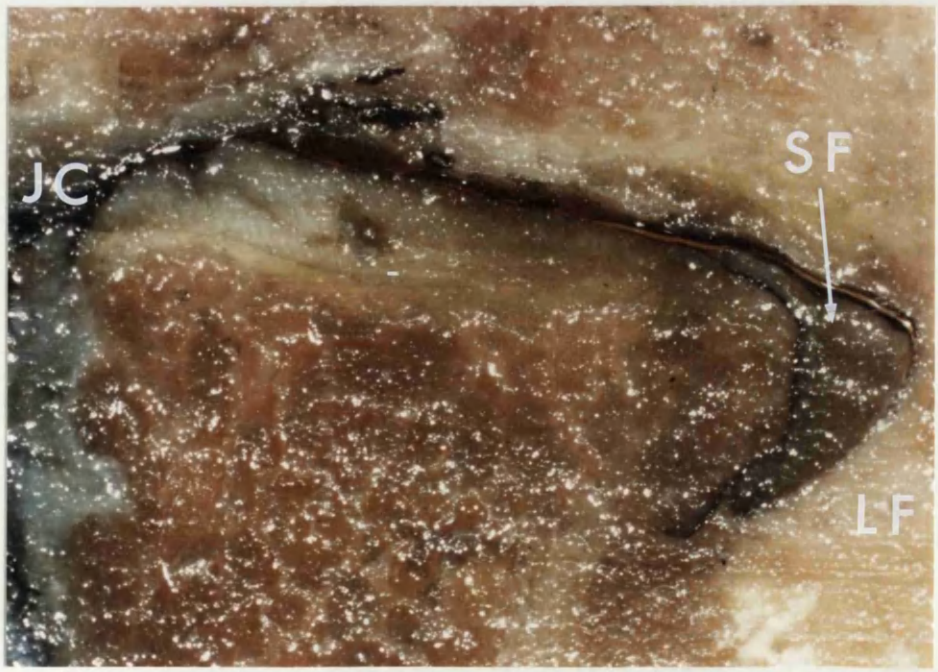


Figure 5-18

FIGURE: 5.17

L5 posterior primary ramus (ppr) seen clear of the dye (India Ink).
Both of its branches, the medial (mb) and the intermediate (ib) were also clear of the dye.

FIGURE: 5.18

A horizontal section of the L4-5 zygapophysial joint showing India Ink in the joint cavity.

JC : posterior joint capsule

LF : ligamentum flavum forming the anterior joint capsule

SF : synovial fold

On using the ventral approach in tracing the posterior primary ramus at L5 level, we found that although India Ink was seen at the outer surface of the ligamentum flavum, and the spinal ganglion. The posterior primary ramus was clear from the marker. (figures 5.16 & 5.17)

The horizontal and histological sections revealed that the India Ink had actually entered the joint cavity, as it was seen between the facet surfaces and the inner side of the ligamentum flavum forming the ventral aspect of the joint capsule. (figures 5.18, 5.19 & 5.21)

Macrophotographs of the specimen injected with Patent Blue V also showed the dye in the joint cavity. (figure 5.20)

5.4 DISCUSSION

What we have attempted to do here is to imitate in the cadaver, the clinical injection of local anaesthetic into the zygapophysial joint, and to trace the diffusion of the injection by adding a visible tracer to it.

This method of tracing the diffusion of the injection by adding a visible tracer in the cadaver is open to a fair number of objections. It may be argued that the tracer has a different osmolarity, or viscosity or penetrating power

Figure 5-15

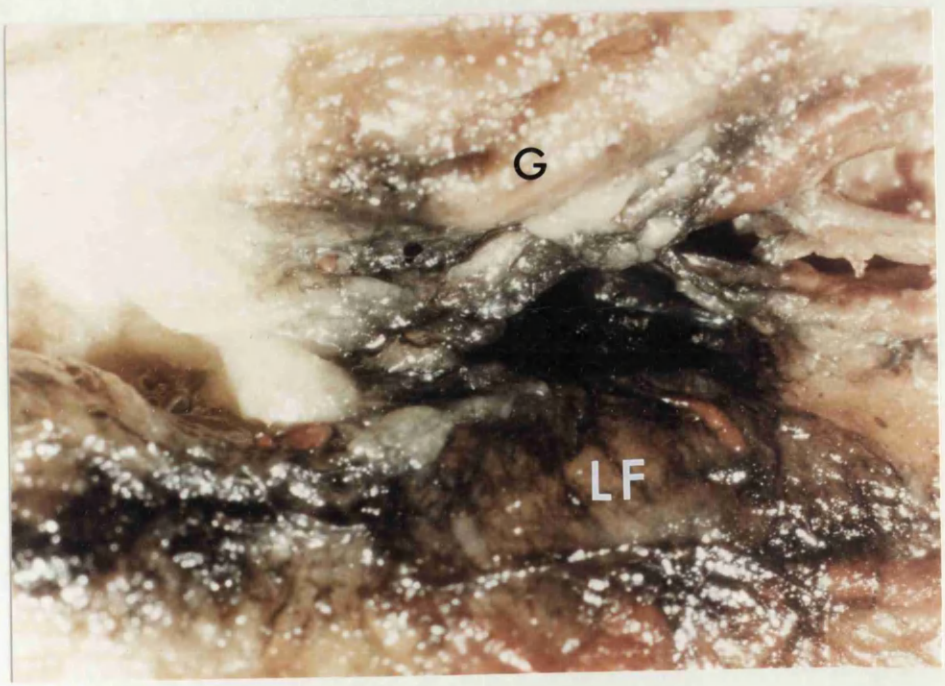


Figure 5-16

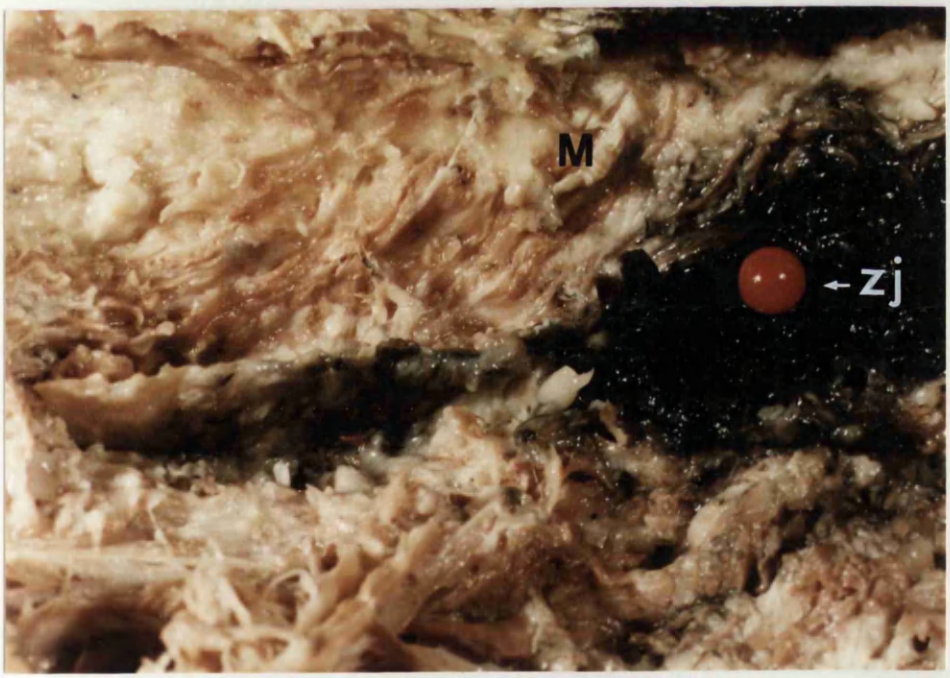
FIGURE: 5.15

Spread of the dye (India Ink) in the abdominal aorta.

FIGURE: 5.16

India Ink is seen on the outer surface of the ligamentum flavum (LF) and the spinal ganglion (G)

Figure 5-14 (A)



(B)

FIGURE: 5.14 (A)

Spread of the dye (India Ink) in the erector spinae muscle (E) and the outer surface of the multifidus (M)

(B)

Insertion of the pin indicates the location of the L4-5 zygapophysial joint. The area is seen stained with India Ink.

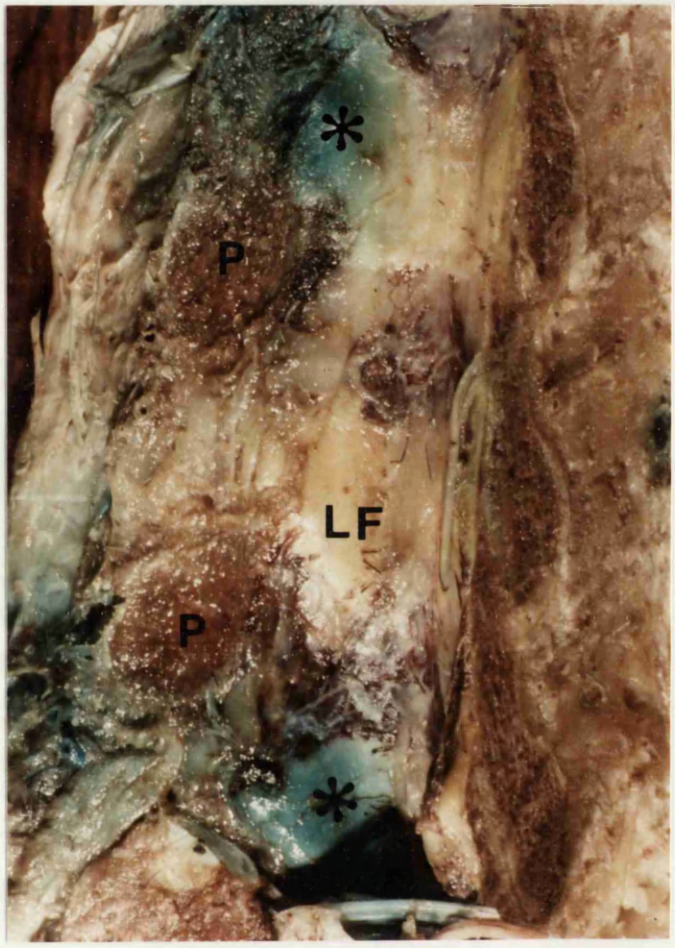


Figure 5-13

FIGURE: 5.13

L4-5 and L2-3 zygapophysial joints stained with Patent Blue V from the ventral side, the capsule being formed by ligamentum flavum (LF).

P : pedicle

We have dissected the dorsal rami of the lumbar nerves in 15 dissecting room cadavers, using microdissection and histology to confirm the finer articular branches. We are attempting to trace these nerves into the tissues of the joint in serial histological sections and by immunohistochemical methods, using protein gene product (PGP 9.5).

Preliminary results show that each joint is supplied from the medial branch of the dorsal ramus of its own level, and of the level above. The medial branch approaches the joint through a fibro-osseous tunnel formed by the mamillo-accessory ligament, and goes on to supply the multifidus.

The results suggest that there are fewer articular nerves than has been supposed and offer hope of greater precision in diagnosis and treatment of low back pain.

HEYLINGS, David J.A., School of Biomedical Science/Anatomy, Queen's University of Belfast, UK.

Human anatomy: A vehicle to enhance personal transferable skills?

Human anatomy has been taught to vocational students in the health professions for many years. Small groups of science students have taken degrees in anatomy, frequently studying a course similar to medical students, especially in the first two years. However in more recent years many more students now study dissection room anatomy as a minor subject. These students usually have less study time than traditional students and can be swamped by the volume of material. The anatomist has to decide on the focus of the course, the best teaching methodology, and what benefit the study of human anatomy will be for the student's future career.

In this paper the experience gained from teaching and developing such a course was outlined. A decision was made to use the learning of human anatomy as a vehicle to enhance the personal transferable skills of each student, to encourage observation, communication, presentation, and listening skills. Team/group working skills are embedded in the design and used to assist learning and the management of two small research projects. The advantages and disadvantages for student and staff were discussed.

AUJLA, Ranjit K., W. Angus WALLACE, Alan MOULTON, R. Geoffrey BURWELL, Alanah S. KIRBY, Simon A. WEMYSS-HOLDEN, Departments of Orthopaedic & Accident Surgery and Human Morphology, University of Nottingham, UK.

Lateral rotation of the femora with asymmetry in moving from the knees extended to the flexed position revealed by using real-time ultrasound to measure "functional anteversion" at the hips in healthy children.

Femoral anteversion angles (AV angles) can be determined by ultrasound (U/S) using two methods. Method 1 uses a head-trochanter (HT) line at the hip and a transcondylar line at the knee (B-mode U/S, Aujla et al., 1991). Method 2 uses only an HT line at the hip with the knees flexed 90° over the edge of the table (real-time, Terjesen and Anda, 1987). We have now compared real-time with B-mode U/S for determining AV angles in 20 healthy children scanned repeatedly at the hips and knees with the knees extended and then flexed. The best reliability is obtained by scanning only the hips (±3°, 95% confidence limits). The flexed knee position gives higher AV angles by 7–8° than the straight knee position. The findings suggest that during unlocking of the knees there is lateral rotation of both femora with considerable individual variation (up to 21°) and up to 14° of asymmetry. We conclude that real-time ultrasound is best used to measure "functional anteversion" at the hips in relation to the feet with shins and ankles fastened together and knees extended.

BAHAL, Vijay, R.P. GRIMLEY, S.H. SILVERMAN, Department of Surgery, Wordsley Hospital, Stourbridge, West Midlands, UK.

Varicose veins: Not just a cosmetic problem.

Varicose veins (VV) are one of the commonest conditions encountered in surgical practice. VVs are widely regarded as being a mainly cosmetic problem, so much so that some Health Authorities do not now offer treatment on the National Health Service.

In a prospective study of 80 patients (120 legs) undergoing VV surgery between August and November 1991, we assessed symptoms preoperatively and 6 weeks post-operatively by means of a linear visual analog score (LVAS).

	Pre-operative		Post-operative	
	None	Severe	None	Severe
LVAS	(0)	(6–10)	(0)	(6–10)
Pain	21	44	88	4
Cramp	55	32	112	2
Itching	59	33	100	7
Cosmetic	14	95	81	6

In conclusion, VVs cause many symptoms which are frequently severe and are largely relieved by surgery. VVs are not just a cosmetic complaint and their treatment should receive appropriate priority.

BAHAL Vijay, R.P. Grimley, S.H. SILVERMAN, Department of Surgery, Wordsley Hospital, Stourbridge, West Midlands, UK.

Can "redo" vascular surgery be avoided by using laser disobliteration?

Laser angioplasty has a role in vascular occlusion/stenosis but has not been used in occluded grafts. As part of a study to assess laser in disobliterating occluded grafts, the thrombogenic effects of laser on synthetic PTFE grafts fresh and removed from amputated legs was examined. Eight segments of fresh PTFE grafts were subjected to laser power of 15 W for 5 seconds. Occluded grafts removed from patients were subjected to power of 20 W for 5 seconds.

Grafts were put in a circuit using fresh blood containing platelets labelled with Indium^{111} for 30 minutes. Grafts were imaged using a Gamma camera and platelet numbers counted by sample counter. Platelet uptake conveys an estimate of graft thrombogenicity in laser-treated grafts.

Fresh grafts showed an increase in platelet uptake in areas damaged by laser. Grafts removed from patients had a very high platelet uptake all over. However, laser damage did not increase platelet deposition any further.

In conclusion grafts become thrombogenic when they are in patients for a period of time and laser disobliteration does not increase thrombogenicity.

DANGERFIELD, P.H., S. DHAR, N.G. BARTON-HANSON, C. PERRY, Department of Human Anatomy and Cell Biology and Orthopaedic Surgery, University of Liverpool, U.K.

Longitudinal study of skeletal maturation in Perthes' disease.

Perthes' disease is accompanied by abnormal growth and development and retarded skeletal maturity. The high incidence of the condition in Liverpool has allowed a study of the skeletal maturity of 93 patients together with a control sample using the Tanner Whitehouse method. Longitudinal study was undertaken if more than three hand radiographs were available. Skeletal maturity was correlated to the grade of disease at presentation, progress of the disease, sex of the patient, and unilateral or bilateral involvement. Results demonstrated significant skeletal retardation. The carpus scores showed the greatest retardation with the triquetral and lunate most affected. The delayed maturity for the long bones demonstrated a "catch up" to normal by about 14 years of age, becoming advanced until the attainment of maturity. This was not related to age of presentation or Catterall grade. The retardation was more marked in bilateral disease. "Skeletal standstill" was not encountered. The finding of marked skeletal retardation in children with chronic hip pain should enable a diagnosis of Perthes' disease to be made. Further longitudinal studies are required to explain the mechanism behind the observation of "catch up" and later increased skeletal maturity.

HUGHES, Ciara M., David J. A. HEYLINGS, School of Biomedical Science/Anatomy, Queen's University of Belfast, U.K.

Radio-opaque masses within the marrow cavity of intact long bones: Indicative of pathology?

In a recent survey of 630 long bones (73 individuals) excavated near Cork in the Republic of Ireland, various pathological conditions were noted, visible to the naked eye and confirmed on X-ray. An unusual abnormality was noted on X-ray, radio-opaque masses within the marrow cavity of intact bones. This paper presents the initial findings in identifying their nature.

Masses were found in 16% of all long bones representing 24% of the individuals. There would appear to be no pattern to the incidence in the distribution between the four burial periods found on the two main excavation sites. Representative intact bones were sectioned and samples removed for examination by scanning EM, thick sections for polarizing LM and elemental analysis. Bone was observed occasionally alongside crystalline material; otherwise there was no recognizable cellular detail. Elemental analysis reveals high levels of silicon and aluminum, compared to low levels of potassium, iron, and calcium.

The source of these masses is puzzling, though leaching in from surrounding soil is a possibility. It remains to be explained why the effect is not seen to the same extent in all bones in the vicinity, not even in all bones within the same skeleton.

BOWSHER, David, Juan LAHUERTA, Pain Research Institute, Liverpool, UK.

Anatomo-clinical correlation in 30 cases of percutaneous cervical radiofrequency cordotomy.

The second cervical segment of the spinal cord was examined in 30 patients with 44 cordotomies, surviving from 1 to 505 days. Sections were projected onto a millimetric grid to allow comparison. Results show that i) the "pain pathway" lies, cranialmost fibres ventromedially, within an area bounded dorsally by the level of the denticulate ligament and ventromedially by a line drawn perpendicularly from the medial angle of the ventral grey horn to the ventral surface of

LATIF, Nasir A.,* John SHAW DUNN, Department of Anatomy, University of Glasgow, Glasgow, U.K. The mammillo-accessory ligament - a possible site of nerve entrapment.

The zygapophysial joints of the lumbar vertebrae and the adjacent multifidus muscles are supplied by the medial branches of the posterior primary rami of the lumbar spinal nerves. In its course each of these nerves passes round the base of the superior articular process of the vertebra in a groove which lies between the accessory and mammillary processes. The groove is bridged over by a band of fibrous tissue, the mammillo-accessory ligament, leaving a narrow fibro-osseous tunnel for the nerve. It has been claimed that this may be site for nerve entrapment, and that pressure on the nerve could caused referred pain in the joints and spasm in the muscles.

We have studied the fibro-osseous tunnel in 28 dissecting room cadavers, and in 224 sets of vertebrae. The ligament was present on all the vertebrae from L1 to L5 in all the dissections, and was ossified in approximately 30% of the bones, especially at lower levels.

In one dissection, a swelling was present on the nerve as it approached the tunnel, which is suggestive of an entrapment neuropathy.

Modern methods of imaging such as CT and MRI are able to show the nerve and fibro-osseous tunnel. We are investigating the possibility of surgical intervention to release the nerve in cases of back pain where a narrow foramen is present.

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