

**DETAILED HISTOLOGICAL STUDY
OF GREY MATTER OF SPINAL CORD
IN ALBINO RAT**

**THESIS
SUBMITTED FOR THE PARTIAL FULFILMENT
OF THE DEGREE OF M. Sc. (ANATOMY)**

**BY
GEORGE FAYEK BARSOUM**

**Supervised by
PROF. DR. WAGDY M. GHALY**

*Professor of Anatomy
Faculty of Medicine
Ain Shams University*

617.93
G.F.

5696

PROF. DR. LUCY MORRIS ESKANDER

*Assist. Professor of Anatomy
Faculty of Medicine
Ain Shams University*

DR. HASSAN MOUSTAFA SERRY

*Lecturer of Anatomy
Faculty of Medicine
Ain Shams University*

**FACULTY OF MEDICINE
AIN SHAMS UNIVERSITY
1992**

ACKNOWLEDGEMENTS

It is my great honour to express my deepest appreciation to Professor **Dr. Wagdy Mahmoud Ghaly**, Professor of Anatomy, Faculty of Medicine, Ain Shams University, to whom I shall always be indebted for his guidance, support, and understanding. His kindness, patience, and keen supervision can never be rewarded.

My grateful thanks and sincere gratitude are expressed to Professor **Dr. Lucy Morris Eskander**, Assistant Professor of Anatomy, Faculty of Medicine, Ain Shams University, for her continuous enthusiastic encouragement throughout this work.

I wish to express my deepest gratitude to **Dr. Hassan Moustafa Serry**, Lecturer of Anatomy, Faculty of Medicine, Ain Shams University, for his great help, assistance, and invaluable instructions as well as criticism which were essential for the progress of this work.

I am also indebted to Professor **Dr. Sawsan Ahmed Abd-El-Rahman**, Professor of Anatomy, Faculty of Medicine, Ain Shams University, for kindly providing the laboratory facilities necessary for this work.

My deepest thanks go as well to Professor **Dr. Kamal Asaad Ibrahim**, Assistant Professor of Anatomy, Faculty of Medicine, Ain Shams University, for his generous help and support.



CONTENTS

- Introduction and Aim of the work	1
- Review of Literature	2
- Material and Methods	10
- Results	11
- Discussion	30
- Summary	38
- References	40
- Arabic Summary	

**INTRODUCTION &
AIM OF THE WORK**

INTRODUCTION AND AIM OF THE WORK

Waldeyer (1888) recognized a thin lamina placed at the dorsal part of the posterior horn of the spinal cord. From 1888 to 1952, up to our knowledge, no single author mentioned the lamination of the grey matter of the spinal cord, and most authors followed the classical descriptions mentioned in most textbooks. Rexed (1952) pointed out that the grey matter of the cat's cord consisted of ten laminae. The concept of laminar architecture of the grey matter of the spinal cord was then adopted. However, little was mentioned in the literature about the rat's cord.

The aim of the present work was to study the grey matter of the spinal cord of the albino rat and whether it coincided with that of the cat described by Rexed (1952).



REVIEW OF LITERATURE



REVIEW

Waldeyer (1888) recognized a zone similar to lamina I of the grey matter of the spinal cord. This lamina was named after him and was called lamina marginalis, or layer of Waldeyer.

Rexed (1952) was the first author to state that in the cat, the spinal cord grey matter was organized into nine cytoarchitectonically different regions stretching along the whole length of the cord. In cross-section, such regions or laminae followed each other from the dorsal to the ventral surfaces of the grey matter, and were enumerated I to IX in that order. Moreover, an additional tenth lamina of the grey matter was found around the central canal. The author added that lamina I was a thin layer of loosely distributed triangular or spindle-shaped cells of variable size that covered the top of the dorsal cell column. Lamina II formed a band of tightly packed small cells across the dorsal cell column around the apex that corresponded to the substantia gelatinosa of Rolando. Furthermore, the cells of lamina III were uniform in size and a little larger than those of lamina II, while those of lamina IV were of different sizes, and both laminae occupied the rest of the head of the dorsal horn. Moreover, lamina V went straight across the dorsal horn and it comprised a medial zone consisting of many medium-sized lightly stained cells, and a lateral zone containing large darkly stained cells. The author noticed that lamina VI, which occupied the base of the dorsal cell column, was also divided into a medial zone of compact small or medium-sized cell groups and a lateral zone of larger star-shaped more loosely arranged cells. Lamina VII occupied the zona intermedia and had a rather homogenous appearance and consisted of relatively lightly stained star-shaped cells. The investigator added that lamina VIII was present in the medial part of the ventral cell column and its

constituent cells were heavily stained and of different sizes. On the other hand, lamina IX was noticed to consist of large heavily stained cells that comprised the medial and lateral motor nuclei for skeletal muscles. Again, lamina X included the region close to the central canal that was poor in nerve cells which were small to medium-sized.

Rexed (1954) recognized regional variations in the lamination of the grey matter of the spinal cord of the cat and suggested that if these variations were added together, three different cytoarchitectonic types of the spinal cord could be identified. The first type prevailed in segments C₅ - T₁ and L₅ - S₂ which innervated the extremities, was called by the author the intumescence type. This type was characterized by a broad dorsal cell column (laminae I - V), a large lamina VI, a large lamina VII penetrating into the ventral horn center, a small lamina VIII occupying only the medial part of the ventral horn, and lastly a large lamina IX with a very complex lateral and a small medial motor groups. The second type, called by the author the thoraco-caudal type, dominated in segments T₄ - T₁₂ and cul-end of the cord. This type was characterized by a small rather flat dorsal cell column (laminae I - V), an absent lamina VI, a moderately developed lamina VII, a large lamina VIII covering the dorsal and middle parts of the ventral horn from side to side, and lastly a small lamina IX consisting only of the medial group of motor nuclei. Finally, the third intermediary type was found in segments C₂₋₃ and L₂₋₃. This type was characterized by a dorsal horn similar to that of the first type and a ventral horn similar to that of the second type.

Nieuwenhuys (1964) mentioned that in spite of the progressive development of the spinal cord grey matter in the series of vertebrates, the primitive configuration

of a central core of grey matter surrounded by an outer zone of white matter was maintained throughout the subphyllum. However, the evolutionary differentiation of the spinal cord grey matter was manifested by a progressive segregation into separate cytoarchitectonic entities, as cell columns and layers.

Rexed (1964) in his study on the cytoarchitectonics and synaptology of the spinal cord of the cat revealed that the cells of laminae I–IV constituted the starting point of the spinothalamic tracts. Moreover, the cells of laminae III and IV corresponded to the nucleus proprius. The worker suggested that laminae V and VI formed a reflex cortically-mediated area important for regulation of movement, while lamina VII acted as a reflex midbrain-dominated area with extensive propriospinal connections. On the other hand, lamina VIII was found to act as a reflex area for the excitation of motor activity through the excitatory gamma neuron system. Also, lamina IX was found to receive direct collaterals from the dorsal roots as well as from other laminae especially laminae VI, VII, and VIII, and hence acting as the primary motor area of the spinal cord grey matter.

Szentagothai (1964) while tracing the propriospinal pathways of the lumbosacral cord of the cat found that laminae IV and V received three types of fibers that included primary sensory collaterals, descending corticospinal pathways, and ascending propriospinal pathways mainly from the ipsilateral posterior horn. Moreover, laminae VI, VII, and VIII received many types of fibers that included ascending & descending, crossed & uncrossed propriospinal pathways, and descending cortico-spinal, tecto-spinal, vestibulo-spinal & reticulo-spinal pathways.

The author added that the motor nuclei were found to receive short collaterals from propriospinal neurons originating from laminae VI, VII, and VIII.

Wall (1967) stated that it was physiologically possible to determine three horizontal laminae in the dorsal horn of the lumbar region of the cat's spinal cord that responded to different stimuli. These laminae corresponded approximately to laminae IV, V, and VI described by Rexed (1952). Furthermore, the author noticed that all the three laminae responded to cutaneous stimulation while lamina VI responded to movement as well.

Dilly, Wall, and Webster (1968) found that stimulation of the medial lemniscus at its entry into the thalamus of cats and rats revealed that cells located in laminae V and VI responded antidromically.

Heimer and Wall (1968) noticed a massive degeneration in laminae I, II, and III of Rexed following dorsal root section of the rat. This degeneration appeared as heavy argyrophilia of the degenerating axons, and as degenerating boutons.

Truex and Taylor (1968) stated that the ten cell laminae of the grey matter of the cat spinal cord described by Rexed (1952, 1954, and 1964) were identified in man as well. However, laminae V, VI, and VII were less well defined and more variable in man due to the configuration and smaller diameter of the grey matter adjacent to the central canal. Moreover, the authors stated that lesions of C₆ that

injured the fibers of the lateral corticospinal and rubrospinal tracts resulted in preterminal and terminal axodendritic degeneration in the ipsilateral neurons of laminae VI and VII at lumbar and sacral levels.

March (1972) stated that variations in the outline and shape of the grey matter of the spinal cord existed between the cat and the pig. However, both were similar in the cytoarchitecture of their grey matter except for the S₁ segment where the grey matter of the pig's cord was devoid of lamina VIII while lamina VII was separated into regions; designated "A" and "B", by the massive outflow of axons from lamina IX through its ventral extremity.

Mikhail (1972) mentioned that in the albino rat, the posterior horn of the spinal cord could be divided into three portions : an apical expanded portion, middle laminated portion formed of 3-6 laminae separated by bundles of nerve fibers, and a relatively wide basal portion. The author added that the middle laminated portion coincided partially with that of Rexed (1952, 1954, and 1964).

Steiner and Turner (1972) found that the organization pattern of the cytoarchitecture of the rat spinal cord was basically similar to the scheme described by Rexed (1952) in the cat. The authors found that laminae I-V and VII-X, particularly II, V, and IX, were distinguishable throughout the cord, and were characterized by the presence of cells similar to but smaller in size than those in the cat. However, lamina VI could not be identified with certainty at any level.

Bowsher (1979) stated that the spinal cord of man presented a high degree of organization and could be divided into distinct morphological and functional laminae arranged dorso-ventrally. Lamina I constituted the marginal zone and received small myelinated ($A\delta$) primary afferents, while laminae II and III received unmyelinated (C) primary afferents coming from mechanoreceptors and sent their axon collaterals up and down for a few cord segments forming the tract of Lissauer. Moreover, lamina IV received primary afferents of $A\beta$ type coming from cutaneous mechanoreceptors, and also received descending fibers from the corticospinal tract which exerted an inhibitory influence on the cells of lamina IV. The author stated that long collaterals of the axons of the neurons of lamina V formed the spinothalamic fibers ascending in the contralateral anterolateral columns. Also, lamina V was influenced by corticospinal and rubrospinal fibers. Moreover, lamina VI, at the base of the dorsal horn, was divided into a medial part sending efferent fibers that would form the dorsal spinocerebellar tract, and a lateral part sending efferent fibers that would form the ventral spinocerebellar tract. The author added that laminae VII and VIII were influenced by the opposite side of spinal cord through lamina X, and by the reticulospinal & the vestibulospinal tracts. These two laminae (VII and VIII) could be regarded as the spinal component of the reticular formation. Furthermore, the author recognized two kinds of motor neurons in lamina IX: large alpha motor neurons supplying extrafusal muscle fibers, and smaller gamma motor neurons supplying intrafusal muscle fibers of the spindle apparatus.

Ralston (1982) found that the dorsal horn of the adult macaque monkey exhibited a well-defined border between laminae II–III and the reticulated zone characterizing the lateral margin of lamina V. The worker also found scattered

medium-sized neurons through lamina IV, and only occasional cells of this size in lamina III. Moreover, lamina VI contained many large elongated or spindle-shaped cells.

Priestley (1987) stated that in the human spinal cord, small neurons carrying information mainly about cutaneous pain and temperature sensibility were of $A\delta$, C type and terminated mainly in laminae I, II, V, and X. Larger neurons carrying information from cutaneous touch and hair receptors were of $A\alpha$, $A\beta$ types, while those from muscle spindles were of $I\alpha$, II types, and those from tendon organs were of the *Ib* type. Moreover, the author mentioned that spinothalamic projection neurons were located in laminae I, IV-VI, VII, and VIII and they sent axons across the midline to ascend in the ventrolateral funiculus, but a few cells, mainly in lamina VIII, projected ipsilaterally. Furthermore, the axons of the dorsal spinocerebellar tract were derived from the cells of the Clarke's column located in laminae VI and VII of segments C8 to L3. The author also stated that the rubrospinal tract ended in laminae V-VII, the vestibulospinal tract in laminae VII and VIII, the reticulospinal tract in laminae VII and VIII, the raphespinal tract in laminae I, II, V, and VII-IX, the hypothalamospinal tract in laminae I-III, VII, and X, and finally the tectospinal tract ended in laminae VI and VII. Lastly, interneurons were identified in laminae II, III, and VIII in all regions of the spinal cord.

Hughes (1989) stated that in the human spinal cord, substance P was normally abundant in laminae I, II, and III. However, it was depleted following posterior rhizotomy and was bilaterally absent in the congenital insensitivity to pain. Moreover, enkephalin was abundantly found in laminae I and II, and seemed to be locally

produced and derived from intrinsic neurons of the spinal cord. Furthermore, the author mentioned that neuropeptides such as substance P, cholecystokinin/gastrin-like peptide, calcitonin gene-related peptide, and vasoactive intestinal polypeptide were found in lamina X and seemed to be related to fibers relaying afferent information from the posterior horn.

Williams, Warwick, Dyson, and Bannister (1989) described the ten laminar architecture of the grey matter of the spinal cord and found that lamina VII included much of the intermediate grey column and contained prominent neurons of the thoracic nucleus, the intermediomedial and intermediolateral columns at their spinal levels of the cord. Moreover, the remaining area of this lamina (between these columns and, in limb enlargements, between lamina VIII and groups of IX) contained a homogenous array of medium- sized triangular or stellate somata. Furthermore, the author stated that lamina IX consisted of a complex array of columns including very large somata of alpha motor neurons and numerous smaller ones. The smaller somata were found to include motor neurons with small-diameter gamma efferent fibers for muscle spindles, and numerous interneurons, some perhaps being inhibitory Renshaw cells.