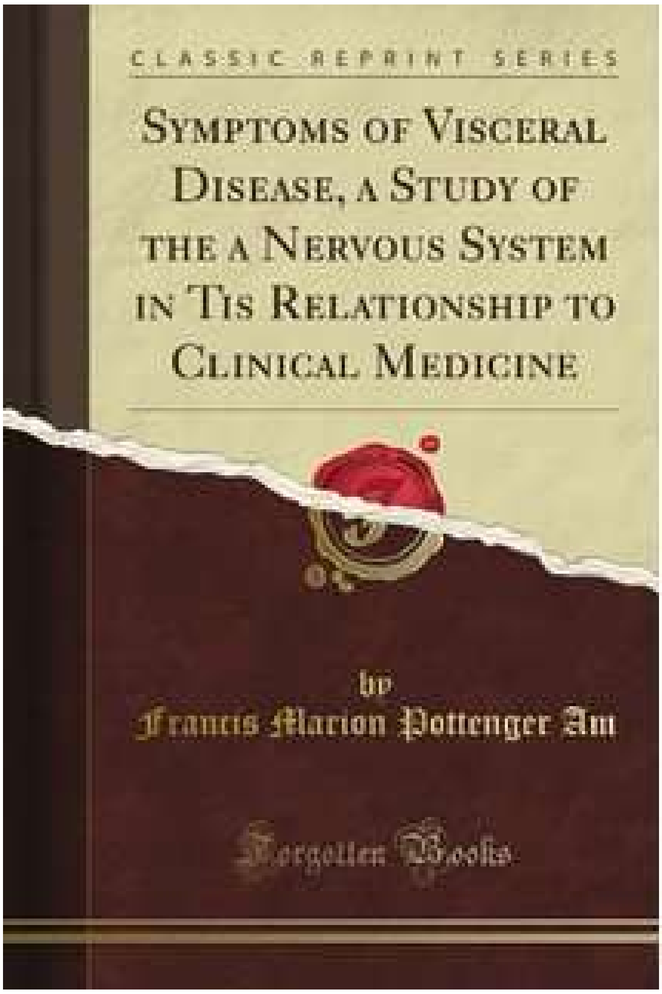

Symptoms of Visceral Disease

A Study of The Vegetative Nervous System In Its Relationship To Clinical Medicine

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FRANCIS MARION POTTENGER, A.M., M.D., LL.D., F.A.C.P.

In Memory of

ROBERT FREDERICK WARNSHUIS

JULY 12. 1909. June 7, 1935

June 7, 1916

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Relationship to Clinical Medicine

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SECOND EDITION

WITH TWENTY-SIX TEXT ILLUSTRATIONS AND

TEN COLOUR PLATES

ST. LOUIS

C. V. MOSBY COMPANY

1932

Printed in the USA

Press of C. V. Mosby Company

St. Louis

Contents

Symptoms of Visceral Disease i

A Study of The Vegetative Nervous System In Its Relationship To Clinical Medicine i

- **Table of Figures** 1
- **Preface to Second Edition** 1
- **Preface to first Edition** 1
- **Explanation of Terms Used in the Text** 11
- **Part 1** 12
- **Chapter 1** 12
  - **Introductory** 12
  - **The Evolution of Modern Medicine** 12
  - **Necessity of a New Viewpoint in Clinical Medicine** 13
  - **Pathology and Modern Medicine** 14
  - **Inaccuracy of Clinical Observations** 14
  - **Modern Clinical Teaching at Fault** 15
  - **Physical Condition Changes Body Control** 17
  - **Psychic Activity Changes Body Control** 18
  - **Disease Expresses Itself Both Physically and Psychically** 18

A Rational Basis For Study of Disease 19
Organic Versus Functional Disease 19
Chapter II 21
Basis of Classification of Symptoms and Disease 21
Cause of The Variability of Symptoms 23
Chapter III 26
Symptoms Due To Toxaemia 26
Chapter IV 28
Segmentation of the Body 28
Chapter V 38
Viscerogenic Reflex 38
Definition of Terms 38
Two Distinct Groups of Visceral Reflexes 41
Conditions Underlying Visceral Reflexes 42
Simple and Complex Reflexes 42
Relationship Between The Sensory and Motor Segments in the Central Nervous System 46
The Relation Between the Viscerogenic Reflex and Visceral Inflammation 47
Chapter VI 49
Reflexes Whose Afferent Impulses Course in the Sympathetic Nerves 49
Distribution of Sympathetic Nerves 49
Distribution of Sympathetic Reflexes 49
Nature of Sympathetic Reflexes 50
Variable Sensibility of Different Tissues. 54
Visceral Versus Somatic Pain 55
Referred Character of Visceral Pain 57
Hyperalgesia. 59
Recurrent Pain in Sensory Spinal Nerves Resulting from Visceral Disease 63
Cause of Trophic Reflex. 65
Chapter VII 67
Reflexes Whose Afferent Impulses Course In The Parasympathetic Nerves 67
Distribution of Parasympathetic Reflexes 67
Relationship of Trigeminus Nerve to Parasympathetic Reflexes 67
Examples of Parasympathetic Reflexes 71
Functional Disturbances and the Parasympathetic Reflex 72
The Nature of Parasympathetic Reflexes 73
Importance of the Parasympathetic Trophic Reflex 74
Common Parasympathetic Symptoms and Syndromes 74
Chapter VIII 76
Sympathetic and Parasympathetic Syndromes 76
Syndrome of Sympathetic Stimulation 76
Syndrome of Parasympathetic Stimulation 76
Special Service Rendered to the Organism by the Sympathetic and Parasympathetic Nerves 76
General Sympathetic Responses 78

General Parasympathetic Responses ... 80
Local Parasympathetic Syndromes ... 80
Antagonism of Sympathetic and Parasympathetics ... 80
Degenerations ... 81
Part II ... 83
Innervation of Important Viscera With a Clinical Study of the More Important Viscerogenic Reflexes ... 83
Chapter IX ... 83
Introductory ... 83
Grouping of Structures Supplied by the Vegetative Nerves ... 83
The Enteral System ... 84
Tissues Activated by the Sympathetics ... 88
Chapter X ... 89
Oesophagus ... 89
I. Innervation of the Oesophagus ... 89
II. The Oesophagus: Clinical Consideration ... 89
Chapter XI ... 92
The Stomach ... 92
I. Innervation of the Stomach ... 92
Digestive Control Both Nervous and Chemical ... 93
II. The Stomach: Clinical Consideration ... 94
Psychic Influence on Digestion ... 94
Gastric Visceromotor Reflex. ... 95
Gastric Viscerosensory Reflex ... 95
Gastric Parasympathetic Reflexes ... 96
The Manner in Which the Stomach Is Reflexly Influenced by Other Organs. ... 97
Hyperchlorhydria. ... 97
Hypermotility. ... 97
Hypochlorhydria ... 97
Dilatation of the Stomach ... 98
Nausea and Vomiting ... 98
Chapter XII ... 99
The Intestinal Tract ... 99
1. Innervation of the Small Intestine ... 99
Sympathetics ... 99
2. The Innervation of the Colon and Rectum ... 99
3. The Innervation of the Sphincters ... 100
II. THE INTESTINAL TRACT: CLINICAL CONSIDERATION ... 102
Sympathetic Reflexes ... 102
Intestinal Visceromotor Reflex. T ... 102
Intestinal Viscerosensory Reflex, ... 103
Parasympathetic Reflexes Shown in the Intestinal Tract Itself and in Other Organs, the Impulse Originating in the Intestinal Tract. ... 105

Action of Such States as Anger, Fear and Pain upon the Motility and Secretory Activity of the Intestinal Tract 112
Chapter XIII 113
The Liver and Gall Bladder 113
I. The Innervation of the Liver and Gall Bladder 113
II. Liver and Gall Bladder: Clinical Consideration 113
Chapter XIV 117
I. Innervation of the Pancreas 117
II. Pancreas: Clinical Consideration 118
Pancreatic Visceromotor and Viscerosensory Reflexes 118
Chapter XV 119
The Diaphragm 119
I. Innervation of the Diaphragm 119
II. The Diaphragm: Clinical Consideration 119
The Bronchi and The Lungs 126
I. Innervation of the Bronchi and the Lungs 126
II. The Lungs: Clinical Consideration 127
Symptoms of Pulmonary Tuberculosis 128
Pulmonary Viscerosensory Reflex 131
Pulmonary Viscerotrophic Reflex 132
Parasympathetic Reflexes Shown on the Part of Other Viscera, The Impulses Originating in the Lung. Vagus 135
Parasympathetic Reflexes Shown on the Part of the Lung, The Impulses Originating in the Lung, or in the viscera 141
Chapter XVII 143
The Pleura 143
I. Innervation of the Pleura 143
II. The Pleura: Clinical Consideration 143
Chapter XVIII 148
The Heart 148
I. Innervation of the Heart 148
II. Clinical consideration 151
Chapter XIX 155
The Aorta 155
I. Innervation of the Aorta 155
II. The Aorta: Clinical Consideration 155
Chapter XX 157
The Blood Vessels 157
Arteries 157
The Vasomotor Nerves 158
The Blood Vessels 159
The Splanchnic Nerves 160
Vasodilator Nerves 161
Vessel Tone 162

Chapter XXI ... 166
The Salivary Glands ... 166
I. Innervation of Salivary Glands ... 166
II. Salivary Glands: Clinical Consideration ... 167
Chapter XXII ... 168
The Nasal and Pharyngeal Mucous Membranes and Accessory Sinuses ... 168
I. Innervation of Nasal and Pharyngeal Mucous Membranes and Accessory Sinuses ... 168
II. Nasal and Pharyngeal Mucous Membranes and Accessory Sinuses: Clinical Consideration ... 168
Chapter XXIII ... 170
The Larynx ... 170
I. Innervation of the Larynx ... 170
II. The Larynx: Clinical Consideration ... 170
Chapter XXIV ... 173
The Eye ... 173
I. Innervation of the Eye ... 173
II. The Eye: Clinical Considerations ... 175
Chapter XXV ... 177
The Lachrymal Glands ... 177
I. Innervation of the Lachrymal Glands ... 177
II. The Lachrymal Glands: Clinical Consideration ... 178
Chapter XXVI ... 179
The Urogenital Tract ... 179
I. Innervation of the Urogenital Tract ... 179
II. The Urogenital Tract: Clinical Consideration ... 183
Chapter XXVII ... 190
The Subdermal Musculature ... 190
I. The Pilomotor Nerves ... 190
II. The Sweat Glands ... 191
Chapter XXVIII ... 192
Endocrine Glands ... 192
I. Innervation of the Thyroid Gland ... 193
II. Innervation of the Adrenals ... 194
The Endocrine System: Clinical Consideration ... 195
Part III ... 198
The Vegetative System ... 198
Chapter XXIX ... 198
The Vegetative Nervous System: General Consideration ... 198
Chapter XXX ... 214
The Vegetative Nervous System Anatomically Considered ... 214
Chapter XXXI ... 226
The Vegetative Nervous System: General Physiologic Considerations ... 226
Relationship Between the Vegetative and the Central Nervous System ... 226
Response in Voluntary and Vegetative Systems Compared ... 226

Distribution of the Neurons of the Thoracicolumbar and Craniosacral Outflows 227
Antagonist Action of the Thoracicolumbar and Craniosacral outflows 228
Tonus 228
Methods and Results of Studying Thoracicolumbar Control of Body Structures 230
Sensory, Sympathetic and Craniosacral Nerves 231
Functions of the Sympathetic Ganglia 232
Chapter XXXII 239
Pharmacologic Differentiation Between Neurons of the Thoracicolumbar and Craniosacral Outflow 239

Table of Figures

Figure 1. Diagram of human embryo, 5th week, 28
Figure 2. Diagrammatic representation of a vertebrate animal 29
Figure 3. Relationship of the spinal segments to the spinal nerves 30
Figure 4. Illustrating the cutaneous sensory zones of the anterior surface 31
Figure 5. Illustrating the innervation of the muscles of the anterior of the body. 32
Figure 6. Illustrating the cutaneous sensory zones on the posterior of the body. 33
Figure 7. Illustrating of the muscles of the posterior of the body. 34
Figure 8. Diagrammatic representation of cutaneous regions of sensibility 35
Figure 9. The connector neurons for the important thoracic, abdominal and pelvic viscera. 37
Figure 10.Diagram to show general and distribution of the efferent vegetative fibres. 39
Figure 11. Plate I. Schematic illustration of the distribution of the two components of the vegetative nervous system, 40
Figure 12. Schematic showing the paths through which intrasegmental and intersegmental reflexes are produced. 44
Figure 13. Schematic representation of the physiologically different conductions 45
Figure 14. Diagrammatic representation of the nervous system and the tissues supplied by the sensory and the motor systems 48
Figure 15. Diagrammatic representation of the spinal cord showing the important centres from which the sensory and motor fibres take their origin. 52
Figure 16. Diagrammatic representation of location of pain when different portion of the gastrointestinal tract are involvement. 57
Figure 17. Diagram of zones and hyperalgesia 60
Figure 18. Diagram of the zones and hyperalgesia 61
Figure 19 Table showing relations between cutaneous area and the internal organs 62
Figure 20. Graphic illustration of causes of chronic pain in sensory neurons 64
Figure 21. the sensory and motor nuclei of the medulla. 68
Figure 22. Plate II - The reflex paths of the voluntary system in the cranial region. 69
Figure 23. Plate III. The reflex paths in the cord. 72
Figure 24 Effect of Stimulation or Sympathetic and Parasympathetic of Important viscera 81
Figure 25. Plate V. Distribution of the connector fibres (black) and excitor neurons (red) in the bulbo-sacral or enteral system. 85
Figure 26. Plate VI. The connector fibres and excitor nerves of the sphincter system of the involuntary muscles. 87
Figure 27. Showing the innervation of the muscles of deglutition 90
Figure 28. Innervation of the double innervation of the enteral system. 93
Figure 29. Showing the gastric visceromotor reflex. 95
Figure 30. Showing the location of the gastric viscerosensory reflex. 96
Figure 31. Showing the cutaneous areas supplied by the sacral nerves in the perineal region 101
Figure 32. Pathways of the visceromotor reflexes of the abdominal viscera. 102
Figure 33. Showing are of pain in appendicitis. 104
Figure 34. Reflex bradycardia due to tuberculous involvement of the intestine. 110
Figure 35. Showing the hepatic visceromotor reflex. 114
Figure 36. Hepatic viscerosensory reflex. 115
Figure 37. Pancreatic viscerosensory reflex. 117
Figure 38. Showing the pancreatic visceromotor reflex. 118
Figure 39. Diaphragm viewed from the front and below. 120
Figure 40. Site of diaphragmatic viscerosensory reflex. 122
Figure 41. Schematic illustration of the influence of the diaphragm in enlarging the intrathoracic space. 123
Figure 42. Showing the diaphragmatic from other organs. 124
Figure 43. Reflex paths in the spinal cord. 127
Figure 44. Symptoms of Pulmonary Tuberculosis 128
Figure 45. Schematic illustration of pulmonary visceromotor reflex. 129
Figure 46. Pulmonary viscerosensory reflex. 130

Figure 47. Hilus viscerotrophic reflex. 133
Figure 48. Pulmonary viscerosensory and viscerotrophic reflexes. 134
Figure 49. Spasm and degeneration as observed clinically. 135
Figure 50. Bradycardia in the presence of cavity formation in the lung. 138
Figure 51. Chart showing how inflammation in the lung reflexly slows the heart. 138
Figure 52. Pleural visceromotor reflex. 144
Figure 53. Pleural viscerosensory reflex. 145
Figure 54. Innervation of the heart. 148
Figure 55. Cardiac visceromotor reflex. 151
Figure 56. Cardiac viscerosensory reflex. 152
Figure 57. Distribution of vasomotor centres and nerves. 157
Figure 58. Schematic illustration of the vasomotor supply of the vessels of the head, neck and arm. 159
Figure 59. Schematic illustration of vasomotor supply to lower (posterior) extremity, abdominal and pelvic viscera. 160
Figure 60 Table showing vasomotor supply for parts of the body 161
Figure 61. Innervation of the salivary glands. 166
Figure 62. Nerve supply of nasal mucous membrane. 169
Figure 63. Nerve supply of the larynx. 170
Figure 64. Schematic illustration of motor disturbance in cords through recurrent laryngeal nerves. 171
Figure 65. Innervation of the eye. Nerves of orbit. Lateral view. 173
Figure 66. Diagrammatic illustration of the ocular fibres of the cervical sympathetics (After Purves Stewart) 174
Figure 67. Innervation of the lachrymal glands. 177
Figure 68. Innervation of the generative organs (male) 180
Figure 69. Innervation of generative organs (female). 181
Figure 70. Nerve supply of the kidney (After Renner). 183
Figure 71. Areas of distribution of cord segments involved in uterine, ovarian and tubal diseases. 184
Figure 72. Illustrating area of pain in prostatic disease. 185
Figure 73. Common areas of pain when the testicles and ovaries are inflamed. 187
Figure 74. Renal visceromotor reflex.. 187
Figure 75. Renal viscerosensory reflex. 189
Figure 76 Connection of spinal nerves with sympathetic ganglia 190
Figure 77. Showing the direct connection of chromaffin cells to the adrenal medulla. 195
Figure 78. Diagrammatic section across the back of an anencephalic child. 202
Figure 79. Transverse section of human embryo at 2.4.mm. 202
Figure 80. Diagram to show how the ectodermal cells of the medullary plates are differentiated into nerves cells or neuroblasts and supporting cells or spongioblasts. 203
Figure 81. Plate VII Diagrammatic illustration of autonomic nerve distribution 204
Figure 82. A two neuron reflex in a vertebrate. 207
Figure 83. A three neuron reflex arc 208
Figure 84. Three stages in the closure of the neural tube and the formation of the neural crest (spinal ganglion rudiment). 209
Figure 85. Dissection showing thoracic, lumbar and sacral of right gangliated cord and their branches. (Piersol) 215
Figure 86. Superior cervical ganglion and the structures supplied by it. 217
Figure 87. Structures supplied by the medium cervical ganglion. 217
Figure 88. Structures supplied by the inferior cervical ganglion. 218
Figure 89. Structures supplied by the stellate ganglion. 218
Figure 90. Structures supplied by the coeliac ganglion. 219
Figure 91. Structures supplied by the inferior mesenteric ganglion. 219
Figure 92. Plate VIII The arrangement of the connector fibres (black) and the excitor neurons (red) of the sympathetic system in the spinal region. 220
Figure 93. Plate IX. Illustration of the distribution of the vegetative nervous system in innervation of the tissues of the head. 222

Figure 94. Plate X. Cross section through the nerve of the vagus in the medulla. 224
Figure 95. Mechanism of action of reflexes. 234
Figure 96. Section of a sympathetic ganglion in the coeliac region of a frog. 239

Preface to Second Edition

The fact that the first edition of this book was exhausted so soon after its publication came as a welcome surprise. It indicates an awakened interest in that phase of medicine which makes the patient himself the chief object of study. In the present edition I have followed the same arrangement as in the preceding one. No new chapters but much new material has been added. The text has been amplified and clarified throughout. Factors which offer a basis for the classification of symptoms; the segmental relationships of tissues and organs with reference to the mediation of reflexes; principles and laws governing reflexes; particular factors which operate to cause variability of symptoms; and effects of certain internal secretions upon the vegetative nerves and their power to modify nerve response both in health and disease; have all been discussed more fully than in the previous edition. The effect of psychical states in the initiation of symptoms or in modifying them when due to disease processes has been given considerable attention. Some new material with also be found in Part II, in those chapters which deal with the innervation and common symptoms of the important viscera. The changes in Part III are of minor importance and mainly for the purpose of clarifying the text.

Some criticism has been made to the effect that the names of the reflexes are cumbersome, but this same criticism is made of the terms used in other new fields of knowledge and is largely due to unfamiliarity with the subject. They are not as cumbersome as they seem and they have the advantage that the name suggests a description of the reflex.

In describing and classifying reflexes I followed a plan, in which the name indicates both the organ and the nerve path through which the reflex is produced. Sympathetic reflexes had previously been designated by the prefix "viscero". This I have continued. Among sympathetic reflexes we have (1), muscle tension which is described as a pulmonary, cardiac, gastric or other, "visceromotor reflex"; (2) pain, which, while not a true reflex, is, for clinical convenience, described as a "viscerosensory reflex," with the name of the organ involved accompanying it; (3) degenerations such as we find when the lung and kidney are involved are described as, " viscerotrophic reflexes," with the name of the organ attached, and (4) the various reflex "functional symptoms" which are for the most part of parasympathetic origin are designated as "parasympathetic secretory," "parasympathetic motor," "parasympathetic sensory," and "parasympathetic trophic" reflexes with the name of the organ attached.

The conception which has dominated recent advances in medicine has been an anatomic one; but that which must dominate in the future or, at least, that which must be considered as of equal importance, is the physiologic one. This study not only shows the physiologic basis for many of the symptoms commonly met in disease, but offers a means for understanding their vagaries as met in practice. I hope that this work may continue to stimulate interest in the patient's reactions, and at the same time afford a basis for their better understanding.

Francis Marion Pottenger.   Monrovia, Cal.

Preface to first Edition

Though I have devoted myself to the study of diseases of the chest — a so called "specialty" — for more than twenty years, experience has led me to see that such a thing as a medical specialty in the accepted sense of the term, cannot exist. Diseases cannot be divided into those of this and that organ; for the human body is a unit. One part cannot be diseased without affecting other parts. No organ can be understood except in its relationship to other organs and to the body as a whole.

In this monograph an attempt is made to interpret so far as may be possible in terms of visceral neurology, symptoms which are found in the everyday clinical observation of visceral disease.

It is a study of visceral disease not from the standpoint of the disease process, important as that is, but from the no less important standpoint of the patient who has the disease. It is an attempt to show how pathologic changes in one organ affect other organs and the organism as a whole, through the medium of the visceral nerves. In contradistinction to the usual treatment of disease processes in their pathologic anatomic relationships this is a study in pathologic physiology. It is largely a discussion of "viscerogenic" reflexes; and, as such, causes us to examine somewhat carefully into the problems connected with the vegetative nervous system. It aims to show the importance of careful clinical observation and analysis.

The idea of the viscerogenic reflex is developed more fully than is usual in medical discussions; and the parasympathetic reflexes have been given as much attention as those of sympathetic origin. In this respect my discussion will differ from that of Mackenzie in his book on "Symptoms and Their Interpretation," to which I have referred so often in these pages. I have also emphasized the importance of the "viscerotrophic" reflex, a subject which has been almost wholly omitted from other works.

While the importance of the vegetative nervous system has long been known to physiologists, clinicians generally have ignored it and failed to see its intimate relationship to clinical medicine; yet it is the key which unlocks the door to many of the secrets of visceral activity. An understanding of the vegetative nervous system and the activities of the endocrine glands will explain to the clinician most of the physical acts connected with visceral function and furnish the bridge between the pathologic changes in tissues and the expression of the disease in altered organic function. In other words, the vegetative nerves and the products of the endocrine glands are the mediums through which visceral symptoms are expressed.

The study of the vegetative nervous system here presented is brief; at the same time it is sufficiently complete to furnish the essential facts which one should have in order to understand the manner in which body activities, both physiologic and pathologic, express themselves through it. It is hoped that a brief presentation of this and will be appreciated and that it may help popularize the subject among medical men.

The monograph is arranged in three parts: **Part I.** ***The Relationship Between the Vegetative Nervous System and the Symptoms of Visceral Disease;*** **Part II.** ***Innervation of Important Viscera, with a Clinical Study of the More Common Viscerogenic Reflexes***; **Part III.** ***The Vegetative Nervous System.*** A natural order would be to consider the vegetative nervous system first, since it is the basis of the study. Owing to the fact, however, that its consideration must necessarily be somewhat technical, it seemed best to place the more practical subjects first. Parts I and II, therefore, which contain the practical application of the principles of visceral neurology to clinical medicine, including many of my original discussions, are placed first; while a brief review of the vegetative nervous system will be found in Part III.

The discussion of the reflexes arising in or expressed in each organ as described in Part II is preceded by a statement of the innervation of the organ in question. The difficulty which the writer experienced in gathering this data from books on anatomy and physiology is sufficient assurance of the importance of making this data easily accessible to the clinician.

This book is an attempt to show the relationship between physiologic facts and clinical observation and is given forth with the hope that it may stimulate greater interest in clinical observation and interpretation.

My thanks are due to Messrs. Marion, Alcorn and Shumway for assistance in preparing the illustrations and to my secretary, Miss Donahue, for aid in preparing the manuscript.

I shall be gratified if this monograph helps in any degree to emphasize the importance of more accurate clinical observation and interpretation of symptoms, thus aiding in the better understanding and enjoyment of that phase of clinical medicine upon which we are just entering, in which the patient who has the disease is to receive a consideration equal to the disease which has the patient, I realize that the suggestions contained herein are not all final; but I trust that they may stimulate observation and call out discussion which will lead to a better understanding and interpretation of clinical phenomena. This work, however, must be looked upon as being only a brief excursion in a large field.

Francis Marion Pottenger.

Monrovia, Cal.

CONTENTS (Original)

PART I
THE RELATIONSHIP BETWEEN THE VEGETATIVE NERVOUS SYSTEM AND THE SYMPTOMS OF VISCERAL DISEASE

CHAPTER I
INTRODUCTORY
The Evolution of Modern Medicine, 17; Necessity of a New Viewpoint in Clinical Medicine, 20; Pathology and Modem Medicine, 21; Inaccuracy of Clinical Observations, 22; Modern Clinical Teaching at Fault, 23; Normal Control of Body Activities, 24; Chemical Control, 24; Nerve Control, 23; Physical Condition Changes Body Control, 26; Psychic Activity Changes Body Control, 27; Disease Expresses Itself Both Physically and Psychically, 28; A Rational Basis for Study of Disease, 29; Organic Versus Functional Disease, 30.
CHAPTER II
Basis of Classification of Symptoms of Disease Cause of the Variability of Symptoms, 33.
CHAPTER III
Symptoms Due to Toxemia
CHAPTER IV
Segmentation of the Body
CHAPTER V
Definition of Terms, 33; Two Distinct Groups of Visceral Reflexes, 55;
Conditions Underlying Visceral Reflexes, 57; Simple and Complex Reflexes, 58; Relationship between the Sensory and Motor Segments in the Central Nervous System, 63; the Relation between the Viscerogenic Reflex and Visceral Inflammation, Go,
CHAPTER VI
Reflexes Whose Afferent Impulses Course in the Sympathetic Nerves
Distribution of Sympathetic Nerves, 68; Distribution of Sympathetic Reflexes, 68; Nature of Sympathetic Reflexes, 71; Visceromotor Reflex, 71 J Viscerosensory Reflex, 74 ; Adequate Stimulus, 75 ; Variable Sensibility of Different Tissues, 76; Visceral Versus Somatic Pain, 79; Referred Character of Visceral Pain, 81 ; Hyperalgesia, 84; Recurrent Pain in Sensory Spinal Nerves Resulting from Visceral Disease, 89 ; Viscerotrophic Reflex, 91; Cause of Trophic Reflex, 91; Examples of Trophic Reflex, 92.
CHAPTER VII
Reflexes Whose Afferent Impulses Course in the Parasympathetic Nerves Distribution, of Parasympathetic Reflexes, 95; Relationship of Trigeminus Nerve to parasympathetic Reflexes. 9.i ; Examples of Parasympathetic Reflexes, 100; Functional Disturbances and the Parasympathetic Reflex, 100; Nature of Pa rosy in pathetic Reflexes, 101; Importance of the Para sympathetic Trophic Reflex, 102; Common Parasympathetic Symptoms and Syndromes, 103.
CHAPTER VIII
Sympathetic and parasympathetic Syndromes
Syndrome of Sympathetic Stimulation, 105; Syndrome of Parasympathetic Stimulation, 106; Special Service Rendered to the Organism by the Sympathetic and Parasympathetic Systems, 106; General Sympathetic Responses, 109; Defence against an Enemy, 109; Infections, 110; Shock, 111; Injury and Asphyxia, 111; High Blood Pressure, 111; General Parasympathetic Responses, 112; Local Parasympathetic Syndromes, 112; Antagonism of Sympathetics and Parasympathetic, 112; Degenerations, 114.
PART TWO
INNERVATION OF IMPORTANT VISCERA WITH A CLINICAL STUDY OP THE MORE IMPORTANT VISCEROGENIC REFLEXES
CHAPTER IX
Introductory
Grouping of Structures Supplied by the Vegetative Nerves, 117; Subdermal Musculature, II7; Vasodermal Musculature, II7; Sphincter System, 117; Urogenitodermal System, 117; Enteral System of Musculature, 117; Smooth Musculature of the Head, 119; Enteral System, 119; Tissues Activated by

the Sympathetics, 124; Eye, 124; Lachrymal Gland, and Vegetative Fibers in the Nose, Accessory Sinuses, Pharynx, and Larynx, 124.
CHAPTER X
OESOPHAGUS 126
Innervation of the Oesophagus, 1S6; Clinical Consideration, 126.
CHAPTER XI
The Stomach 129
Innervation of the Stomach, 129; Parasympathetics, 129; Sympathetics, 129; Digestive Control Both Nervous and Chemical, 11: Clinical Consideration, 131; Psychical Influence on Digestion, 1.12; Gastric Visceromotor Reflex, 133; Gastric Viscerosensory Reflex, 134; Gastric Parasympathetic Reflexes, 135; Manner in Which the Stomach is Routinely Influenced by Other Organs 136; Hyperchlorhydria, 136; Hypermotility, 137; Hypochlorhydria, 137; Dilatation of the Stomach, 137; Nausea and Vomiting, 138.
CHAPTER XII
The Intestinal Tract 139
Innervation of the Intestinal Tract, I.3i); Innervation of the Small Intestine, 139; Parasympathetics, 139; Sympathetics, 139; Innervation of the Colon and Rectum, 140; Parasympathetics, 140; Sympathetics, 140; Innervation of the Sphincters, 141; Sympathetics, 142; Parasympathetics,]43; Clinical Consideration, 143; Sympathetic Reflexes, 143; Intestinal Visceromotor Reflex, 143; Intestinal Viscerosensory Reflex, 144; Peritoneum, 147; Parasympathetic Reflexes, 148; Parasympathetic Reflexes Shown in the Intestinal Tract Itself and in Other Organs, the Impulse Originating in the Intestinal Tract, 148; Colicky Pains, 149; Spastic Constipation, 130; Intestinal Stasis, lol ; Diarrhoea, 132; Bradycardia, 153; Hectic. Flush, 13;; Increased Nasal and Pharyngeal Mucus (Catarrh), 1;)7; Herpes, MS; Headache, I.J7; Parasympathetic Reflexes Shown on the Part of the Intestinal Tract, the Impulse; Originating in Other Organs, 157; Action of Toxins on Motility and Secretory Activity of the Intestinal Tract, I19; Action of Such States on Anger, Fear, and Pain upon the Motility and Secretory .Activity of the Intestinal Tract, 139; Endocrine Glands, 160.
CHAPTER XIII
The Liver and Gall Bladder 161
Innervation of the Liver and Gall Bladder, 161 ; Parasympathetics, 161 ; Sympathetics, 161; Spinal Nerves, 162; Clinical Consideration, 162; Hepatic Visceromotor and Viscerosensory Reflexes, 162; Hepatic Parasympathetic Reflexes, 164 ; Spasm of Sphincter of Common Duct, 164 ; Cholecystitis, ma.
CHAPTER XIV
PANCREAS.48 166
Innervation of the Pancreas, 166; Parasympathetics, 166; Sympathetics, 166; Clinical Consideration, 167; Pancreatic Visceromotor and Viscerosensory Reflexes, 167; Pancreatic Parasympathetic Reflexes, 168.
CHAPTER XV
THE DIAPHRAGM 169
Innervation of the Diaphragm, 169; Sympathetics, 169; Parasympathetics, 169: Spinal Nerves, 171; Clinical Consideration, 171; Sympathetic Reflexes, 171; Diaphragmatic Visceromotor Reflex, 171; Diaphragmatic Viscerosensory Reflex, 171; Parasympathetic Reflexes, 172; Reflexes through the Spinal Nerves, 172; Reflexes Shown in the Diaphragm, the Afferent Impulse Coming from Other Organs, 174; Lung, 176; Pleura, 176; Abdominal Organs, 177; Peritoneum, 178.

CHAPTER XVI
The Bronchi and Lungs 179
Innervation of the Bronchi and Lungs, 179; Parasympathetics, 179; Sympathetics. 179; Clinical Consideration, 181; Reflex Symptoms from Lung, 182; Sympathetic Reflexes, 183; Diaphragmatic Visceromotor Reflexes, 183; Pulmonary Viscerosensory Reflex, 186; Diaphragmatic Viscerotrophic Reflex, 187; Parasympathetic Reflexes, 193; Parasympathetic Reflexes Shown on the Part of Other Viscera, the Impulses Originating in the Lung, 193; Vagus, 193; Oculomotor Nerve, 199; Trigeminus, 200; Facialis, 201; Facialis and Glossopharyngeal, 201; Accessorius, 201 ; Hypoglossus, 202 ; Pelvic Nerve, 202 ; Parasympathetic Reflexes Shown on the Part of the Lung, the Impulses Originating in Other Viscero, 202.
CHAPTER XVII
The Pleura 205

Innervation of the Pleura, 205; Parasympathetics, 205; Sympathetics, 205; Spinal Nerves, 205; Clinical Consideration, 206; Sympathetic Reflexes, 206; Pleural Visceromotor Reflex, 20fi; Pleural Viscerosensory Reflex, 208; Pleural Viscerotrophic Reflex, 209; Spinal Nerve Reflexes, 210; Parasympathetic Reflexes, 211.
CHAPTER XVIII
The Heart 212
Innervation of the Heart, 213; Sympathetics, 212; Parasympathetics, 212; Peculiarities of Heart Innervation, 214; Rhythm, 215; Clinical Consideration, 217; Cardiac Visceromotor Reflex, 217; Cardiac Viscerosensory Reflex, 217; Cardiac Parasympathetic Reflexes, 219; The Manner in Which the Heart is Influenced by Stimuli from Other Organs, 219.
CHAPTER XIX
The Aorta 221
Innervation of the Aorta, 221; Sympathetics, 221; Parasympathetics, 221; Clinical Consideration, 231.
CHAPTER XX
The Blood Vessels 223
Arteries, 233; Vasomotor Nerves, 223; Head and Nock, 225; Anterior Extremity, 226; Posterior Extremity, 226; Abdominal and Pelvic Viscera, 227; Reciprocal Stimulation of Viscera and Somatic Structures through Vasomotors, 227; Vasomotor Control, 2'27; The Splanchnic Nerves, 228; Vasodilator Nerves, 229; Vessel Tone, 230; Action of Adrenin Upon the Vasomotors, 230.
CHAPTER XXI
The Salivary Glands 235

Innervation of Salivary Glands, 235; Parotid Gland, 235; Submaxillary and Sublingual Glands, 236; Clinical Consideration, 337.
CHAPTER XXII
The Nasal and Pharyngeal Mucous Membranes and Accessory Sinuses 238 innervation of Nasal and Pharyngeal Mucous Membranes and Accessory Sinuses, 23S; Sympathetics, 23S; Parasympathetics, 238; Clinical Consideration, 23S; Disturbance in Secretion, 23S; Dryness of the Mucous Membrane of the Nose and Throat, 23S; Excessive Secretion, 239; Motor and Sensory Disturbances, 239.
CHAPTER XXIII
The LARYNX 241
Innervation of the Larynx, 241; Clinical Considerations, 241; Parasympathetic Trophic Reflex, 244.
CHAPTER XXIV
The Eye 245
Innervation of the Eye, 245; Sympathetics, 245; Parasympathetics, 245; Clinical Consideration, 247; Pupil, 248; Argyll Robertson Pupil, 248; Rigidity of the Pupil to Light, 248; von Graefe's Sign, 249; Dalrymple’s Sign, 250; Reflexes in Other Organs from the eye, 250.
CHAPTER XXV
The Lachrymal Glands 251
Innervation of the Lachrymal Glands, 251; Sympathetics, 251; Parasympathetics, 2.11; Clinical Consideration, 2.11; Dryness of the Eyes, 251; Epiphora, 252.
Chapter XXVI
The Urogenital Tract 253
Innervation of the Urogenital Tract, 253; Fallopian Tubes, Uterus, Vagina, Vas Deferens, Seminal Vesicles, Ureter, 254; Prostate and the Glands of Cowper and Bartholin, 256; Penis, 257; Urinary Bladder, 257; Ovary and Testicle, 257; Kidney, 258; Clinical Consideration, 259; Fallopian Tubes, Uterus, Vagina, Vas Deferens, Seminal Vesicles, 251) ; Motor Reflex, 260; Sensory Reflex, 260; Prostate, 262; Penis, 263; Bladder, 264; Visceromotor Reflex, 264; Viscerosensory Reflex, 264; Ovary and Testicle, 265; Motor Reflex, 265; Sensory Reflex, 265; Kidney and Ureter, 265; Renal Visceromotor Reflex, 265; Renal Viscerosensory Reflex, 266; Renal Viscerotrophic Reflex, 267; Ureteral Visceromotor Reflex, 268; Ureteral Viscerosensory Reflex, 268.

CHAPTER XXVII
The Subdermal Musculature 270

Pilomotor Muscles, 270; Sweat Glands, I! 71.
CHAPTER XXVIII
Endocrine Glands 273
Innervation of the Thyroid Gland, 275; Sympathetics, 276; Parasympathetics, 276; Innervation of the Adrenals, 276; Sympathetics, 276; Parasympathetics, 277; Clinical Consideration, 277; Thyroid, 278; Adrenals, 279.

THE VEGETATIVE NERVOUS SYSTEM
CHAPTER XXIX
The Vegetative Nervous System; General Considerations 281
Control of Protoplasm Activities, 281; Chemical Control of Body Activities, 283; Nerve Control of Body Activities, 285; Psychical Control of Body Activities, 286; Significance of the Nervous System, £88; Significance of the Vegetative Nervous System, 280; Confusion in Names, 291; Divisions of the Vegetative System, 292; Reflex, 293; Vegetative Nervous System Embryologically Consideration, 296; Development of Afferent and Efferent Neurons, 2!i8; Relationship Between Cerebrospinal and Vegetative Nervous System, 298; Adequate Stimulus, 299; Afferent Impulses Over Sympathetics and Parasympathetics Cause Different Reflexes, 300.
CHAPTER XXX
The Vegetative Nervous System Anatomically Considered 303 Sympathetic Nervous System, 303; Gangliated Cord, 305; Collateral and Terminal Ganglia, 30fi; Some of the More Important Sympathetic Ganglia, 306; Superior Cervical Ganglion, 306; Medium Cervical Ganglion, 307; Inferior Cervical Ganglion, 308; Stellate Ganglion, 308; Celiac Ganglion, 300; Inferior Mesenteric Ganglion, 309; Difference in Number of Preganglionic and Postganglionic Fibers, 309; White Rami Communicantes, 309; Gray Rami Communicantes, 311; Sacral Vegetative Nerves, 313; Cranial Vegetative Nerves, 313; Vagus, 314.
CHAPTER XXXI
The Vegetative Nervous System: General Physiologic Considerations 316 Relationship Between the Vegetative and the Central Nervous System, 316; Responses in Voluntary and Vegetative Systems Compared, 317; Distribution of the Neurons of the Thoracolumbar and Craniosacral Outflows, 318; Antagonistic Action of the Thoracicolumbar and Craniosacral Outflows, 319; Tonus, 320; Methods and Results of Studying Thoracicolumbar Control of Body Structures, 323; Sensory, Sympathetic and Craniosacral Nerves, 323; function of the Sympathetic Ganglia, 327.

CHAPTER XXXII
PHARMACOLOGIC Differentiation BETWEEN Neurons OF THE THORACICOLUMBAR AND Craniosacral Outflow 337
Adrenalin, 337; Acetylcholine, 339; Ergotoxin. 340; Atropin, 140; Pilocarpine, 341.

ILLUSTRATIONS (Original List)

Fig.
1. Diagram of human embryo, showing segmentation of the body.
2. Diagrammatic representation of a primitive vertebrate....
3. Showing the relationship of the segments of the spinal card. . .
4A. cutaneous sensory zones of the anterior surface of the body.
4B. Innervation of the muscles of the anterior surface of the body
&A. Cutaneous sensory zones of the posterior surface of the body .
.5B. Innervation of the muscles of the posterior surface of the body
6. Diagrammatic representation of cutaneous areas of sensibility; .
7. The connector neurons for the important thoracic, abdominal, and pelvic viscera 51
S. Diagram to show general origin and distribution of efferent vegetative fibers 54
9. Schematic representation of intra segments I and intersegmental reflexes 60
10. Schematic representation of the physiologically different conductions 62
11. Diagrammatic illustration of the central nervous system and the tis-sues supplied with motor and sensor)' nerves from each segment . 66
12. Diagrammatic representation of the principal centres in the cord. . 73

13. Diagrammatic illustration showing location of pain when different portions of the gastrointestinal tract are dissected SO
14. Diagram of zones and areas of hyperalgesia after the clinical researches of Head (anterior and posterior view) 86
15. Diagram of zones and areas of hyperalgesia after the clinical researches of Head (lateral view) 87
16. Graphic illustration of cause of recurrent pain in sensory neurons, the cell bodies of which have been rendered hyperirritable by disease 90
17. The sensory and motor nuclei of the medulla SO
18. Showing the innervation of the muscles of deglutition 127
19. Schematic illustration of the double innervation of the enteral system. 130
20. Showing the gastric visceromotor reflex 133
21. Showing the location of the gastric viscerosensory reflex 134
22. Showing the cutaneous areas supplied by the sacral nerves in the perineal region 141
23. Paths of the visceromotor reflexes of the abdominal viscera.... 142
24. Area of pain in appendicitis 140
2fi. Chart showing reflex bradycardia due to tuberculous involvement of the intestine 156
26. Showing the hepatic visceromotor reflex 1S2
37. Hepatic viscerosensory reflexes 163
28. Pancreatic Tissue sensor; reflex 167
29. Showing the pancreatic visceromotor reflex 108
30. Diaphragm viewed from below and in front 170
:il. Site of diaphragmatic viscerosensory reflex 171!
35. Schematic illustration of the influence of the diaphragm in enlarging the intrathoracic space 173
33. Showing diaphragmatic reflex from other organs 177
34. Keflex paths in the spinal cord showing the manner in which impulses are distributed to other levels by intercalated neurons ISO
SS. Pulmonary visceromotor reflex 184
36. Pulmonary viscerosensory reflex 185
37. Hilus Viscerotrophic reflex 189
3SA. Slowing the cutaneous and subcutaneous areas which are affected by the pulmonary viscerosensory and viscerotrophic reflexes (anterior view) 190
3SB. Showing the cutaneous and subcutaneous areas which are affected by the pulmonary ^ viscerosensory and viscerotrophic reflexes (posterior view) 190
39. Illustrating schematically= the degenerative effects upon soft tissues produced reflexly by a chronic inflammation in one apex 191
4(1. Illustrating both spasm and degeneration as observed clinically . . . 192
"IIA. Chart showing bradycardia in presence of cavity formation in the lung 106
41B. Chart showing how inflammation in the lung reflexly slows the heart through the pulmonary and cardiac branches of the vagus nerve . 197
42. Pleural visceromotor reflex 20G
43. Pleural viscerosensory reflex 209
44. Innervation of the heart 213
45. Cardiac visceromotor reflex 217
46A. Cardiac viscerosensory reflex. (Anterior view) 218
46B. Cardiac viscerosensory reflex. (Posterior view) 218
47. Distribution of vasomotor centres and nerves 224
48. Schematic illustration of vasomotor supply for head and neck . . . 221)
49. Schematic illustration of vasomotor supply for anterior extremity . . 226
50. Schematic illustration of vasomotor supply for posterior extremity . . 227
51. Schematic illustration of vasomotor supply of abdominal and pelvic viscera 227
52. Innervation of salivary glands 236
63. Nerve supply of nasal mucous membrane 239
54. Nerve supply of larynx 242
55. Schematic illustration of motor disturbance in cords through recurrent laryngeal nerves 243
56. Schematic illustration of motor disturbance in cords through superior laryngeal nerves 243
07. Innervation of the eye 246

58. Diagrammatic illustration of the bulbar fibers of the cervical sympathetic 247
59. innervation o(lachrymal glands 253
60. Innervation of generative organs. (Male) 255
61. Innervation o£ generative organs. (Female) 256
62. Nerve supply of the kidney 239
63. Areas of distribution of cord screwing involved in uterine, ovarian, and tubal diseases 2C1
64A. Illustrating area of pain in prostatic disease. (Anterior view'} . . 262
64B. Illustrating areas of pain in prostatic disease. {Posterior view) . . 262
C5A. Showing the common locution of pain when the bladder is inflamed
(Anterior view) 263

63B. Showing the common location of pain when the bladder is inflamed
(Posterior View) 263
06. Common area of pain when the testicles or the ovaries are inflamed . 264
07. Benny visceromotor reflex 266
68A. Renal viscerosensory reflex. (Anterior view) 267
08B. Renal viscerosensory reflex. (Posterior view) 267
m. Showing the ureteral visceromotor reflex 268
70. Common area of pain in ureteral viscerosensory reflex 269
Tl. Showing the direct sympathetic innervation of chromaffin cells of the medulla of the adrenal body 277
72. Diagrammatic section across the back of an anencephalic child in which the medullary plates were exposed on both head and spine . . . 287
73. Transverse section of human embryo of 2.4 mm. to show developing neural canal £87
74. Diagram to show how the ectodermal cells of the medullary plates are differentiated into nerve cells or neuroblasts and supporting cells or spongioblasts 287
75. A two-neuron reflex arc in a vertebrate 294
76. A three-neuron reflex arc 293
77. Three stages in the closure of the neural tube and formation of the neural crest (spinal ganglion rudiment) 20G
76. dissection allowing thoracic, lumbar, and sacral portions of right gangliated cord and their branches 304
79. Superior cervical ganglion and tissues supplied by it, shown schematically 307
SO. Structures supplied by medium cervical ganglion 307
PI. Structures supplied by the inferior cervical ganglion 308
82. Structures supplied by the stellate ganglion 308
83. Structures supplied by the celiac ganglion . . . ,' 310
84. Structures supplied by the inferior mesenteric ganglion 310
85. Mechanism of action in pseudo- or pre-ganglionic axonal, and true reflexes 32!)
86. Section of a sympathetic ganglion in the celiac region of a frog . . 338

COLOUR PLATES

PLATE PAGE

I. Schematic illustration of the vegetative nenous swatch differentiating the sympathetic and parasympathetic components 54
II. Reflex paths of voluntary system in cranial region 9fl
III. Reflex paths in the cord 100
IV. Reflex paths in the Milia region 100
V. Distribution of connector fibres and excitor neuron of the bulbosacral or enteral system 118
VI. The connector fibers and excitor neurons of sphincter system of involuntary muscles 1S2
VII. Schematic illustration of vegetative nervous system 288
VIII. The arrangement of connector fibers and the excitor neurons of the sympathetic system in the spinal region 312
IX. Scheme of vegetative nerve supply to the structures of the head . 312

X, Section through the nuclei of the vagus in the medulla after Miller. 314

"THERE IS A PATIENT WHO HAS THE DISEASE, AS WELL AS THE DISEASE WHICH HAS THE PATIENT."

Explanation of Terms Used in the Text

Vegetative Nervous System. That system of nerves which supplies all the smooth muscles and secreting glands of the botty and which, together with the secretion from the endocrine glands, control oil (functions which are absolutely essential to life. This is also called "involuntary'* and "autonomic."

Sympathetic Nervous System. That division of the vegetative nervous system which arises from the thoracic and upper lumbar portion of the cord.

Parasympathetic Nervous System. That division of the vegetative nervous system which arises from the midbrain, medulla and the sacral portion of the cord; its fibers coursing in the IIIrd, VIIth, IXth and Xth cranial and

Viscerogenic Reflex. A reflex which is produced by stimuli which arise in internal viscera.

Visceromotor Reflex. A reflex commonly recognized as a "spasm of muscles," produced by afferent impulses which come from an inflamed organ and go to the spinal cord over the sympathetic sensory nerves and there mediate with the spinal nerves which supply the skeletal muscles.

Viscerosensory reflex. A reflex usually recognised as "pain in the superficial tissues — akin, subcutaneous tissue, and muscles" — which is produced by inflammation of internal viscera. The stimulus passes to the cord over sensory sympathetic neurons and is there transferred to adjacent cell bodies which give origin to the spinal sensory nerves which supply the superficial soft tissues. This is not a true reflex in a physiological sensor but is rather a clinical convenience

Viscerotrophic reflex. A degeneration of the skin, subcutaneous tissue and muscles resulting from a stimulus which is due to inflammation in internal viscera. The stimulus passes from the inflamed organ over the sensory neurons of the vegetative system to the cord and medulla and is there transferred to the sensory and motor nerves which supply the superficial tissues. The viscerotrophic reflex results from long-continued nerve stimulation. It also is probable that viscerotrophic reflexes result from efferent impulses passing lo the viscera over vegetative neurons.

Parasympathetic Reflex. The parasympathetic reflexes which are best known are those which are usually considered as "functional disturbances". For the most part they are motor or secretory in character, although they may be sensory and trophic. The afferent impulses course principally over the' sensory fibers of the Vth and Xth nerves in the medulla and the sensory sacral neurons; the efferent impulse may course in any of the nerves which contain parasympathetic neurons IIIrd, VIIth, IXth and Xth, and pelvic nerve, or in the Vth, XIth, and XIIth cranial nerves.

Adequate Stimulus. A stimulus of such character and such intensity that it is able to overcome the resistance between the neurons which it affects, in such a manner as to produce action.

Part 1

The Relationship Between the Vegetative Nervous System and The Symptoms of Visceral Disease

Chapter 1

Introductory

The Evolution of Modern Medicine

As our studies in medicine penetrate deeper into the problems of each individual branch or specialty one fact stands out with ever increasing emphasis; namely, that medicine is a unit and incapable of real division into specialties. The superior man in the medicine of the future will not be the great laboratory worker, or the man who is known for his studies in metabolism or the expert gastroenterologist, or neurologist, or surgeon or he who stands pre-eminently above his confreres in his knowledge of diseases of the heart and arterial system or of the lungs, but the man who recognizes the fact that the truths derived from all of these sources of study and investigation must be interpreted as belonging to the human patient as a whole—in other words the internist who appreciates the unity of medicine. The distinguished specialist will be one who regards his field of study in its intimate relationships to the body as a whole.

Modern medicine is a wonderful illustration of the triumphant force of truth and knowledge. It is not necessary to go back more than half a century to find that the greatest clinical teachers were almost wholly ignorant of the scientific basis of disease. Many of them were good clinical observers, hut they were armed with few of the scientific facts which form the basis of modem medicine. Their knowledge was almost wholly gained from observing the sick patient, and this without anything more than the most rudimentary ideas of physiologic function. It was a medicine founded upon clinical observation based upon a smattering of anatomic and pathologic knowledge.

The state of mind which ruled medicine at that time is well illustrated by Pasteur's biographer, Vallery-Radot, who cites as an example of the lack of appreciation of scientific effort the manner in which Claude Bernard's lectures on experimental physiology applied to medicine were received by the Academe de Medicine in 1870. His hearers affirmed that "Physiology can be of no practical use in medicine; it is but a science *deluxe* which could well be dispensed with." The wonderful epoch-making contributions of Pasteur which laid the foundation of modem scientific medicine were received with no greater enthusiasm; but, on the other hand, met with the same opposition born of ignorance and conservatism. Nor is this to be wondered at, for his new idea, of diseases being due to microbes, was opposed to the theory of spontaneous generation which up to this time had held absolute sway in the minds of scientists. It is difficult for most men to change their opinions, even though they have never examined the reasonableness of those to which they subscribe; for "If it is painful to tenants to leave a home in which they have spent their youth, what must it be to break with one's whole education."

The status of every branch of science, every profession, every business rests upon a mass of supposedly established and accepted facts. Whether these arc true or not does not matter, as far as their influence upon the branch of science, the profession or the business is concerned. They dominate it; and progress can be made only as increased knowledge displaces error or as these "facts" are changed to meet new conditions. This "consensus of opinion" makes for and establishes a "conservatism," which forces the discoverer of new truths to not only promulgate them but to fight for their acceptance. Such conservatism prevents many unproved and false theories from being accepted, and in this manner renders valuable aid to science. At times, it prevents, at other times, postpones the acceptance of truths and hinders progress. This delay in recognizing truths caused Claude Bernard to say: "Those who BOW on the field of science are not destined to reap the fruit of their labours," meaning, that recognition is so slow that it comes after the scientist is dead. New discoveries depend upon increased knowledge or new application of known facts; but alas, those who sit in judgment upon them too often render their opinion without familiarizing themselves with the facts upon which they are based. The conservatism of the medical profession in the last quarter of the nineteenth century opposed the findings of the laboratory and made many fundamental discoveries fight for recognition; but when they had been understood and accepted, they seemed so plain that the ignorance and conservatism which had opposed them was in turn opposed; and, clinical observation, which had previously been the corner stone of medicine, was now discredited. One by one, the basic truths underlying modern scientific medicine be- came established, each emphasizing the particular branch of medicine in which it originated; now bacteriology, now pathology, now biochemistry and again one or the other of the clinical specialties; and all further emphasizing the lack of scientific foundation upon which medicine had previously rested. The result of this movement was that the physician of the old school was discredited. He either accepted the new advances that were being made or dropped by the wayside. The laboratory and the clinical specialist and those who could think in terms of the laboratory and of the specialties came into the ascendancy. This is where medicine stands today; but it is an illogical position in which the parts are emphasized at the expense of the whole. The mass of established facts in each of these branches, however, is now sufficient to call for a constructive unification. Fundamentally there is no antagonism between laboratory and clinical observation, none between the specialties and general clinical medicine. They must be brought together in the construction of the future unified medicine. Any study or analysis, therefore, which will show the interdependence of the various tissues and organs of the body and any study or analysis which will show the interdependence of the various branches and specialties of medicine will further this end and should be welcomed.

Necessity of a New Viewpoint in Clinical Medicine

The one outstanding need of modern medicine is accurate clinical observation and interpretation. This statement is not made to underrate or belittle the truly great observations that heretofore have been made, nor in a spirit of ingratitude toward those who have blazed the way. It is made rather in the spirit of an admission that clinical observation has lagged behind when compared with the various phases of laboratory investigation. In fact, clinical medicine has been in danger of becoming not the master but the willing servant of the laboratory worker. Medical laboratories arc operated for two purposes, to aid in the prevention of disease and to aid in the study and cure of those afflicted with disease.

The transposition by which the laboratory has been placed above clinical observation, has been due to many influences. Medicine has developed unevenly. Laboratory medicine has been an inviting field and has succeeded in interesting many of the brightest minds among the best trained of the younger men, who by dint of hard work have observed and correlated many important facts. The laboratory era, too, opened at a time when clinical medicine was losing some of its former prestige. The former reverence for the physician and the blind faith in his remedies were waning. Instead of seizing upon the new laboratory discoveries as being an aid to clinical observations, the clinician almost ceased to observe and made his opinions secondary to the laboratory findings; and "laboratory diagnosis" became an accepted fact in medicine, and was over and above the observations of those who saw and studied the patients.

While laboratory workers deserve the greatest credit for the untiring energy which they have exerted and the invaluable contributions which they have made to medicine, through which it has been placed upon n scientific basis, yet we are now able to look further ahead; and as we do, we recognize the clinician, the one who sees and studies the patient, as the one who must evaluate diagnostic data from all sources and give the final opinion. In order to be able to do this, he must not only be familiar with laboratory methods and be able to properly interpret such findings, but he must also cultivate the same accuracy of observation for the study of the patient as the laboratory worker has developed in the study of his subject. The clinician's subject, however, is the patient, with all his departures from normal function and all the abnormal tissues, secretions, and excretions found by whatever method of examination.

Pathology and Modern Medicine

Modem medicine has been dominated by a one-sided pathology which has devoted itself to the earnest study of disease and to the changes which this disease produces in the various tissues, secretions and excretions of the body. Pathologic anatomy, bacteriology, and serology and laboratory chemistry under conditions of disease, have thus received most of the thought of our rapidly developing science.

It can readily be seen that, no matter how interesting and how valuable studies of tissues, secretions and excretions are, they leave much to be desired from the standpoint of the everyday practice of our profession. As long as it shall be necessary for physicians to treat disease, the patient must be the subject of our earnest study and solicitation.

The one who is suffering from annoying or serious symptoms does not care nearly so much for the pathologic changes as he does for the annoyance which the symptoms give him or the harm that may accrue from them. While as scientific men it is desirable for us to have all the aid that pathologic anatomy, bacteriology, serology, and laboratory chemistry are able to give us, yet this is all on one side of the question. In this the patient does not see the intimate relationship which is borne to his sufferings. Is there nothing on the side of the patient that we may also study? Can we not by studying the patient loam how and through what agencies disease processes affect changes? These questions must be answered in the affirmative.

There is no study today that offers us greater hope for the future practice of medicine, than the study of the individual who has the disease and the means by which the disease expresses itself in his tissues, secretions and excretions, — the study of pathologic physiology or "functional pathology" as it is often called. Increased knowledge in this line of research is absolutely indispensable if we are to make the greatest use and application of the principles and facts revealed by the modern laboratory.

Inaccuracy of Clinical Observations

No one who has experienced the difficulties which beset the physician in his examination of the patient, can doubt that great inaccuracies are bound to creep into the data obtained through studying the patient. Much of this inaccuracy arises because of our own lack of knowledge; part of it to inaccurate and insufficient observation. It is not all due to the wrong application of knowledge, nor is it all due to misinformation furnished by the patient.

If one compares clinical observations and interpretations with laboratory data and their interpretations, there is not so much difference in the degree of accuracy of the two as is generally believed. Too much dependence is put in laboratory findings, while clinical observation is underrated and often belittled. Nothing at our command will detect clinical tuberculosis as early as careful study and examination of the patient and the evident departures from normal physiologic function which he manifests; while dependence on the laboratory will often postpone diagnosis until the chances of cure are greatly reduced. In the examination of sputum for tubercle bacilli, J, E. Pottenger' has shown that the percentage of diagnoses increases with any given method up to a certain point, according to the amount of time spent in the search. In examining sputa containing few bacilli, the most accurate method of examination reveals on a two-minute search of the specimens, only 10 per cent of the positive diagnoses that are shown in a fifteen-minute search. Nearly all diagnoses made in clinical laboratories depend upon a method much inferior to this. As a rule the search is carried on for only a few minutes, there being no accurate measurement made, yet the findings are often taken as final. Syphilis as a clinical entity is often determined by the clinical observer when the laboratory shows doubt. The real estimate of the heart when this organ is diseased can only be derived, as is so well emphasized by Mackenzie, by studying the patient.

Both laboratory and clinical observations should go hand in hand; but that department of examination which comes in intimate relationship with the patient, — clinical observation, — must assume more and more responsibility in diagnosis and prognosis as observers familiarize themselves more with the normal physiologic processes in the body. Let us recognize the fact that good clinical observation can be made as valuable and probably about as accurate as good laboratory observation. Neither method is free from error, nor is one so vastly superior that the other should be deprecated. Without an accurate knowledge of the physiologic processes going on within the body, and the pathologic changes wrought in them by disease, proper interpretation cannot be placed on laboratory data.

Modern Clinical Teaching at Fault

"While students are taught to reason for themselves more than they were in former times, yet the study of medicine is made too much a matter of memory. Principles should be taught and then the pupil should be guided in the careful study of their application. If students were to become familiar with the basic studies, anatomy, physiology, chemistry, bacteriology, pathologic anatomy, pathologic physiology and pathologic chemistry, it would make little difference in what branch of medicine they were taught the application of the principles. The application of principles, however, involves higher mental processes than their memorizing; so every student should be given a thorough drill in clinical analysis in which he should be made to see the relationship which exists between his fundamental facts and their clinical application.

There has been too much of a tendency in modem medicine to underrate the value of theorizing. Science cannot unfold alone as a succession of facts. The active inventive mind looks at things not only as entities, but in their broad relationships. From facts, theories spring up which must be followed out and proved or dis- proved. Theorizing is a legitimate instrument for the advancement of science. It was ably championed by Pasteur who said: "Without theory, practice is but routine born of habit. Theory alone can bring forth and develop the spirit of invention."

One must not, however, be a slave to any theory no matter by whom propounded. One should be ready to change when knowledge of fundamental facts warrants change. This has been well stated by Claude Bernard as follows: "When you meet with a fact opposed to a prevailing theory, you should adhere to the fact and abandon the theory, even when the latter is supported by great authorities and generally adopted."

Imagination should be cultivated in medicine. How dull our practice of medicine when we see no relationship between our primary facts and our end results! How interesting and how wonderful the unfolding when one can see relationships in all the branches of this wonderful science! A fact is worth little unless it can be applied; and it cannot be applied unless the one who knows the fact has vision enough to see where it fits in.

Many relationships which should be obvious to the clinician, are facing him each day, but are unrecognized because of his lack of imagination. He fails to connect the cause and the effect, because he fails to recognize the instrument through which the cause operates.

In this monograph I shall attempt to gather together data from many sources bearing upon one of the chief factors in the correlation of activator and result in the human organism. In other words, I shall attempt to gather together from the labours of our physiologists, data with which we may construct a bridge between cause and effect in certain disease processes.

The cells of the adult human body, according to physiologists, depend for the most part upon nerves for their nutrition and for their power to act. While it has been suggested, from a failure to find nerve connection to a few minor structures, that they may be free from direct nerve influence, yet this has not been proved ; and, in our discussion of practical clinical relationships, we are safe in assuming that action means nerve control. We shall see, however, that there is also a chemical control, consisting of the products of the glands of internal secretion, which act centrally through, or with, the nerves as they influence tissues.

Noel Paton[2] in the introduction to his monograph, "Regulators of Metabolism," says: "It is now universally recognized that the chemical changes in protoplasm which constitute its metabolism, are the basis of all the phenomena of life, alike of the manifest activities of movement and of the less visible but no less real activities of development, growth and repair. In fact, we no longer look upon protoplasm as a substance; we now recognize that it is protoplasm only in virtue of its constant cycle of chemical changes." These chemical changes result from activity in chemical or nerve control.

1. Chemical Control. The lowest forms of life have no nervous system, yet they live and change, which means chemical action. They adapt themselves to their surroundings, that is, they react to physical stimulation. The human embryo, in its earliest development, likewise, has no nervous system, yet growth and change take place, which is evidence of chemical activity. Paton attributes the first impulse to development to hereditary inertia, but considers that it is superseded by chemical control and later by nervous control.

After development proceeds and the viscera are formed, there are certain ones which produce secretions which are discharged into the blood stream and have as their function the influencing of growth and body activities. These are called "internal secretions," They have the power of influencing distant tissues and to a limited degree, have the property possessed so highly by the nervous system, of correlating activities. The glands which produce the principal substances having such control, are the thyroid, parathyroid, thymus, hypophysis, pituitary, adrenals, pancreas, mucosa of small intestines, and gonads.

The thyroid and adrenals are known to be under nerve control, and it is probable that future study will show that others, if not all, are influenced by nerve stimulation although they may also be influenced by chemical substances such as internal secretions from other organs. These internal secretions also influence the nervous system.

It is generally accepted that thyroid secretion sensitizes nerve cells, although Plummer and Kendall* in their revolutionary work upon the thyroid suggest a different mode of action. They suggest that thyroxin, the active principle of the thyroid isolated by Kendall, acts as a catalytic agent in the tissue cells themselves controlling the energy output. Other secretions act peripherally, at or beyond the myoneural junction, and produce the same effect as though the nerves were centrally stimulated. Such are the secretions from the adrenal body and possibly that from the hypophysis.

The internal secretions must be studied along with the vegetative nerves in order to understand the normal physiologic control and the pathologic disturbance in function of the smooth musculature and secretory structures of the body ; in other words, in order to understand normal and pathologic physiologic activity.

2. Nerve Control. As the human embryo develops, it becomes necessary that there be a quicker response and a greater correlation of activity; so, before the viscera are formed the neural canal comes into existence and the motor cells which are to give origin to the fibers of the vegetative nervous system, escape and start their migration peripheralwards. They send out their fibers which enter the various organs even before the tissues of the organs are fully differentiated.

With the development of the central nervous system, the reflex comes into its greatest perfection. While some lower forms of life seem to be physically influenced by their surroundings, yet reflex control is not perfected until the central nervous system is formed, and does not come into its highest perfection without the fullest development of the brain and spinal cord. This latest development also shows the greatest degree of integrative action which makes the physical man superior to all other animals.

The vegetative nervous system, being that system which cares for those functions without which the animal cannot exist, is given an intimate and direct control of metabolic activity.

It is especially necessary to emphasize this because it is so commonly asserted that metabolism is controlled by the endocrines. There is an intimate relationship between these two vegetative systems; but it is not yet known whether or not all endocrine secretion is under nerve control and whether or not all internal secretions are through the nerves. Nevertheless, we are within the bounds of known facts when we assert that the adult human being expresses most of his physiologic activity through vegetative nerves and through secretion from endocrine glands, and that his normal visceral functions and metabolic activity are entirely under the control of these systems. Therefore the study of the physiologic activity of the vegetative nervous system becomes a duty of clinicians. Its pathologic activity expresses itself in disturbed function and is the most important bridge between pathologic stimuli and the pathologic changes in tissues, secretions and excretions. *The vegetative nervous system then, when its normal action is disturbed, is the chief cause of the symptoms of visceral disease*. It affords the common bridge between activator and end result. See Part III for discussion of the vegetative nervous system.

Physical Condition Changes Body Control

The chief factor in adjustment to surroundings is the afferent or ingoing impulse of the reflex. In this the nervous system is like a telephone exchange; the call is put in through a wire, the connection is made and the action is then carried out over the outgoing wire — afferent neuron, synapse and efferent neuron.

The first part of every reflex is a sensory stimulus; so every portion of the body is provided with sensory nerves, which, when acted upon, carry the impulse to the central nervous system. If the sensory stimulus is slight, it may not be enough to overcome the resistance in the synapse. In such case, no effect would be transmitted beyond the sensory system. If the .stimulus is greater, however, then it is transmitted to other neurons, either motor or sensory, or both; and some near-by or distant structure is influenced, — it may be a pain is felt, a muscular contraction occurs, or secretory activity is influenced. These sensory nerves may be the senses of sight, smell, hearing, taste or touch, or nerves excited by chemical and mechanical stimuli. The immediate result is motor or sensory action; and, if it changes normal physiologic activity sufficiently, it results in symptoms of disease. The physical reactivity and reaction of the patient then greatly influence both nerve and chemical control; and, as we shall see, affect man's physical and psychical state.

Psychic Activity Changes Body Control

Man is further endowed with a psychic system which is above nerve and chemical control, and capable of influencing them. As the *reflex* is the basis of physical action, the idea is the basis of psychic action; *and as normal function on the part of the nervous system is essential to physical equilibrium, so are normal trends of thought necessary to a mental or psychical equilibrium.*

While we do not understand fully the relationship which exists between the physical and the psychic, we do know that they bear a close relationship to each other. The psychic condition is influenced greatly by man's physical condition and the manner in which he reacts or has reacted to his environment; his physical condition on the other hand depends much upon the equilibrium or loss of equilibrium in his psychic being. Of the two it would seem that the psychic influence over physiologic body function is greater than the physical over the psychic. We often see those physically weak with apparently perfect trends of thought, but it is rare to see one with a disturbed psychic equilibrium who does not at the same time have distorted physiologic function. Wrong trends of thought, if persisted in, are usually followed by pathologic change in physiologic action. This result is brought about through nerve stimulation and changes in internal secretions.

Some writers insist that we must get away from the idea that the psyche resides in a certain portion of the brain. It is a force, an energy which we must conceive of as being present in all body structures. Its normal activity results in normal conduct, its pathologic activity in abnormal conduct. As the action of the body depends on the reflex, the manner in which the physical man reacts to outward stimuli; so man's conduct results largely from his psychologic reaction towards his surroundings.

Disease Expresses Itself Both Physically and Psychically

Diseases affect both the physical and psychic equilibrium. The nature and extent of the harm done depends upon the previous condition of the patient as well as the nature and duration of the disease.

Conditions of disease affect the physical being, mainly through stimulation of nerves and a resultant reflex action which results in a disturbance of function. This action expresses itself mainly through the vegetative nervous system because this is the system which presides over vegetative activity and consequently controls the most important functions of the body. It also alters the secretion of endocrine glands, and in this manner produces changes in normal physiologic activity.

The influence of disease upon psychic reaction manifests itself both in acute and chronic maladies. Sometimes acute, serious psychic reactions follow acute diseases which run their course in a few days. Chronic pathologic conditions, however, result in prolonged harmful stimulation of nerve cells which produce in them a condition of fatigue and irritability which leads to a more or less general disturbance in body function. This often results in a change in the individual's reaction toward his social as well as his physical surroundings. The former results in wrong trends of thought and shows in instability of conduct. Nearly all patients who suffer from chronic disease, and this is especially true of chronic infections, show some degree of neurasthenia and psychasthenia. No patient with well-marked neurasthenia or psychasthenia can escape disturbance in physiologic equilibrium. Irritability on the part of nerve cells means unstable action, which has as its necessary concomitant, disturbed function; and this when long continued is prone to disturb the individual's method of thought and influence his conduct.

There can be no doubt that psychic unbalance affords a basis for disease. By altering nerve and chemical control, it produces pathologic metabolic states; and it is but natural that these should lower resistance and predispose to infection.

A Rational Basis For Study of Disease

The study of medicine in the future should give more attention to the individual who has the disease, a phase of the subject which has been sadly neglected in the past. The fact should be emphasized that *there is not only a disease which has the patient but a patient who has the disease.* It is necessary to continue study along the lines of pathologic anatomy, bacteriology, serology, and laboratory chemistry; but it is equally important to seek out the means through which bacteria and other harmful agencies produce the pathologic changes in tissues, secretions, and excretions. This we find by studying the normal and pathologic nerve and chemical body controls which result in disturbances in function of body cells and those groups of cells which are called organs.

In a recent paper, I suggested that, inasmuch as normal physiological control of the body is affected through nerves and internal secretions, and *inasmuch as most symptoms of disease are expressions of disturbances in this normal physiologic control, therefore most symptoms are due to altered nerve and endocrine activity. I further suggested that the stimuli which disturb this physiologic control may be either physical or psychical in origin.* Mackenzie" has recently announced as the law governing the production of most symptoms that they are due to disturbances in normal reflexes. In this he recognizes, in the endocrine system a modifier of nerve action rather than a distinct control.

The rational basis for this study of disease, whether it be for the purpose of diagnosis, prognosis or therapy, demands an understanding above all else of the physiologic control of the body as exerted through the two vegetative systems — the vegetative nervous system and endocrine glands. In the discussion which follows, the internal secretions will be connected up with the vegetative nerves where the action is evident, but it would make the task too great to undertake a complete discussion; and would lead me too far from my purpose, which is particularly to show the relationship of the visceral nerves to the symptoms of disease, and to show how symptoms arc produced and what symptoms may be expected with a given disease.

Organic Versus Functional Disease

The inevitable result of the rapid strides in the study of bacteriology, and pathologic change in tissues and secretions, and the comparatively slow progress which has been made in studying the patient, has been an undue emphasis of the importance of the disease and a minimizing of the importance of the patient who has it. This in the recent past had gone to such an extent that no matter how annoying or distressing the symptoms on the part of any organ, if no organic changes could be found in the organ, the symptoms were disregarded and turned aside as being "functional." The only kind of disease that was worthy of accurate study seemed to the one attended by a definite injury to or destruction of tissue. The dawning of a better day in medicine, however, is now evident, a day in which the patient and the disturbances in function of his various organs will receive due study and investigation.

It matters nothing to the comfort of the patient who is suffering from a distressing symptom, whether or not it has an underlying pathology in the particular organ in which the symptom manifests itself. It is of great importance, however, for the physician to know that symptoms on the part of one organ or system may be reflexly caused by pathologic changes in some other organ.

This is well illustrated in pulmonary tuberculosis, in which reflex symptoms for the most part group themselves in organs and tissues - outside of the respiratory system, thus: Hoarseness, tickling in the larynx, and cough, refer to the larynx; the digestive disturbances, whether motor or secretory, refer to the gastrointestinal canal; the rapid or slow heart to the cardiovascular system; while the reflexes through the sympathetics cause sensory, motor and trophic changes in the superficial soft structures which are usually interpreted as local nerve lesions. It is necessary to understand reflex relationships in order to correctly interpret these symptoms. Because of the reflex nature of the symptoms patients suffering from pulmonary tuberculosis are continually consulting specialists in other lines, particularly laryngologists and gastroenterologists, who, also, too frequently treat the functional derangement as an entity. The chest specialist, on the other hand, often approaches a case of asthma as though it were a disease of the lungs, when in reality it is only a condition expressive of a general or reflex stimulation of the vagus nerve; the cause of which may be as varied as the causes which stimulate the pulmonary branches of the vagus.

It shall be the purpose of this study to show the interrelationship of organs and systems of the body; to point out the manner in which they are bound together by the nervous system and how the action of different parts is correlated and integrated; and, further, how a disturbance in one organ influences others through this nervous system. It is a study of symptoms, the interpretation of which is the basis of clinical medicine. In this, I hope that the true worth of functional disturbances on the part of organs will appear.

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Chapter II

Basis of Classification of Symptoms and Disease

A symptom of a disease is a change in physiologic equilibrium, which expresses itself either subjectively or objectively and, which results either directly or indirectly from the presence and action of such disease. Many classifications of symptoms may be offered, depending upon the point of view of the author; but a rational classification of the symptoms of visceral disease must take into consideration the nervous and endocrine systems through which all normal control of function takes place.

All smooth muscles of the body, the striated heart muscle and all secreting glands depend for action and inhibition of action upon the vegetative nerves, and are supplied with sensory fibers, through which not only is their action correlated with the action of other structures, but also through which impulses course centralward to reflexly affect other structures. It must be evident, therefore, that this system of nerves is largely responsible for symptoms arising in or expressed in visceral structures. Smooth muscles and secreting glands are also influenced by the products of the glands of internal secretion. The secretion of these glands is also dependent partly, possibly wholly, upon stimuli arising in the vegetative nerves. Whether the hormones produced by the glands of internal secretion act in all instances through the vegetative nervous system, or in part, stimulate the structures directly is not known; but if the physiologists are correct in maintaining that all action and inhibition of action in these structures is under control of the vegetative nerves, then it is evident that these hormones must act through these nerves centrally or with them peripherally, and their action may be described as being sympathicotonic, or vagotonic, (parasympathicotonic) according to the symptoms produced.

Man is a dual being — physical and psychical. Through his physical being he adjusts himself to the physical surroundings; through his psychical being be adapts himself to the psychical surroundings.

Stimuli arising in physical structures may produce symptoms confined to physical structures or which extend to the psychical being. So may stimuli of psychical origin affect both the psychical and physical? I can conceive of no marked physical or psychical stimulus, however, which confines its action to the system in which it arises.

Some physical and psychical stimuli show a preference for the sympathetic, others for the parasympathetic division of the vegetative nervous system. It is also self-evident that they affect the endocrine glands differently. Thus toxins of disease act upon the nervous system as a whole, but produce symptoms in visceral structures which are characteristic of stimulation of the sympathetic system. They stimulate the adrenal and thyroid also; the secretions from which are added factors in the production of symptoms. Such emotions as fear, anger, and pain act upon the sympathetics as shown by Cannon and his co-workers, while joy and happiness tend to preserve the normal physiologic nervous and endocrine equilibrium. Anaphylaxis expresses itself peripherally in the production of symptoms characteristic of parasympathetic stimulation.

It is evident that symptoms must necessarily vary according to the nature of the disease; whether inflammatory or not; or whether accompanied by toxic or anaphylactic phenomena; also, according to the character of the tissues involved; and according to the relationship which such tissues bear to other organs or structures through the nervous system, through the internal secretions, or other chemical substances. In this connection it must be borne in mind that many pathologic chemical products are produced under the influence of disease.

For inflammatory diseases of important internal viscera, I have suggested the following classification of symptoms, varying according to whether or not the process is infectious and accompanied by toxemia, and also according to the degree of toxemia: (1) Symptoms due to toxemia; (2) Symptoms due to reflex action; (3) Symptoms due to the disease process itself; and another may be added (4) Symptoms which appear after the disease has expressed itself markedly (1, 2, and 3). These include many changes in body function resulting from disturbances in nervous and endocrine balance such as respiratory, circulatory, and metabolic changes; mechanical disturbances; and disturbances in psychic equilibrium.

Another group of symptoms consists of those which accompany anaphylaxis. These, however, are not commonly met in the syndrome which accompany diseases of the viscera.

This classification was first suggested for pulmonary tuberculosis, but will hold for many other inflammatory conditions of internal viscera.* its advantage lies in the fact that the symptoms cease to be independent entities and fall into related groups which result from some definite acting cause. This grouping of symptoms emphasizes the unity of the human body, hence the unity of medicine. It points out the interrelationship of the various viscera and how a given stimulus simultaneously disturbs the normal equilibrium in many organs. It further suggests that symptoms are produced through a disturbance of the factors which normally control the activity of these viscera; namely, visceral nerves and the products of the endocrine glands.

The important symptoms of early tuberculosis arranged according to this classification are as follows:

Group I	**Group II**	**Group III**
Symptoms due to toxemia	**Symptoms due to reflex cause**	**Symptoms due to the Tuberculous Process, per se**
Malaise Lack of endurance Lack of strength Nerve instability Digestive disturbances (hypomobility and hyposecretion) Metabolic disturbances resulting in loss of weight Increased night sweats Increased pulse rate Temperature Blood changes	Hoarseness Tickling in larynx Cough Digestive disturbances (hypermobility and hypersecretion, which may lead to loss of weight) Circulatory disturbances Chest and shoulder pains Flushing of face Apparent anaemia	Frequent and protracted colds Spitting of blood Pleurisy Sputum

In advanced tuberculosis these early symptoms are exaggerated and others of a reflex nature, such as anorexia and vomiting appear, and symptoms of a fourth group which appears when the disease becomes more severe," as follows:

Symptoms Resulting from Marked Effects of Pulmonary Tuberculosis

Respiratory changes.
Circulatory changes.
Changes on part of nervous system.
Changes in blood.
General metabolic changes.
Degenerative changes.
Menstrual irregularities.
Other changes in internal secretions.

If we analyze such diseases as tonsils and whooping cough, the symptoms would be grouped. Something like the following:

Tonsillitis

Toxic

Malaise; nervousness; headache; general aching; deficient secretion and motility in the gastrointestinal canal (coated tongue, hypochlorhydria, constipation); increased Pulse rate; rise in temperature; and later, anaemia

Reflex

The symptoms of this group are shown mainly in the pharynx and larynx: thus hoarseness, laryngeal irritation (cough); increased mucous secretion; increased salivary secretion; pain; spasm in muscles of deglutition.

Symptoms Due to the Disease per se.

Difficulty of and pain on, swallowing; obstruction to upper air passages; pressure on eustachian tube.

Whooping Cough

Toxic.

Malaise; nervousness; aching; deficient motility and secretion in gastrointestinal tract (coated tongue, Hypochlorhydria, constipation); rapid heart; rise in temperature.

Reflex

Increased secretory activity in bronchi (bronchitis) and upper respiratory passages; laryngeal spasm; cough and vomiting.

Symptoms Due to the Disease Per Se.

The microorganisms which cause whooping cough readily pass through the bronchial mucous membranes and pass to the bronchial glands which enlarge greatly, producing reflex symptoms through the pulmonary and laryngeal vagus, and at times cause pressure symptoms.

Cause of The Variability of Symptoms

One of the most confusing facts met in the diagnosis of clinical disease is the variability of symptoms. The same symptoms are not always present in the same disease. This variability does not only apply to the same disease in different individuals, but may also be noticed in a given disease as it affects the same individual at different times. This is explained by the facts (1) that in the healthy, the relative stability or excitability of the nerve cells in general, and of the sympathetic and parasympathetic systems in particular, differs in different individuals; and (2) the relative stability or excitability of nerve cells of different divisions of the sympathetics and Parasympathetics often differs in the same as well as in different individuals.

Symptoms, as mentioned above, are disturbances in normal function. Normal visceral function depends upon a certain condition of nerve stability or excitability, in which nerve cells will withstand a given stimulus without producing action; and upon the presence of the amount of chemical substances (internal secretions and metabolic products) circulating in the blood that is necessary to meet metabolic requirements. Inasmuch as these latter appear to act through, or if not through at least in harmony with, the nerves, either sympathetics or parasympathetics, which control the body function; we can say, if not expressing the whole truth, yet furnishing a working truth, that a symptom of a disease of an internal viscus is the particular disturbed function which results from all the forces which are acting upon or with the nerves which supply it.

This may be illustrated by a condition which we meet every day in such affections as appendicitis. One patient will have during the acute attack, much more vomiting than another, and also other severe symptoms on the part of the gastrointestinal canal. Some will have so few symptoms that the disease may not be suspected until it is well marked. One patient will have a chronically inflamed appendix for years and not suspect it until acute symptoms appear; while another will have distressing reflex symptoms which cause serious invalidism. Another example is furnished by tuberculosis of the lungs, a disease which is accompanied by many reflex symptoms as described in Chapter XVI. Reflex symptoms on the part of the gastrointestinal canal are largely such as result from vagus stimulation, — hyperacidity, hypermobility, spastic constipation, intestinal stasis, colicky pains and occasionally mushy and frequent stools. These symptoms are usually more marked when the disease is not accompanied by severe toxemia, because toxins stimulate the sympathetic nerves and, in the gastrointestinal canal, this produces an inhibition in the action of the vagus. Thus there are two opposing forces acting upon the gastrointestinal structures; one, reflexly through the vagus, attempting to increase muscular contraction and stimulate secretory activity, the other acting centrally upon the sympathetics attempting to inhibit muscular contraction and secretory activity. The same opposing forces are seen in the heart; the vagus, reflexly trying to slow the contractions; the sympathetics, centrally stimulated during toxemia, attempting to increase the rapidity of contraction. At times the influence of the sympathetics prevails, and at times that of the parasympathetics. So we may have any degree of muscular activity and any degree of secretory activity present in the intestinal canal from a marked hypomotility and hyposecretion to a marked hypermotility and hypersecretion; and a pulse rate in excess of normal or below normal. Further, as the relative influences upon the sympathetics and vagus are not the same in the same individual from time to time, but change with the inflammatory process in the long and the various requirements of the body, the gastrointestinal symptoms and the pulse rate may change from day to day. The influence of psychic stimuli upon symptoms must always be kept in mind; for they are capable of disturbing and altering the symptoms which would naturally be produced by given physical stimuli.

Variability of symptoms is the rule in clinical medicine, a fact which can be readily appreciated by understanding the nerve control of physiologic function.

It is not only necessary to understand that symptoms produced by a given disease may differ in different individuals and in the same individual at different times, but it is equally necessary to bear in mind that while the stimulus which would be expected to produce a given symptom is present, the symptom may not appear. It is necessary, therefore, always to bear in mind that inflammation in organs gives origin to stimuli which have a tendency to produce such and such symptoms, although the symptoms themselves may not materialize.

Many of the most important symptoms arising from diseases of internal viscera are reflex in nature. In order to understand these symptoms, one must study the innervation of the various viscera and the interrelationship which exists between them, also the interrelationship which exists between the viscera and the skeletal structures.

In the following pages will be found discussions of both physiologic principles and clinical observations, dealing particularly with symptoms of a reflex nature which result from inflammation of internal

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Chapter III

Symptoms Due To Toxaemia

A study of the symptoms due to toxemia in the following: table' will reveal the fact that this same group of symptoms is produced no matter what the nature of the toxemia or what tissue is involved:

Symptoms Due to Toxemia	
Caused by harmful stimulation of:	Symptoms
Nervous system generally	1. Malaise
	2. Lack of Endurance
Endocrine system generally	3. Loss of strength
	4. Nerve instability
Sympathetic nervous system	5. Diminished digestive activity
Sympatheticoendocrine	6. Increased metabolic rate
particularly adrenals and thyroid	7. Increased pulse rate
	8. Night sweats
	9. Temperature
	10. Increased leucocytosis

These symptoms naturally divide into two groups:[2] 1. Those due to harmful stimulation of the nervous and endocrine systems as a whole, consisting of malaise, lack of endurance, loss of strength and nerve instability; 2. Those which are due to harmful stimulation of the sympathetic nervous system and sympatheticotropic endocrine glands consisting of, digestive disturbances (hypomotility and hyposecretion), metabolic disturbances, increased pulse rate, night sweats, temperature, and blood changes.

While the symptoms differ according to the degree of the toxemia present, yet some symptoms of this group will be found no matter what the cause, whether a typhoid fever, a whooping cough, a bronchitis, an infected tonsil or gall bladder, a tuberculosis or a syphilis.

This is in accordance with the studies of Vaughan,' who has shown that the toxic molecule is the same in all protein. Toxins may possibly act directly on body cells as -some believe, but the chief effect is unquestionably through the nervous system. The action as well as the nutrition of cells is under control of the nerves supplying them; so it seems rational to assume that stimuli affecting cellular activity must do so through such control.

Toxemia causes an increase in the normal excitability of nerve cells, lowering the threshold of response, thus making the individual more susceptible to harmful stimuli. The entire nervous system is influenced by toxemia, but that particular group of nerves which shows the greatest degree of peripheral stimulation, as indicated by disturbed organic function, belongs to the sympathetic system. This manifests itself in a particularly striking manner as a depressed function of all organs belonging to or derived from the gastrointestinal tract, except the sphincters; a rapidity of heart action; and a vasoconstriction in the cutaneous blood vessels. Toxemia thus causes a dry tongue, a deficient motility and deficient secretory activity in the stomach and intestines, increased rapidity of heart action and a widespread constriction of superficial blood vessels interfering with the dissipation of heat. Heat being augmented for the time being by the increased chemical activity attendant upon the inflammation, results in a rise of temperature."

The malaise and general nerve instability resulting in loss of endurance and strength, is caused by stimulation of nerve cells and centres in the central nervous system as well.

Unfortunately we cannot differentiate the effects of toxemia as it expresses itself in the endocrine glands from that expressed through the nervous system. There are important endocrine glands, however, which are stimulated l>y it, particularly the adrenals and thyroid. These derive their activating nerve supply from the sympathetics, hence are stimulated to increased activity by toxins. The result is increased metabolic activity. One can readily understand then that toxemia exerts a twofold influence which favours loss of weight, a depressed function of the gastrointestinal organs which fail to provide sufficient pabulum, and an increased metabolic activity which hastens the breaking down of the body tissues.

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Chapter IV
Segmentation of the Body

In order to understand the relationships which exist between the sympathetic and the spinal nerves, and which are manifested in visceromotor, viscerosensory and viscerotrophic reflexes, aa described in the following chapters, it is necessary to study the segmentation of the body. While in the adult body, segmentation is markedly irregular, in the embryo it is more striking as is shown in Fig. 1. It is most evident in lower forms of life where each segment is provided with a more or less complete nervous mechanism.

Fig. 2 represents a diagrammatic representation of a primitive vertebrate — the amphioxus. The structures of each segment, both somatic and visceral, are innervated by neurons which arise in it. The viscera thus receive their nerve supply from the same part of the spinal cord as the skin and muscles over them.

A study of Figs. 1, 2, and 6 will show that there is a marked segmental regularity in the innervation of the body tissues of the adult man. It is necessary, however, to understand developmental processes in order to fully appreciate it.

The human vertebral column consists of thirty three or thirty four vertebrae, - 7 cervical, 12 dorsal or thoracic, 5 lumbar, 5 sacral, and 4 or 5 coccygeal. The latter two groups are fused together in the adult to make the two bones, sacrum and coccyx. The spinal cord is made of segments from which arise spinal nerves, one nerve from each segment. These segments correspond in number with the divisions of the vertebral column above the coccyx, except in the cervical region; there being 8 cervical segments, 12 thoracic, or dorsal, 5 lumbar, and 5 sacral.

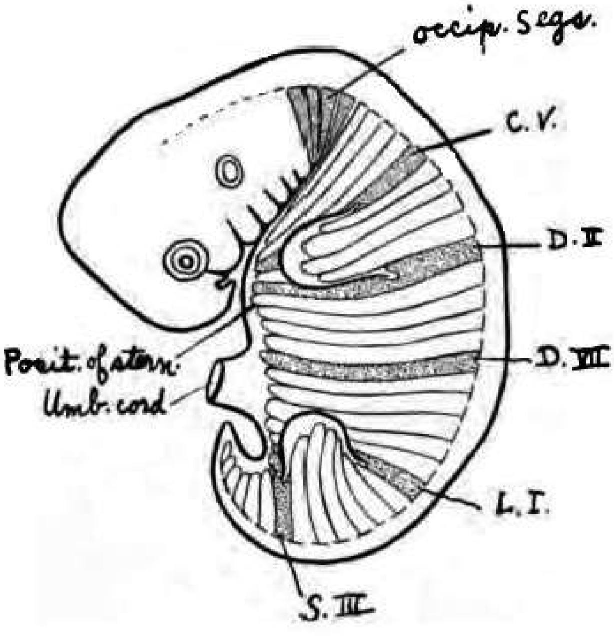

Figure 1. Diagram of human embryo, 5th week, showing the arrangement and extensions of the mesoblastic segments. The first and last of each segment entering into formation of the limbs is stippled. (C V, D III, LI and S III) The position in which the sternum is formed is indicated

While the segments nearly correspond to the number of the vertebrae, they are not on the same level. The spinal cord is much shorter than the vertebral column; in fact, it ends in the adult in the upper lumbar region. The spinal nerves in the upper cervical region pass out horizontally, but become somewhat oblique in the lower cervical, and very oblique in the lumbar and sacral segments. In the lower cervical region the spinal nerves pass out one vertebra lower than their emergence from the cord. The upper thoracic nerves, 1st to 7th, pass out one vertebra lower them their emergence from the cord.

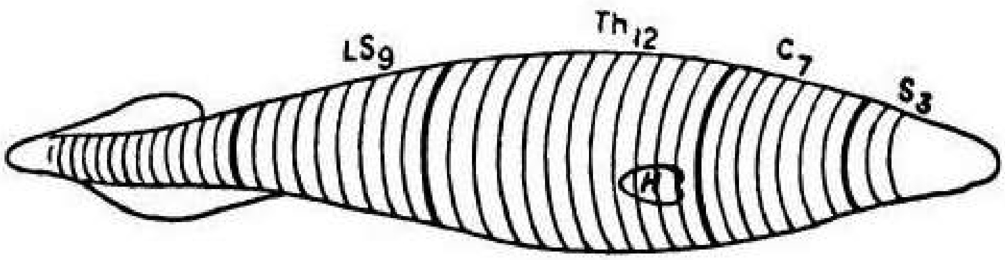

Figure 2. Diagrammatic representation of a vertebrate animal – the amphioxus – divided for convenience for the three segments of the head, seven for the neck, twelve for the thorax, nine for the lumbosacral region and an indefinite number for the coccygeal region. For clearness of the comparison of the heart (H) is represented as in the same space as is occupied as in man so an adequate stimulation from the heart would cause the pain in the upper 4 thoracic nerves covering and protecting the heart

The lower thoracic, lumbar and sacral nerves run down for a considerable distance, within the dura mater {forming the cauda equina) before emerging between the vertebra. As a result of this arrangement, the lower cutaneous segments are not on the same level with their respective segments of the cord or their respective vertebra, but are lower on the surface than either. The 10th thoracic cutaneous segment is on a level with the 1st lumbar vertebra; and the 11th with the 4th lumbar. This accounts for the fact that the areas of reflex cutaneous pain which result from inflammation of viscera innervated by the lower thoracic segments, such as the kidney, ureter, and uterus, are found in the lumbar instead of the lower thoracic region. This relationship may be understood by a study of Figs. 3, 4, and 5.

While considerable differentiation has taken place in some of the segments of the more advanced vertebrates, such as man, and while some of the viscera are markedly displaced from the segments in which they originally developed, they still preserve more or less accurately their primitive nerve connection. A study of this will greatly aid the interpretation of symptoms of visceral disease.

There is a true segmentation of the body surface, which is shown in both the skin and the muscles. Definite skin areas and definite groups of muscles are always {in the same species) innervated by the same spinal nerves. The segmentation of the skin is more regular than that of the muscles. This may be inferred by studying Figs, 4 and 5, wherein it is shown that the motor and sensory nerves supplying the muscles do not at all correspond in areas of distribution to the corresponding sensory nerves supplying the cutaneous surface. This is well illustrated in the spinal nerves originating from the cervical portion of the cord. The posterior or sensory cervical nerves are limited in their skin distribution to the head, neck and arms, and that portion of the chest above the second rib anteriorly, and the spine of the scapula posteriorly; while the motor and deep sensory nerves from the cervical portion of the cord supply such accessory muscles of respiration as the sternocleidomastoideus, scaleni, pectoralis, trapezius, levator anguli scapulae, rhomboidii and diaphragm which are far removed from these areas. The clinical importance of this will be seen in the study of superficial and deep sensation.

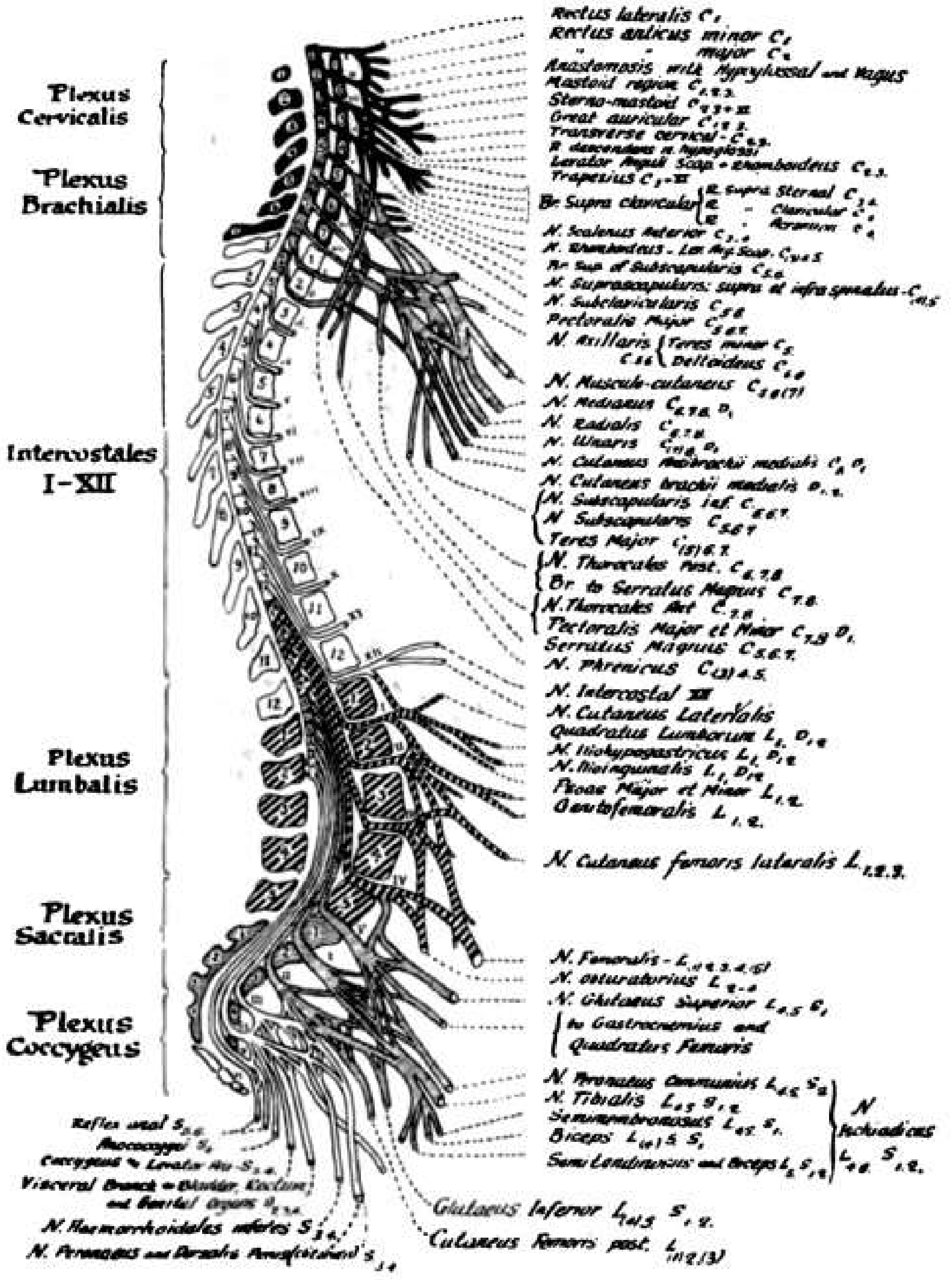

Figure 3. Relationship of the spinal segments to the spinal nerves which emerge from them and to the bodies and spines of the vertebrae. It will be noted that all the cervicals and the first tow thoracics emerge from the cord at practically the same level as the bodies of the corresponding vertebrae. The spinal nerves emerging from the thoracic segments 3rd to the 7th inclusive emerge from the spinal cord about one vertebra below their origin in the cord. From the 8th downwards, they emerge gradually farther and farther below their point of origin in the cord, and in such a manner that the 5th lumbar nerve emerges 4 vertebrae below and the 6th sacral nerve, which originates in the cord on a level with the 3rd lumbar vertebra, emerges from the spinal column at the coccyx

There is a certain amount of overlapping in the skin areas which belong to each spinal segment. While each segment is cared for particularly by its corresponding spinal sensory nerve, the next above and the next below also partially care for it by sending nerve filaments to both the zone above and below.

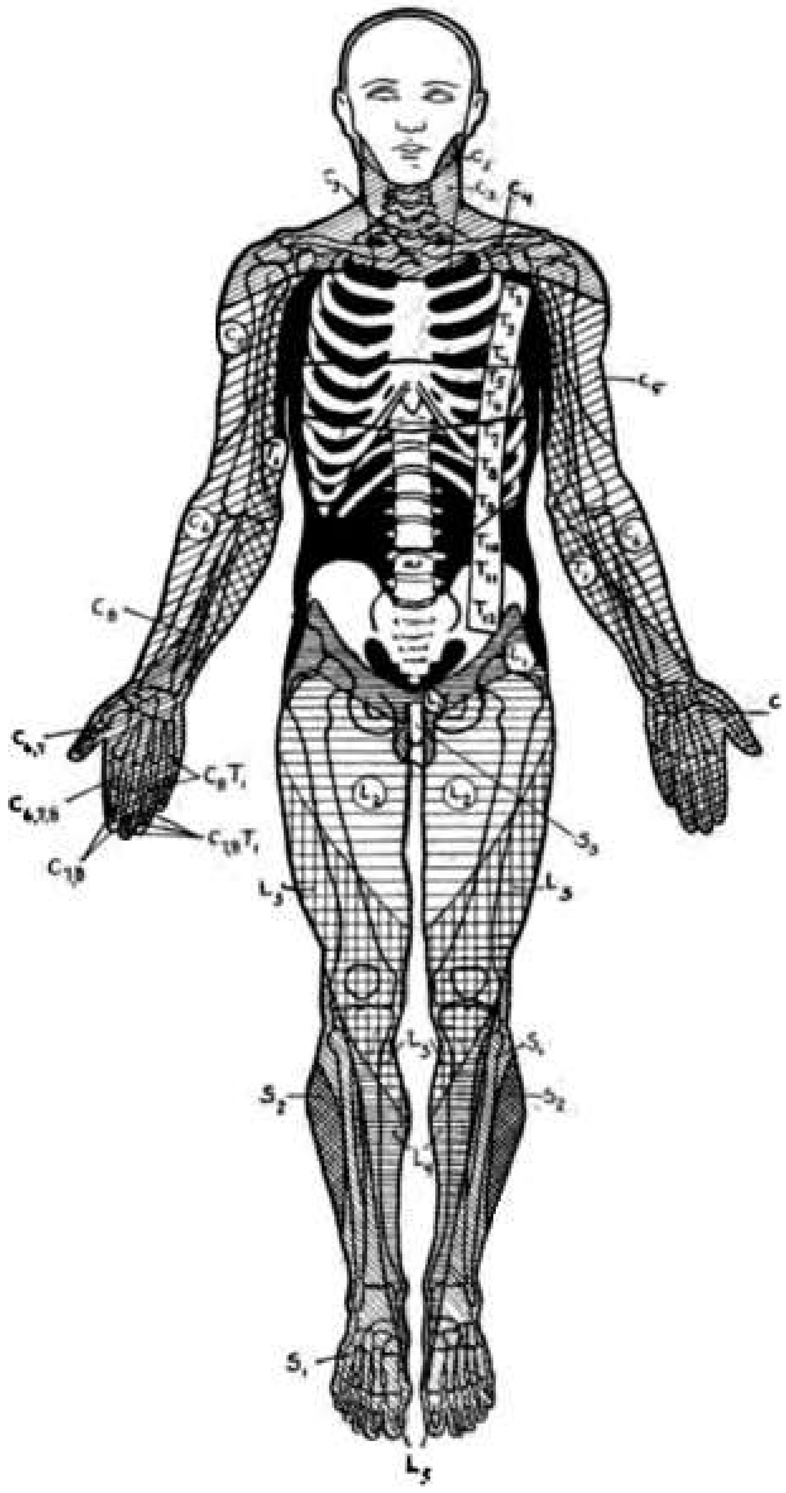

Figure 4. Illustrating the cutaneous sensory zones of the anterior surface of the body. The pilomotor nerves and sweat glands follow the cutaneous innervation; consequently, each segment indicates the area of altered sensation and the changes in the pilomotor muscles, and the sweat glands, which are affected when the innervation of the affected segment is disturbed. Compare with Fig. 5

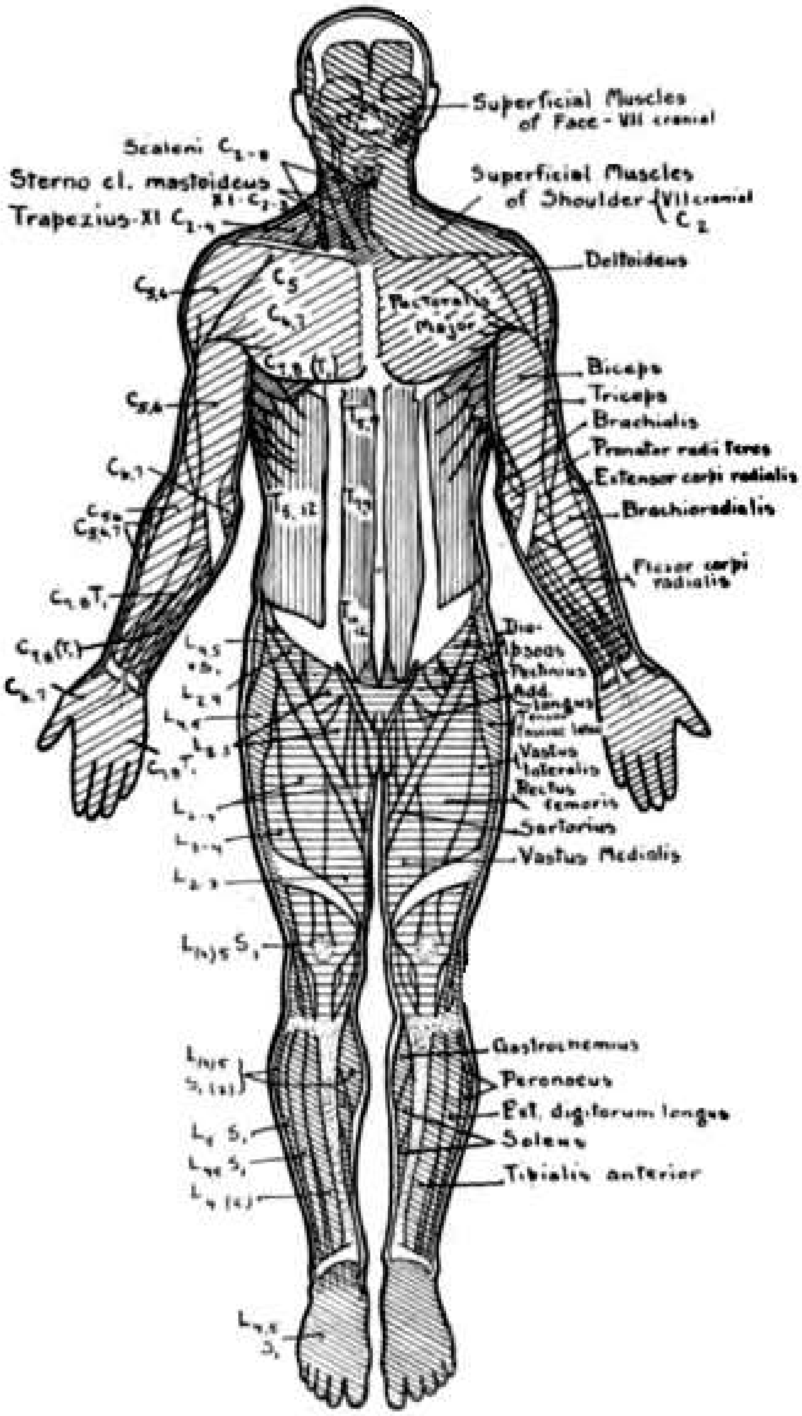

Figure 5. Illustrating the innervation of the muscles of the anterior of the body.it will be noted that the distribution of the motor nerves from the various segments does not coincide with the distribution of the cutaneous nerves, as shown in fig 4. Sensation is supplied to the muscles by sensory nerves which correspond in their origin with the motor nerves

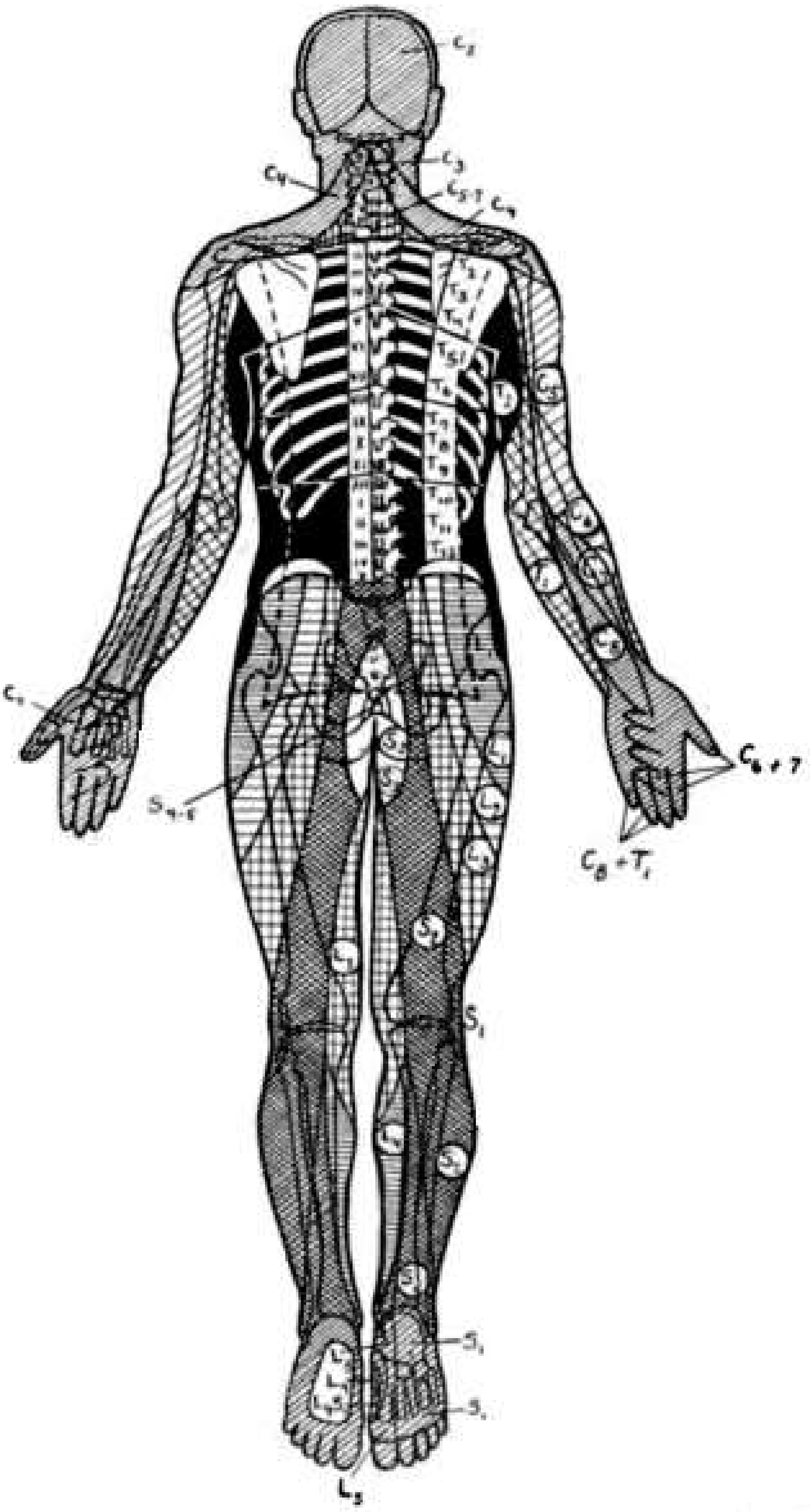

Figure 6. Illustrating the cutaneous sensory zones on the posterior of the body. The pilomotor nerves and sweat glands follow the cutaneous innervation; consequently, each segment represents the area of altered sensation and the changes in the pilomotor muscles and the sweat glands which are affected when the innervation of the affected segment is disturbed. Compare with Fig 7

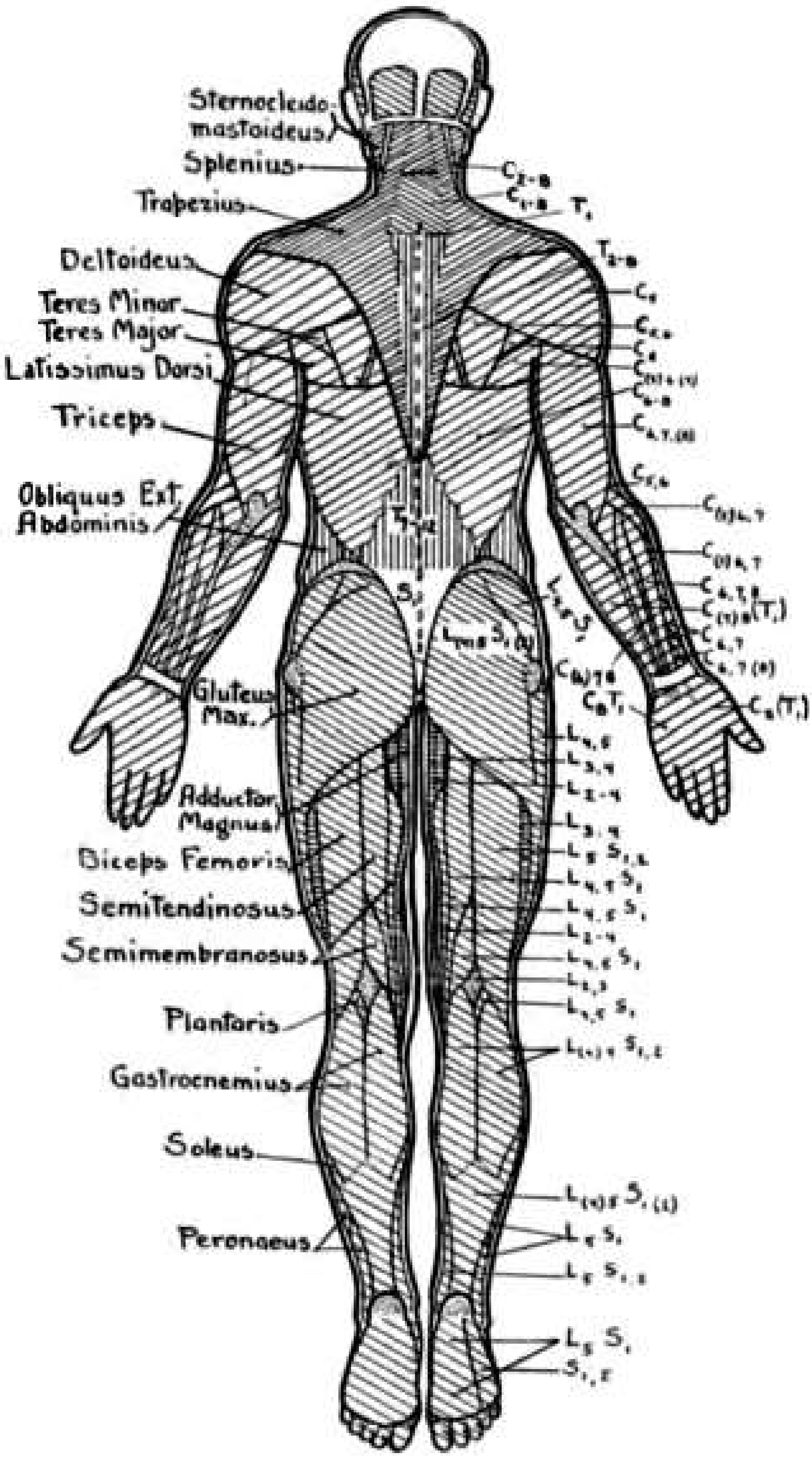

Figure 7. Illustrating of the muscles of the posterior of the body. It will be noted that the distribution of the motor nerves from the various segments does not coincide with the distribution of the cutaneous nerves, as shown in fig 6. Sensation is supplied to the muscles by sensory nerves which correspond in origin to their motor nerves

There is some variation in the segmentation of the muscles as compared with the skin, particularly in the extremities where the muscles have become somewhat displaced; and the sensory innervation of the muscle follows that of the muscle segments and not that of the skin. This affords a physiologic basis for a difference in location of hyperalgesia of the skin and of the muscles when certain viscera are involved in disease processes. The serial segmentation of the pilomotor muscles as well as that of the vasomotor control of the skin corresponds closely to the sensory segmentation of the skin. These segments may be studied from Fig. 6, in which Luciani has diagrammatically represented the results of Bolk's studies of cutaneous metamerism. This diagram shows the arms and legs in the position of their embryonic growth, and emphasizes the manner in which the innervation of the limbs followed their pushing away from the body.

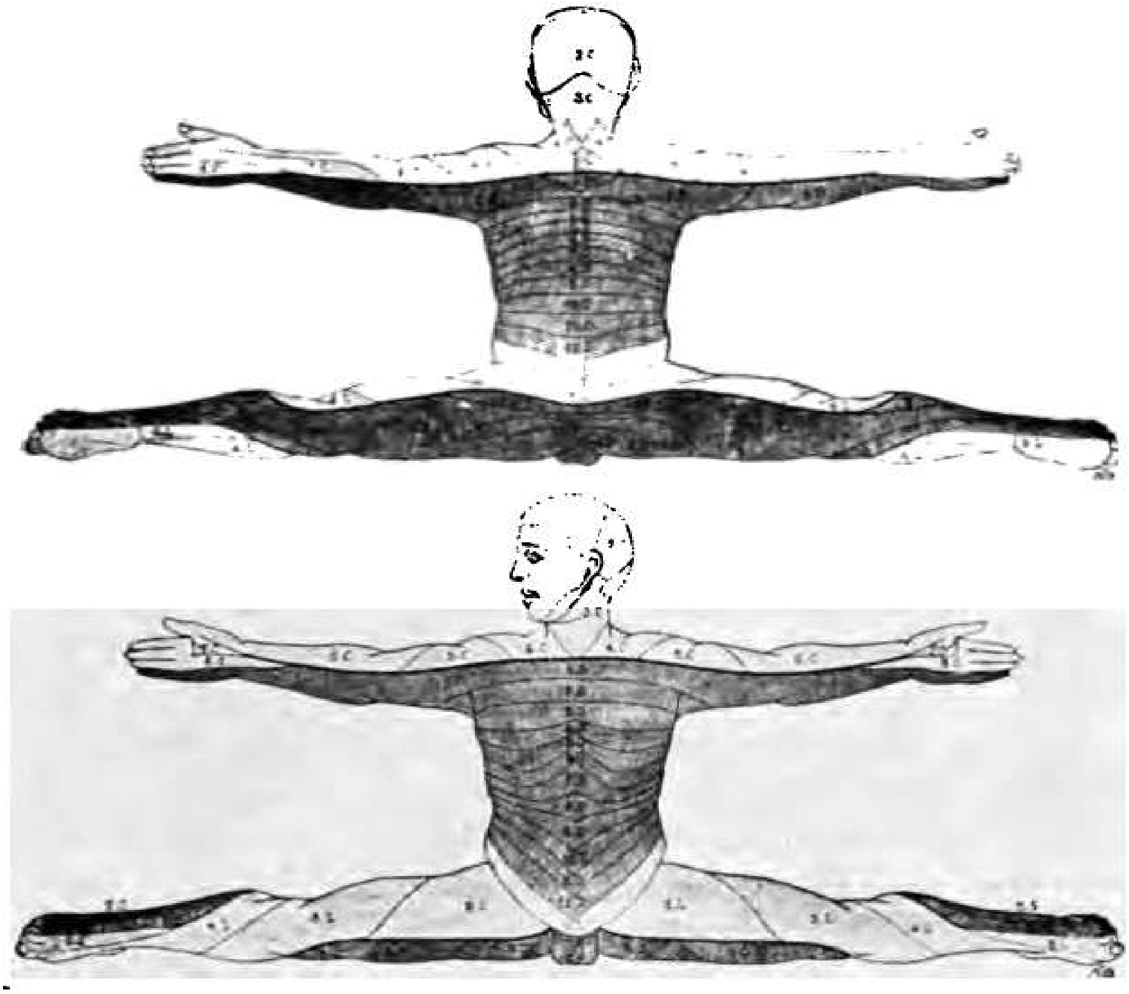

Figure 8. Diagrammatic representation of cutaneous regions of sensibility (after Bolk). Metameric distribution of transverse segmentation of cutaneous areas of sensibility of human body, drawn in the limbs in the position of their embryonic growth. The series of dermatomes which successively correspond to the cervical, thoracic lumbar and sacral roots is indicated by different degrees of shading. This figure is particularly valuable in showing how the sensory nerves extend from the body to the arms and legs and plainly shows the regularity of what, under ordinary circumstances, might seem to be gross irregularity of innervation.

The spinal segments between the 6th and 5th cervical and 1st dorsal anteriorly, and the 6th cervical and 1st dorsal posteriorly, are not represented in the median line of the body, these nerves having slipped out with the developing anterior extremity to supply it. Neither are the segments below the 1st lumbar anteriorly and the third lumbar posteriorly represented in the median line, for the nerves belonging to these segments have travelled out with the posterior extremity to innervate it.

This irregularity in body cutaneous segmentation accounts for sensory symptoms which are at times found in the arms and finger tips in pulmonary inflammation as mentioned on page 129; and which appear in the arm in angina ; and also occasionally in pleurisy, simulating the pain of cardiac origin.

It has been my observation that sensory disturbances in the neck, shoulders and arms, are common in chronic pulmonary tuberculosis, and that intestinal disturbances are sometimes accompanied by pains in the legs. In the presence of diseases in the lungs and intestines (particularly the lower portion) the cell bodies which give origin to the spinal nerves supplying the neck, shoulders and arms in the former, and the legs in the latter, sometimes become hypersensitive; and if states of toxemia appear, aching in the corresponding structures is prone to manifest itself.

It is necessary to understand the visceral relationship to the skin segments. This relationship can best he studied in the embryo before the organs migrate. Beginning from above downward, we find that there is a gradual migration of visceral structures but that they retain their nerve connection with the spinal segments through the sympathetic connector neurons. Prom the connection of the viscera with the spinal nerves through the connector neurones as shown in Fig, 7, we can judge of the original positions of the organ in the body thus:

The diaphragm arises from that portion of the gastrointestinal canal which is near the pharynx and maintains its principal connection with the cord through the phrenics arising from the 3rd and 4th or 5th and Vth cervical segments. The lungs are supplied with sympathetics arising from the 1st to 5th thoracic segments but are in reflex connection with structures which are innervated by the cervical segments of the cord. The pleura is supplied by the thoracic sympathetics 1st to 12th, the intercostals 1st to 12th, and the phrenics and causes reflexes from the sympathetics and intercostals in the thoracic sensory zones, and from the phrenics in the 3rd, 4th, and 5th cervical sensory zones. The heart arises immediately below and is in connection with the cord through the 1st to 5th or 6th thoracic segments and causes reflexes regularly down the inner aspect of the left arm and over the upper portion of the left chest.

The aorta is supplied by sympathetics arising largely from the upper four or five thoracic segments. The spleen is innervated by sympathetics arising from thoracic segments from the 3rd to the 10th of the body, and the liver in the right, but all apparently in the same segments.

The small intestines follow next in order with their connector fibers arising in the Vth to 9th thoracic segments, and reflecting strongest in the 5th and 9th segments. The small intestine is followed by the colon which reflects strongest in the lowest thoracic and 1st to 3rd lumbar segments, having its connection with the cord through the neurons arising from the lower thoracic and upper lumbar segments.

The kidney receives innervation from the lower thoracic and 1st lumbar segments but reflects strongest in the 11th and 12th thoracic and 1st lumbar segments.

The ovary, testicle, uterus, fallopian tubes, ureter and seminal vesicles are innervated by the 10th to 12th thoracic, and 1st to 4th lumbar segments.

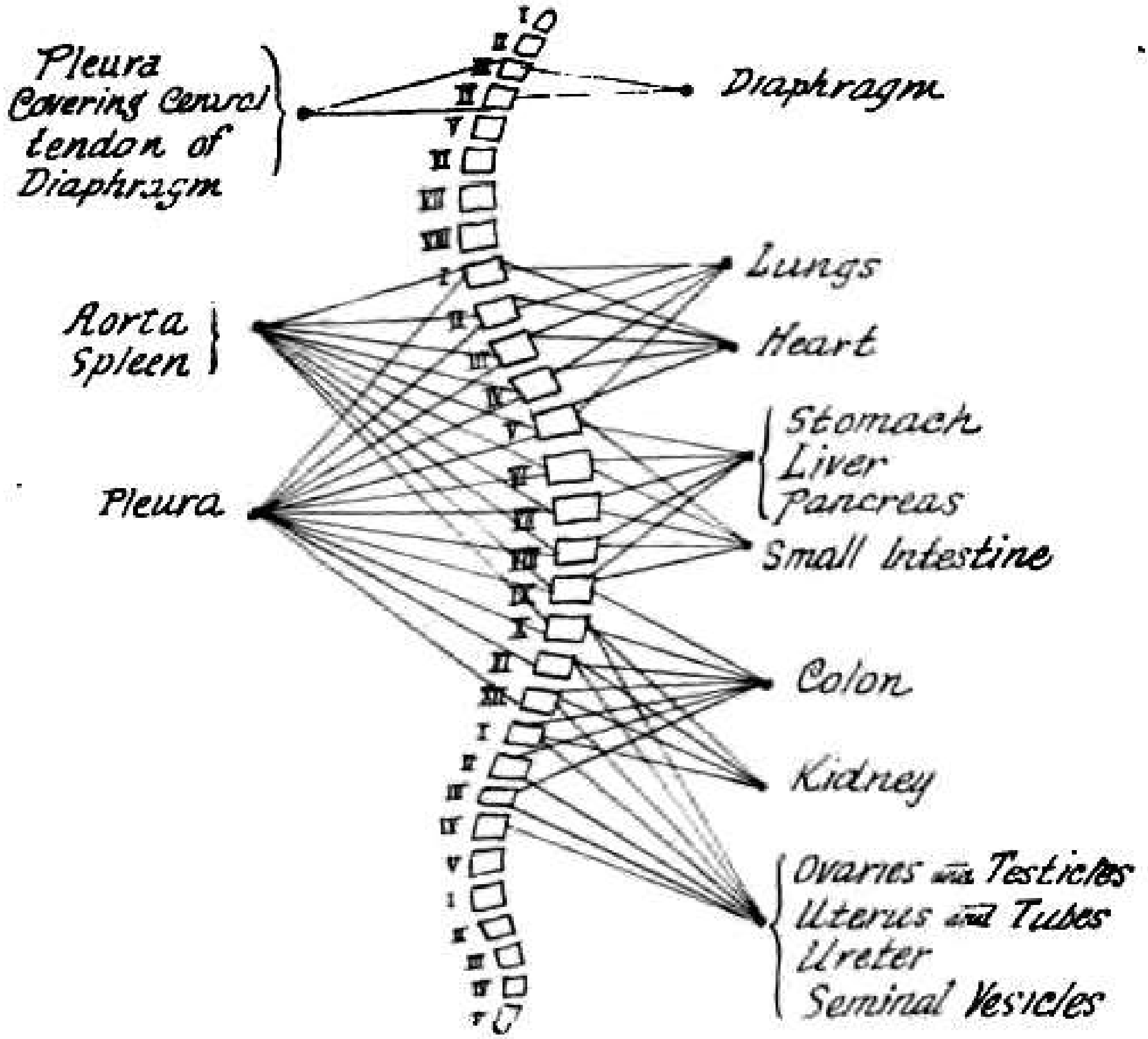

Figure 9. The connector neurons for the important thoracic, abdominal and pelvic viscera. In the figure the connecting neurons are those which belong to thoracicolumbar outflow, except those going to the diaphragm, which are spinal nerves (phrenics). The motor nerves to the viscera are found in various collateral ganglia. The figure shows that the innervation may be divided into various groups. The heart and lungs are innervated from practically the same segments: the upper 1st to the 6th thoracic. The stomach, liver and pancreas from the same segments: 5th to the 9th thoracic. The colon, kidneys and pelvis viscera from practically the same segments: 9th and 10th thoracic to the 3rd and 4th lumbar. In spite of this grouping of innervation, each organ is brought in reflex connection to efferent neurons, both motor and sensory, which are more or less definite, in such a way the sensory and motor reflexes do not overlap as much as might be indicated. This is illustrated in Part two.

Chapter V

Viscerogenic Reflex

We now come to one of the most important subjects in our discussion, — the "viscerogenic reflex." No observing clinician can fail to note the importance of this as a factor in the production of symptoms of disease. As clinical observation develops and becomes more accurate, the interdependence of organs is emphasized. No organ is free from the influence of other organs, and every organ influences other organs and structures. The property of viscera to influence other viscera, and in turn to be influenced by them, lies at the basis of physiologic control. This same property under the stimulus of diseased conditions lies at the bottom of one of our most important groups of symptoms, the group which results from reflex action.

The burden of the study before us is the visceral reflex, the reflex which arises in some tissue or organ and expresses itself in the same or in some other tissue or organ. These reflexes are expressed through nerves which are spoken of as visceral nerves, but which are more properly called vegetative nerves, meaning nerves which preside over the vegetative functions, or those functions without which life cannot exist. They are also called involuntary in contradistinction to the voluntary nerves which innervate the skeletal or somatic structures.

Definition of Terms

While an entire section of this monograph, Part III, is devoted to a discussion of the visceral or vegetative nervous system, yet I deem it wise to briefly define the terms used at this point, so that those who do not care to study the more technical subject may still understand my meaning. This is all the more necessary because of the multiplication of terms used to designate the same structures by different writers as described in chapter XXIX.

I shall employ the term *vegetative nervous system* to designate those nerves which supply the smooth muscles, the heart and the secretory glands of the body. This term will be used to comprise all nerves which do not belong to the voluntary system. The vegetative system supplies all structures which carry on those acts such as breathing, digestion and the circulation of the blood, without which the animal cannot exist. Every bit of unstriated muscle and every secreting gland of the body is under the control of this system of nerves.

The vegetative nervous system is made up of two separate components, one of which takes its origin from the thoracic and upper lumbar segments of the cord, called the sympathetic system; the other arising from two widely separated segments of the central nervous system, the midbrain and medulla on the one hand and the sacral segments of the cord on the other, called by various names, but which I shall call throughout this work the parasympathetic system, Plates I and VII, pages 40 and 204.

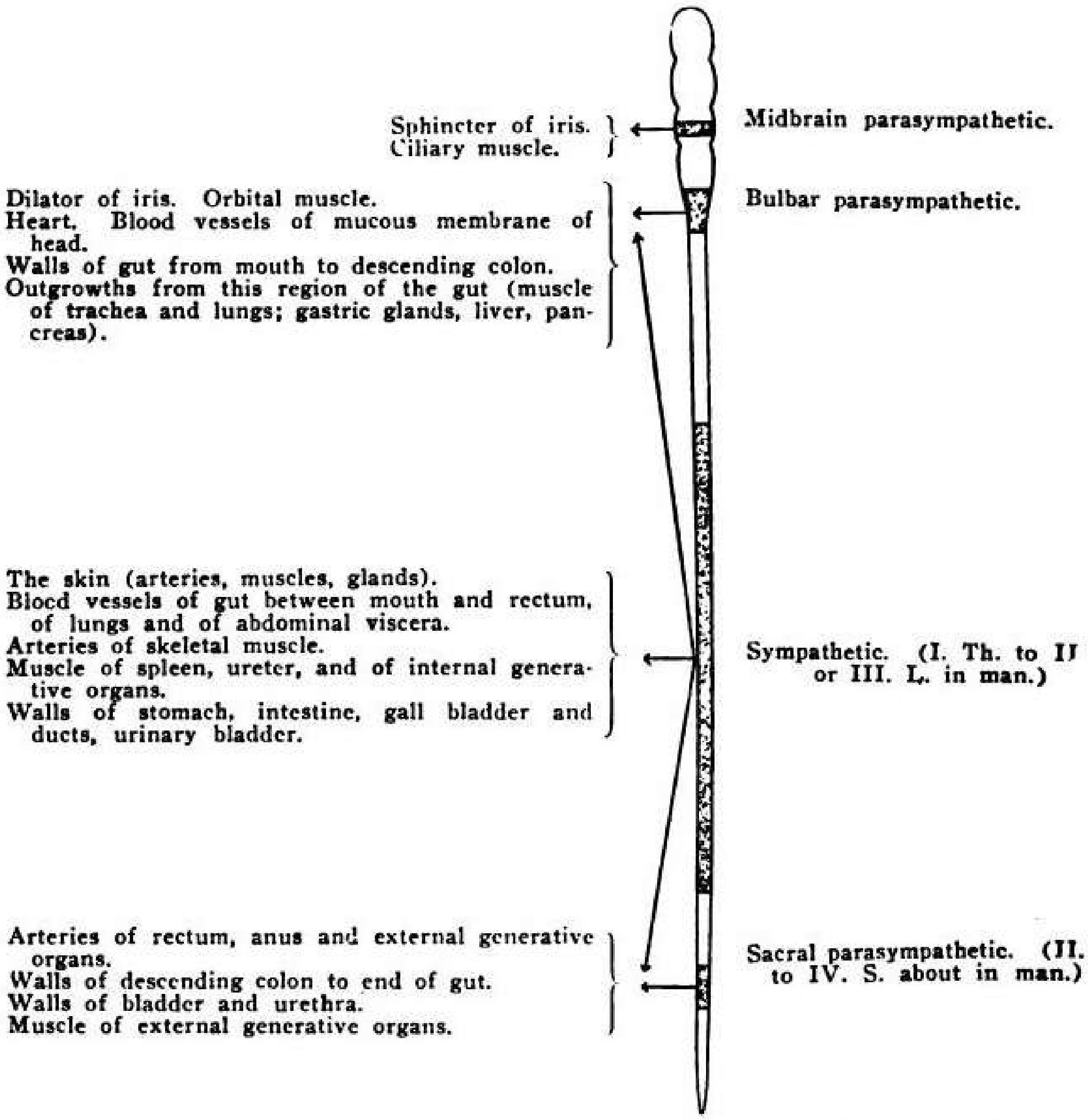

Figure 10.Diagram to show general and distribution of the efferent vegetative fibres. By "muscle" is, of course, meant unstriated muscle only. By the "walls" of a structure is meant all the unstriated muscle in it. The innervation in some cases is still a matter of controversy (gastric glands, liver, and pancreas; vessels of lung; small arteries of the skeletal muscles and arteries of the central nervous system) (Langley). Since this figure was drawn, the controversy on most of these structures has been fairly definitely settled, as will appear in the text

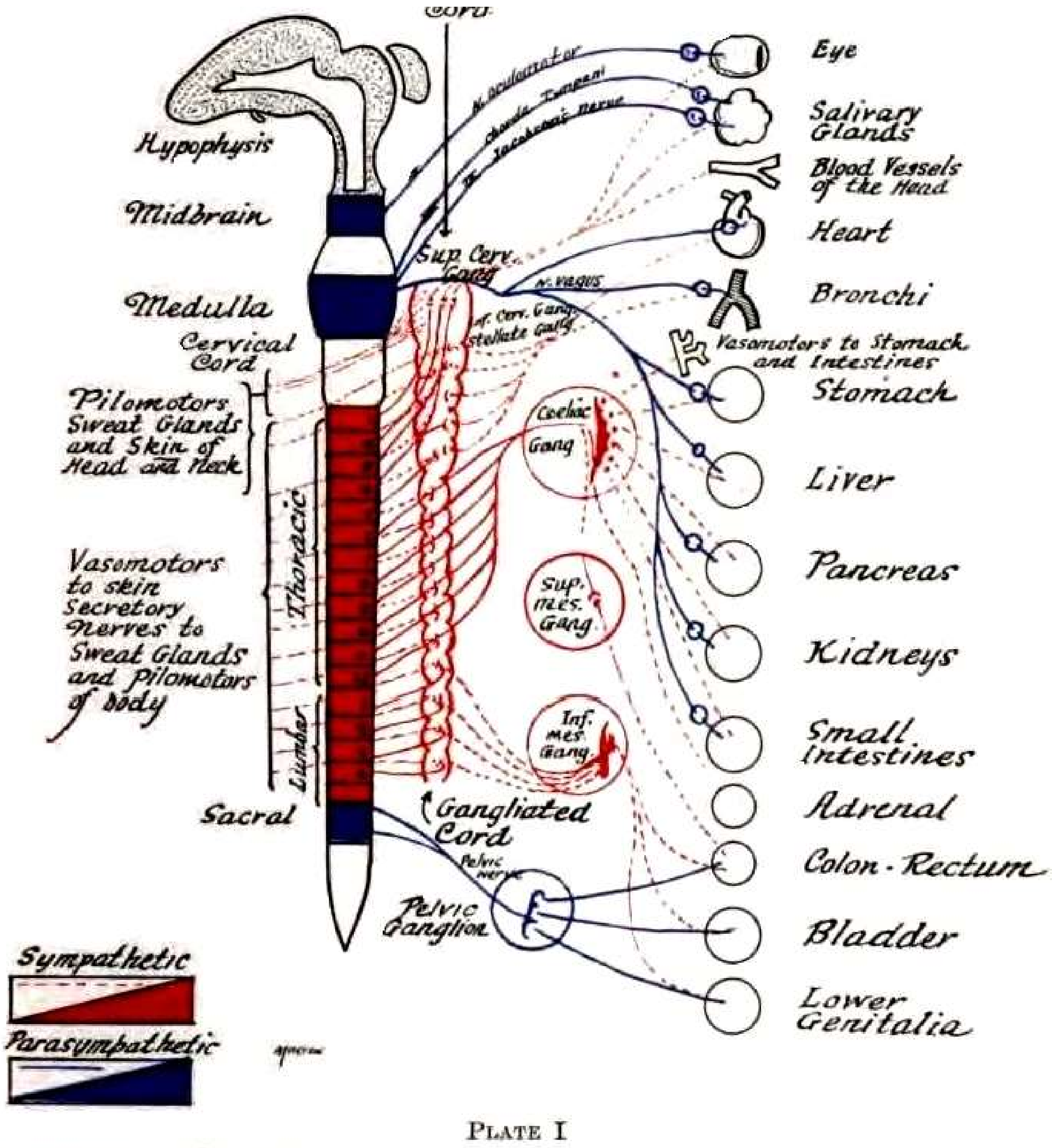

Figure 11. Plate I. Schematic illustration of the distribution of the two components of the vegetative nervous system, showing its divisions into the sympathetic and parasympathetic and their branches to the various organs. The thoracicolumbar portion of the cord, which gives origin to the sympathetic nervous system, is represented in red. The portions of the midbrain and the medulla, and sacral segments of the cord, which give rise to the parasympathetics are represented in solid blue lines, while those representing the sympathetics are shown as red lines. This chart shows the double innervation of the head, heart and entire enteral system and likewise shows single innervation of the blood vessels. Pilomotor muscles and sweat glands of the body

A study of Plate I (Fig. 11) will acquaint the reader with the principle structures supplied by the vegetative nerves. That portion of the central nervous system which is represented in blue, including the solid blue lines running from it, represents the parasympathetic system; that portion of the central nervous system which is indicated in red, represents the thoracicolumbar portion of the cord, from which areas the sympathetic fibers, which arc indicated in the illustration by red lines, take their origin. This plate shows the double innervation of the structures of the head, the heart, and all of the organs of the enteral system. It also indicates the single innervation of the pilomotor muscles and the sweat glands.

A wrong conception might be obtained from the fact that both sympathetic and parasympathetic fibers are indicated as going to the blood vessels of the head. This is only true of part of them. The remaining portion of the blood vessels of the body with possibly a few exceptions are innervated only by the sympathetics.

Figure 11 from Langley shows the relationship between the midbrain, medulla and cord and the unstriated muscle of the various parts of the body.

Two Distinct Groups of Visceral Reflexes

Some structures are innervated by one of these systems alone. Such is the ca.se with the pilomotor muscles, sweat glands, most of the blood vessels, many of the genitourinary structures, the ciliary body, and possibly the cardiac end of the stomach and the oesophagus. Other structures receive fibers from both divisions. This is particularly true of those structures which make up the enteral system, — the gastrointestinal tract and those organs developmentally derived from it, such as the respiratory system, liver, gall bladder, pancreas and body of the bladder; also certain portions of the eye and other structures about the head. Where the same structure receives both sympathetic and parasympathetic fibers, they oppose each other, one activating and the other inhibiting action. In other structures both activating and inhibiting fibers are found in the same system as described in Chapter XXX.

From clinical observation it is evident that there are two definite groups of visceral symptoms, the same as there are two definite groups of visceral nerves. It is further evident that reflexes occur between the sympathetics and spinal nerves, not only in the segment of the cord which receives the afferent, sensory impulse from the viscus, but also in segments removed, the cell bodies receiving the impulse and those causing the reflex action being connected cither by collateral branches of the sensory fibre or by intercalated neurons. The same connections are found in the divisions of the parasympathetic system; afferent sensory neurons which receive impulses joining with efferent neurons to cause reflex action. This connection is particularly close between the sensory neurons of the vagus and the motor neurons of the various branches of the same nerve. We also see it between the sensory fibers of the Vth cranial nerve and the vagus, as shown by asthma resulting from procure in the nose. We also assume it to exist between the pelvic nerve and the vagus as shown in the character of digestive disturbances which sometimes occur, when the rectal tissues and thn.se structures belonging to the urogenital system which are supplied by the pelvic nerve are inflamed.

An important physiologic fact with reference to visceral innervation may be inferred by studying the viscerogenic reflexes, particularly those arising in the lungs. It will be noted that the reflex muscle spasm which is indicative of acute pulmonary inflammation, Fig. 35, p. 184, likewise, the reflex trophic changes which are indicative of old or chronic pulmonary inflammation, see Pig. 38, p. 190; may be present either anteriorly or posteriorly without being present both anteriorly and posteriorly. It is further evident that when the changes in the pulmonary tissue involve the anterior portion of the lung, the reflexes are expressed at least for the most part in the anterior muscles of the shoulder girdle and in the subcutaneous tissue and skin over the anterior surface of the neck and chest above the second rib; and, when the changes are in the posterior portion of the lung, the reflexes arc expressed in the posterior muscles of the shoulder girdle and the subcutaneous tissue and skin over the posterior portion of the neck and shoulders above the spine of the scapula.

Prom this clinical observation we infer that the sympathetic sensory nerves which carry impulses from the anterior portion of the lung, mediate with spinal nerves which supply the anterior surface of the chest; and that those which carry impulses from the posterior portion, mediate with spinal nerves which supply the posterior surface of the chest. The question naturally arises; are we further justified in assuming that the same differentiation in innervation obtains generally for the different viscera? It does for the pleura and peritoneum without doubt.

If such is the ease, anterior and posterior reflexes are produced by different afferent components and are more or less independent.

The importance of the intercalated neuron cannot be overestimated. It is, in fact, the one great nerve factor which makes the difference between the higher vertebrates and lower invertebrates. It is that which leads to integration of action and brings the entire physical being into a unity of action. It is natural as a developmental necessity that the various parts of the physiologic system should be connected by these intercalated neurons so as to integrate their action. The scheme of nerve control seems to require a more or less close connection, and clinical observation demonstrates its existence. These intercalated neurons are illustrated in Figs. & and 10, pages 60 and 62.

Conditions Underlying Visceral Reflexes

It can be seen, then, that the number of reflexes which may originate in the various viscera is almost unlimited. In practice, however, while the number is somewhat confusing, those which are most evident can often be analyzed with comparative ease.

For the guidance of those who are not accustomed to think in terms of visceral neurology, it is necessary to emphasize one very important fact, viz. : An impulse may be started which, if it completes its action, will result in a given action in muscles; or an increase or decrease in glandular secretion ; or in pain : yet, such a result may not occur because the impulse is not adequate to overcome the resistance in the nerve cells involved in the reflex ; or to put it in another common phrase in nerve physiology, the strength of the impulse is not sufficient to overcome the resistance in the synapse, and as a result the stimulation does not pass over to the activating component of the reflex. *Because certain sensory impulses are traveling centralward is no guarantee that they are sufficiently strong to overcome the resistance between afferent and efferent neurons and result in reflex action*. They may; and, again, they may not. One cannot understand the variability of reflex symptoms unless he understands this fact. Stimuli have a tendency to produce certain reflex acts, but may not be adequate and so the reflex may not be apparent.

Simple and Complex Reflexes

Many neurons may take part in a reflex. A sensory impulse may start on the body surface or in the viscera. In order to reach the sensory area in the cortex, so that the individual may become aware of the action of the stimulus, it passes through one neuron whose cells end in the ganglion of the posterior root; a second from the nuclei in the posterior column to the subcortical centre in the thalamus; and a third, which arises in the thalamus and ends in the cerebral cortex. To complete this reflex act, the stimulus must be conveyed from the sensory to the motor nerve center. A neuron then extends from the motor cortical center in the brain to motor nuclei of cranial or spinal nerves where the impulse is transferred to the cells of the activating efferent motor neuron. Other neurons may be inserted and make the reflex still more complicated.

Many stimuli are not sufficiently strong to force the synapses between all of the neurons in the path between the end organ and the cortex. These may result in reflex action without the subject being aware of the stimulus, the transfer to the motor or sensory neurons taking place in the subcortical areas such as the thalamus, or even in the segment or segments near to the one receiving the afferent impulse.

Other reflexes are liberated by means of reflex collaterals. The patella reflex is an example of this. By stroking the tendon of the quadriceps muscle below the patella when the knee is dependent, sensory stimuli pass to the spinal cord by way of the spinal ganglia. On entering the cord the sensory fibers divide into ascending and descending branches which ultimately end in the grey matter of the cord. The ascending branch ends within nuclei of the posterior column. The entering sensory fibers before dividing, also the ascending branches of the same, give off collateral branches to the motor cells in the anterior horn which convey the impulse through the motor neurons and cause the contraction of the muscle.

In other instances, other neurons are intercalated between the afferent sensory neuron and the efferent motor neuron within the substance of the cord. In this manner impulses may be transmitted to segments at quite a distance from the segment which receives them. This is the character of the visceral reflexes from the lung. The impulses travel from the inflamed lung through the afferent sensory neurons of the upper six thoracic segments, but express their motor and sensory action in the cervical spinal nerves whose segments are far above them. These fibers which connect the sensory afferent and motor efferent neurons within the cord, are called association fibers or intercalated neurons as mentioned above. Functionally they are only connector neurons.

In those acts which result from sensory impulses reaching the cerebral cortex, the paths of transfer from the sensory areas to the motor areas are very complex. These are well described by Tilney.

Synapses may take place with commissural fibers which transfer impulses to the opposite side of the cord. This, however, is not illustrated in the figure.

The basis of reflex symptoms is the sensory neurons. Every important organ contains sensory nerve fibers, which carry impulses toward the higher centres usually found in the cord or medulla, which are then transferred to other cells, motor in character, to complete a reflex action. Some of the internal viscera are supplied by only one division of the vegetative system, others by both. An organ supplied by one system will have reflex connection only through that one; while another, supplied by both will have a double source of reflexes. In a few instances, such as the pleura, a third set of reflexes may arise through the spinal nerves. A reflex, according to physiology, must be produced by an impulse traveling centralward over a sensory neuron where it is transferred to an efferent motor neuron. Therefore, a true sensory reflex or a trophic reflex produced through efferent sensory neurons cannot exist. Such pain and such trophic disturbances as result from afferent stimuli being transferred to efferent sensory neurons must be caused by transference of the stimuli occurring in some other manner. A stimulus arising in the viscera travels centralward over neurons which are of much lower sensibility than the sensory cerebrospinal nerves. Head assumes that this visceral stimulus is transferred peripheralward over the neuron of greater sensibility which is the cerebrospinal nerve. See Head's law, page 85. Mackenzie suggests that the afferent stimuli which result in pain cause irritability of the neighbouring sensory cells in the cord which causes them to be affected by the afferent impulse more readily. For this reason, pain arising in the viscera is referred to the surface of the body and called "referred pain." In this work, therefore, I shall use the term "sensory reflex" as a clinical convenience, not as a physiologic fact. Likewise I shall speak of the "trophic reflex" over the sensory neurons with the same understanding.

Different types of reflex paths are shown in Figs. 12 and 13.

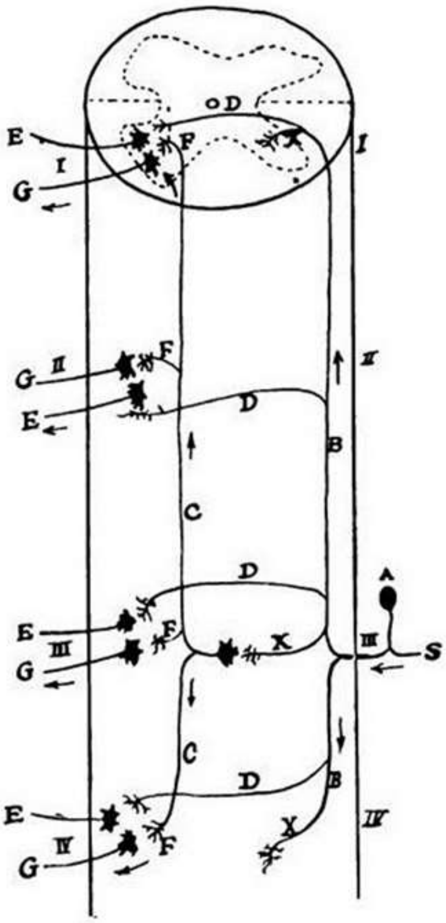

Figure 12. Schematic showing the paths through which intrasegmental and intersegmental reflexes are produced. The impulses are transmitted to the posterior root ganglion A over sensory fibre S. From the ganglion A, root fibres B enter the cord which divide into ascending and descending branches. From these branches collaterals are given off which are transferred to the grey matter in the anterior horn which form synapses with motor nerves E to produce reflexes. Such reflexes occurring the segment of the cord into which the root fibres enter, as indicated in segment III, are called intrasegmental reflexes. Those occurring in segments I, II and IV are intersegmental reflexes. Other collaterals X are given off from the posterior root fibres which form synapses with association fibres C, which also divide into ascending and descending branches and give off collateral F, which form synapses with the anterior horn grey matter with motor neurons G to produce intersegmental reflexes

In Fig. 13 the afferent impulse coming from the skin is conducted over a sensory neuron *2 t*o a nucleus in the posterior root ganglion (nucl. funic, post.), thence to the cord; and then to another neuron *c* which ends in the thalamus; and then over a third to the cerebral cortex. The efferent neuron *e* conducts the impulse from the motor areas in the cortex to the cells in the anterior horn of the cord and transmits them to another motor neuron *3* which supplies a muscle. These paths are called *projection paths*.

A motor reflex may he produced by stimulation of the motor cells in the -same segment of the cord that receives the afferent impulse. Such a reflex might be called an intrasegmental reflex. The cardiac, gastric, and gall bladder motor reflexes are of this type.

Other motor reflexes may be produced by stimulation of cells in adjoining segments of the cord or in segments which are removed from the segment which receives the afferent sensory impulse. Such reflexes are called intersegmental reflexes. The pulmonary reflex is an example of this type.

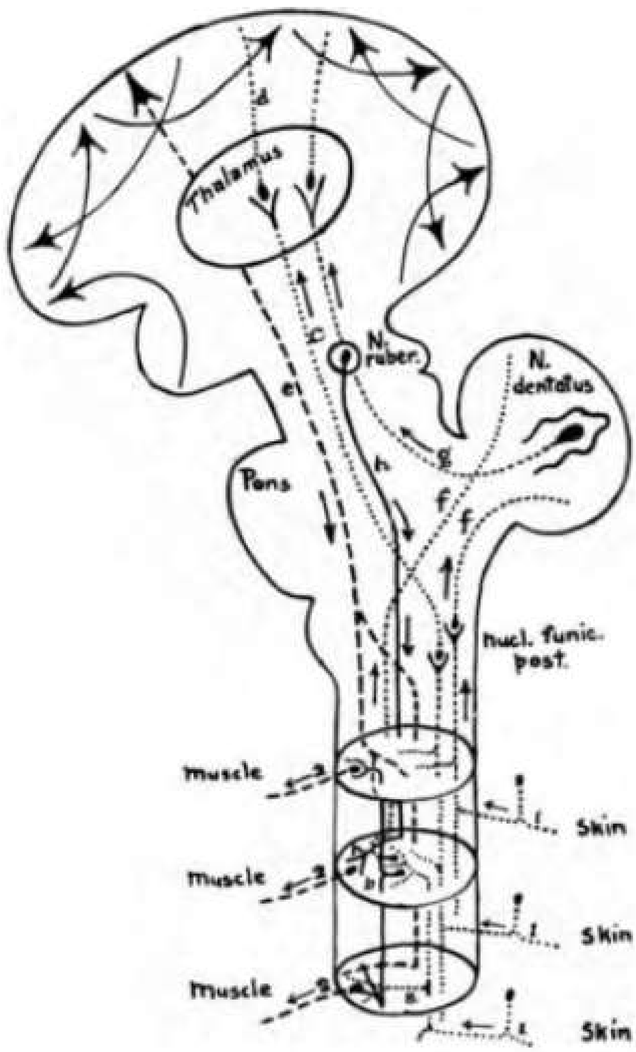

Figure 13. Schematic representation of the physiologically different conductions. Dotted lines - afferent tracts. Broken lines - efferent tracts. Solid lines – intercentral tracts. On entering the spinal cord, the sensory afferent fibres divide into ascending and descending branches. Before dividing into these branches the entering sensory fibre may give off a collateral branch which runs to and, ends in, the anterior horn. Similar collateral branches are given off from the ascending and descending primary branches, as shown in 'a'. By means of these collateral branches, impulses are transferred to the cells in the anterior horn whence they are conveyed by the motor fibres to the muscles to produce reflex action. Instead of reflex collaterals, intercalated neurons may transfer the impulse from the sensory to the motor tracts in higher or lower segments. Such an intercalated neuron is shown in 'b'. A third type of reflex may be produced by the impulse being conducted by the spinal cord to the medulla, and thence to the nucleus ruber where it is transferred to motor paths. This is shown in the illustration by the solid path 'h', running from the nucleus ruber to the motor neuron going to the muscles.

Fig. 13, page 46, illustrates both of these types of reflexes.

In the production of the intrasegmental and intersegmental reflexes the afferent and efferent impulses usually course in the same side of the cord. There are some other reflexes produced in which the impulse crosses from one side of the cord to the other. Such a reflex may be either intrasegmental or intersegmental. Examples of this are found at times in severe cases of angina in which the muscles of the right side are involved in the spasm as well as those of the left.

Relationship Between The Sensory and Motor Segments in the Central Nervous System

While the reflexes which occur between afferent sensory and efferent motor neurons may take place either in the same segments of the cord as they do in simple reflexes, or in segments which are separated as in complex reflexes; yet it is well for those particularly interested in the subject to know the relationship which may be found in the same segments; for reflexes from most organs are most apt to occur between sensory neurons entering and motor neurons leaving the same segment, as Sherrington- says:

(Sherrington: *The Integrative Action of the Nervous System*, New York, 1906. Chai.)

"Broadly speaking, the degree of reflex spinal intimacy between afferent and efferent spinal roots varies directly as their segmental proximity". Thus excitation of the central aide of a severed thoracic root, e. g., seventh, evokes with especial ease contraction of muscle or parts of muscles innervated by the corresponding motor roots, and next easily muscles innervated by the next adjacent motor roots. The spread of short spinal reflexes in many instances seems to be rather easier tailward than headward. This may be related with the oblique correlation that so largely holds between the distribution of the afferent root in the skin and the distribution of the efferent root in the underlying muscles.

"Taken generally*, for each afferent root there exists in immediate proximity to its own place of entrance in the cord (e. g., in its own segment) a reflex motor path of as low a threshold and of as high potency as any open to it anywhere.* Further, in response to excitation even approximately minimal in intensity a single afferent root, or a single filament of a single root, evokes a spinal discharge of centrifugal impulses through more than one efferent root, i.e., the discharge is plurisegmental. And this holds especially in the limb regions. In the limb region the nerve root is therefore a morphological aggregate of nerve-fibers, rather than a functionally determined assortment of impulse-paths. The view that the efferent spinal root is a functional assemblage of nerve-fibers is certainly erroneous. The formation of functional collections of nerve paths (peripheral nerve- trunks) out of morphological collections (nerve roots) seems to be the meaning of the limb-plexuses,"

While these laws hold for reflexes originating in most of the internal viscera, they do not apply to those arising in the lung. Afferent impulses originating in the lung return over sensory sympathetic neurons to the upper five or six thoracic segments of the cord, but mediate through intercalated neurons with sensory and motor spinal nerves arising from the cervical segments as described in Chapter XVI.

Another very important fact which should be understood in the study of reflexes is the relationship of the strength of the stimulus to the reflex response. A given stimulus produces a given reflex response. If the stimulus is increased it will not increase the response in the peripheral structures already affected but the increased strength of stimulus is shown in the fact that more efferent neurons are involved and so the response spreads to adjacent tissues. This is illustrated by cardiac pain which ordinarily is confined to the inner aspect of the left arm and upper left chest, but when the stimulus is very severe the response may cross to the right side of the body or be reflected up into the neck, or, more rarely, downward in the adjoining segments of the cord.

Fig. 10 represents schematically segments in the central nervous system with the organs and tissues which take their sensory and motor innervation from them. Arranged as they are, the sensory on one side of the figure, and the motor on the other, their close relationship can readily be grasped,

The Relation Between the Viscerogenic Reflex and Visceral Inflammation

The manner in which reflexes arise is worthy of consideration. What is there in an inflammatory process which produces a stimulation of the nerve endings so as to result in reflex action? The answer to this is probably supplied by a study of the parenteral digestion of protein.

Parenteral digestion of foreign protein is accomplished as a result of the activity of the body cells; so is the elaboration of the patient's own tissues which are broken down by inflammatory processes. These actions set free products which act upon the nervous system; and, if present in sufficient quantities and surrounded by proper conditions, may produce increased action either in the sympathetic or parasympathetic nerves, or in both.

In inflammations of internal viscera, we have the same process except that we are dealing with homologous protein; and, if the inflammation is infectious, with both foreign and homologous protein. The breaking down of either native or foreign protein, however, is a matter of splitting up of the more complex protein molecules into less complex substances. The effect of cleavage of the protein of the patient's own tissues is also expressed upon the vegetative nervous system, although we assume that there is an absence of the necessity of the protective phenomena of sensitization which is so evident in cleavage of foreign protein. If the cleavage of either foreign or homologous protein is rapid, the toxic molecules are liberated continuously and, if in large amounts, produce the syndrome of toxemia.

Again, as a result of the chemical action, products are formed which irritate the nerve endings in the inflamed parts; and these, probably, in conjunction with other stimulating agencies such as heat and pressure, cause peripheral irritation of the fibers of the vegetative nervous system. The result of this stimulation is shown in reflexes through both the sympathetic and parasympathetic systems.

Those through the sympathetic are commonly expressed in sensory, motor, and trophic disturbances in the skin, subcutaneous tissue, and muscles of those areas of the body surface which arc in segmental relationship with the afferent impulses carried by the sympathetic fibers to the cord. Those of the parasympathetics show commonly in other viscera and tissues supplied by the vagus, pelvis, and certain cranial nerves.

This may be illustrated by inflammation in the lung, which shows reflex sensory, motor, and trophic changes in the skin, subcutaneous tissue, and muscles which receive their innervation from the cervical segments of the cord, because the afferent impulses from the inflamed pulmonary tissue are carried by the sympathetic fibers to the posterior root ganglia of the upper thoracic spinal nerves, and then transmitted through intercalated neurons to this portion of the cord and there reflected through the cervical spinal nerves. The vagus reflexes, on the other hand, show in cough, disturbed innervation of the larynx through both superior and inferior laryngeal nerves; slowing of the pulse which is often quite evident, and commonly some increased secretion and increased motor irritation of the gastrointestinal canal, spastic constipation being particularly common, and nausea and vomiting being frequently met during the acute inflammation accompanying cavity formation. Headache and other sensory reflexes may also be present through mediation with the sensory neurons of the Vth cranial nerve. Other reflexes through cranial nerves, particularly the Vth, VIIth, IXth, XIth, and XIIth, are shown in the table on page 182.

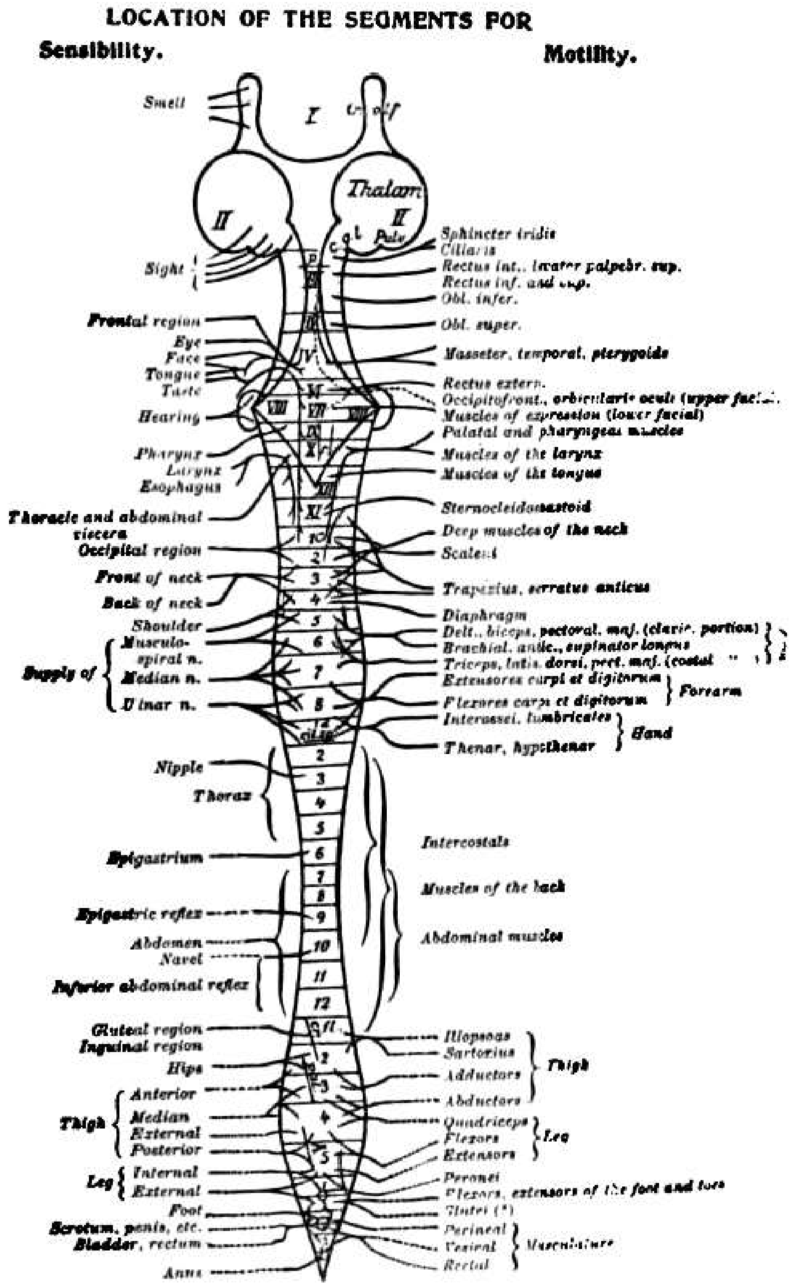

Figure 14. Diagrammatic representation of the nervous system and the tissues supplied by the sensory and the motor systems from each area or segment of the same. On the left of the figure are arranged the nerves of sensation; on the right the motor nerves. [tr. olf. – olfactory tract; c.g.l. – lateral geniculate body; c.r.cr.pat.A – represent approximate locations of the reflex centres of the pupillary (p), the respiratory (r), cremasteric (cr), patellar (pat), and tendino Achilles (A) reflexes] (Jakob)

Chapter VI

Reflexes Whose Afferent Impulses Course in the Sympathetic Nerves

Distribution of Sympathetic Nerves

Every organ and tissue of the body is supplied by sympathetic nerves. (See Chapter XXXI.) These course (1) in the blood vessels, and by their action as vasoconstrictors and vasodilators, influence the most minute body structures; (2) they supply many structures alone, to which as far as we know there are no parasympathetic fibers, such as many of the blood vessels, sweat glands, pilomotor muscles, and most of the urogenital structures; (3) they activate certain structures in which the parasympathetics furnish the inhibiting fibers such as the heart, sphincters of the gut and bladder and trigone of the bladder; and (4) they supply inhibitory fibers, which antagonize the activating parasympathetics to other tissues such as the pupil, the lachrymal and salivary glands, the structures o£ the head, and the enteral system.

Sensory sympathetic fibers are found along with the motor sympathetic fibers in all structures, and when irritated carry impulses centralward where they are transferred to other neurons through which, if the stimuli are sufficiently -strong, they disturb normal physiologic equilibrium in other structures producing symptoms and signs of disease. Many of these disturbances are produced in the skeletal structures, skin, subcutaneous tissue and muscles. Every important organ may generate stimuli which, if sufficiently strong, result in reflex action in the skeletal structures which stand in reflex relationship to it through the spinal nerves which supply them.

Distribution of Sympathetic Reflexes

Sympathetic reflexes are of three kinds, motor, sensory, and trophic, and each of them plays an extremely important role in clinical symptomatology; a role which, though as yet not fully appreciated, will, as it becomes better understood, more and more assume diagnostic value.

While the connector fibers which activate the ganglia of the sympathetic system arise only from the thoracic and upper lumbar segments of the cord, sympathetic nerves are distributed through their control of the blood vessels and in many cases by direct innervation of the tissues, to every part of the body; and afferent stimuli coming from the tissues through sensory sympathetic neurons arc connected by other neurons in the cord with the cervical, lower lumbar and upper sacral segments; so that all of the structures which are supplied by spinal nerves are subject to reflex influences through sympathetic stimulation. This stimulation follows the segmentation of the body in an orderly manner as described in Chapter IV, according to the following law:

Every viscus receives its sympathetic connector fibers from certain segments of the cord and sends back its afferent stimuli to definite segments of the cord; and these stimuli complete the preponderating number of reflexes which arise from a given organ with definite neurons, in such a manner that a given organ, when inflamed, expresses its reflexes regularly in the same structures.

Some variations from this law will be met now and then; but the principle here laid down will hold for most of the reflexes met in clinical practice. The variations which occur also follow a law laid down by Sherrington which is quoted on page 64, viz.: "Excitation of the central side of a severed thoracic root, e. g., seventh, evokes with special ease contraction of muscles or parts of muscles innervated by the corresponding motor roots, and next easily muscles innervated by the next adjacent motor roots." This is well illustrated by the heart and lung reflexes, "While the heart as a rule expresses its reflexes in the 1st to 4th thoracic segments on the left side, the reflex may be met on the right side of the lung, or it may travel upward into the adjoining cervical segments of the cord or downward into lower adjoining thoracic segments. The lung reflex offers an exception to one of Sherrington's laws in that mediation of the reflex does not occur in the same segments of the cord that receive the impulses, the impulses being transferred by intercalated neurons from the upper dorsal segments which receive them from the periphery upward into the cervical portion of the cord) but it does follow the other portion of the law in that the reflex action always takes place most readily through the same efferent fibers. It reflects strongest, as a rule, in the 3rd, 4th and 5th cervical segments but may reflect in the adjoining segments either above or below.

The fact that reflexes are at times more widely spread in the tissues than at other times is explained according to the principle that the stimuli being stronger, the efferent impulses are transferred to more neurons, making the area of reflex response greater.

From physiologic facts we enunciate a second law: *Every important internal viscus is so connected in the central nervous system that it is able to produce reflexes through afferent sympathetic and efferent spinal nerves, with definite skeletal structures; and, if acutely inflamed, should show reflex and altered sensation, and if chronically inflamed, trophic changes. Therefore, spasm of muscles, altered cutaneous sensation and degeneration of muscles, subcutaneous tissue and skin, in areas having definite limited segmental innervation become important diagnostic phenomena.*

In the discussion of physiologic principles, I enter into the question of whether or not the sympathetic ganglia have the power of producing reflexes and show that there is a difference of opinion among physiologists (see page 327), so we are not in a position to say whether a sympathetic reflex may be carried from one viscus to another without the afferent impulse going to the cord. It is important that this point be definitely settled, but as yet we can only say it is uncertain. The weight of physiologic evidence, however, is against it. Clinical observation may produce data which will help to solve this question. This I suggested in a discussion of the question of exophthalmic goitre, where the cervical sympathetic glands have shown pathologic change. A determination of the priority of the relationship between the disease in the thyroid gland, the diseased sympathetic ganglia and the symptoms which develop in the structures supplied by the cervical ganglion cells, might aid in the solution of this most important question.

Not only must we conceive of afferent impulses traveling to the cord to connect with spinal nerves to express reflexes in the skeletal structures; but the reverse is equally true. There is a continuous stream of impulses received by the sensory spinal nerves which are transferred to the connector neurons of the sympathetic system and expressed as reflexes in the internal viscera. It is a common observation that blood pressure may vary according to the temperature of the surrounding atmosphere or other medium surrounding the individual; and also according to the degree of other physical stimulation which is applied to the sensory cutaneous nerves,

Nature of Sympathetic Reflexes

We shall now discuss separately the three reflexes of visceral origin which manifest themselves in the skeletal structures through impulses which reach the cord by way of the sympathetic nerves — (1) the "visceromotor reflex," (2) the "viscerosensory reflex," and (3) the "viscerotrophic reflex," remembering the "sensory" is only a clinical conception.

The medical profession owes a great debt of gratitude to Ross, Head, Mackenzie and Sherrington for their pioneer work in the study of visceral reflexes. Their labours have had much to do with the establishment of these clinical manifestations as signs of visceral disease. At this time I wish to exercise my deep personal obligation to these observers for the aid and inspiration that I have received from their works in explaining the motor and trophic reflexes from the lung,'- * kidney," and intestines," which have been described by me. Study of these reflexes and the underlying visceral nerve control leads to a wealth of observations which is not confined to the sympathetic and spinal nerves, but which applies also to the parasympathetics and cranial. This will appear as we proceed in our clinical discussion.

1, Visceromotor Reflex. The visceromotor reflex is the only true sympathetic reflex in skeletal tissues. (The viscerosensory and viscerotrophic, produced through efferent sensory nerves, are not real physiologic reflexes as will appear from the discussion.) It manifests itself in a contraction of skeletal muscles as a motor response to a sensory impulse coming from a viscus through the sensory fibers of the sympathetics. These muscular contractions have long been recognized in the abdominal muscles; the contractures in cases of appendicitis, gall bladder inflammation, peritonitis and gastric ulcer being particularly well known.

Aside from these there are others which are equally valuable as diagnostic signs. The spasm of the muscles over the right side of the abdomen when the ileum, cecum and ascending colon arc inflamed, and that of the muscles of the shoulder girdle and diaphragm when the pulmonary tissue is inflamed ; and the spasm of the lumbar muscles when the kidney is inflamed, while not 90 generally known are equally important in diagnosis. The visceromotor reflex for each important organ will be discussed in Part II. The motor centres of the cord are shown diagrammatically in Fig. 12.

It is characteristic of the contraction of the broad skeletal muscle in the visceromotor reflexes that the muscle as a whole does not necessarily contract. This is due to the peculiarities of the segmental relationship between the afferent sensory, sympathetic neuron from the viscus, and the efferent, motor neuron to the muscle. While a nerve which supplies a muscle may be made up of many fibers arising from many cells scattered through one or several segments of the cord, only part of those cells may be in reflex connection with the sensory cells which receive the impulse from the \-iscu8 and take part in the motor reflex.

On this point Mackenzie' says:

"Some years ago I pointed out that these muscles could be demonstrated to possess the power of contracting in small sections in response to visceral stimulation. Later I found that Sherrington had described the difference in the reaction to nerve stimulation between these flat muscles and the muscles of the limbs. The fibers that constitute the nerve supply of any given muscle leave the spinal cord in separate bundles. If one of these bundles be stimulated, the whole length of a limb muscle like the sartorius will contract. On the other hand, if one of the bundles that constitutes the nerve supply of one of the abdominal muscles be stimulated, only a portion of the fibers of the muscle will contract."

It can be seen then, that, physiologically, a portion of a muscle may respond by contracting, while the remaining portion remains relaxed. This is what we find clinically. In a visceromotor reflex only those fibers of a muscle contract which are innervated by filaments whose nerve cells mediate with the nutrient sensory cells of the afferent sympathetic fibers leading from the inflamed viscus. This may manifest itself in either a contraction of a given portion of several muscle bundles as shown in the rectus in gastric ulcer, or in the contraction of entire bundles of muscles as we see it is the sternocleidomastoideus and trapezius in pulmonary tuberculosis. As far as the muscles showing the motor reflex are concerned, we must remember that each afferent sensory neuron coming from a viscus has certain spinal motor neurons with which it enters into reflex action most easily according to Sherrington's law cited on page 46.

A visceromotor reflex may be of short duration, passing away after a few days, or it may remain for months as we see it in the muscles of the shoulder girdle in pulmonary tuberculosis, and in the lumbar muscles in tuberculosis of the kidney. When it persists for a long period the tissues involved degenerate. Thus the muscles which show spasm in early tuberculosis, show degeneration (viscerotrophic reflex) when the disease has become chronic. The long continued bombardment of nerve cells by harmful stimuli permanently impairs their function.

2. Viscerosensory Reflex. The "Viscerosensory" reflex is a convenient clinical conception but not a physiologic entity. What we term a viscerosensory reflex does not in any way involve a motor neuron, therefore cannot be the reflex. It is rather a sensation referred from a viscus to those skeletal areas which are innervated by sensory neurons whose nerve cells lie in the cord adjacent to those of the nerves supplying the viscus.

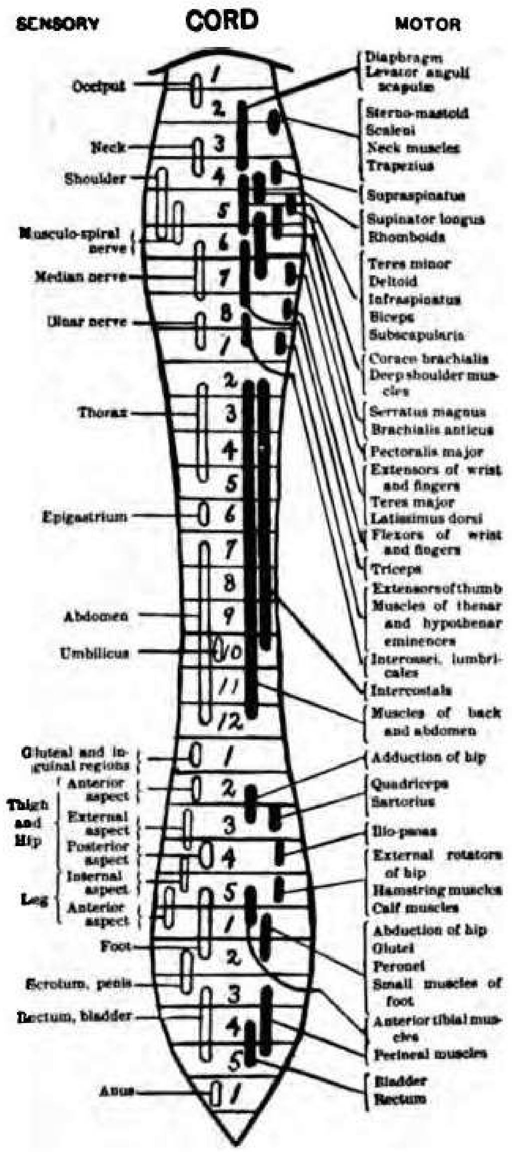

Figure 15. Diagrammatic representation of the spinal cord showing the important centres from which the sensory and motor fibres take their origin. [Jakob, Star, Sachs, Vana, Millia and Butler] Abrams. From this figure, one can observe the sensory and motor centres and gain information which will aid in correlating sensory and motor reflexes

The viscerosensory reflex is closely bound to the subject of pain, although it should include other changes in sensation. That portion of the organism which comes into direct contact with the outside world is well supplied with sensory nerves, the skin having the most, and the subcutaneous tissue and muscles having comparatively less. These nerves aid the organism in distinguishing different sensory stimuli, some of which are harmless, others pregnant with danger. They serve the purpose of informing the individual, through the higher centres, of the nature of or nearness of objects, also as to whether or not they are harmful. They are the outposts of defence. In the internal viscera the danger is lessened because of their protected situation; consequently the viscera are supplied with nerves of much lower sensibility which do not have the power to react to all forms of sensory stimuli, heat for example, Crile has discussed this very fully in his recent studies. Furthermore, the number of sensory fibers going to the viscera as compared with the number of motor fibers, is much smaller. According to Langley and Anderson, the hypogastric nerve contains 1 sensory, afferent fibre to 10 motor efferent; and the *nervus erigens* contains 1 sensory, afferent to 2 motor efferent.

Pain which is the most definite of sensory stimuli is wholly absent from some portions of visceral structures, as determined by methods which cause it in skeletal structures. Mackenzie' who has made careful observations on the conscious subjects under many circumstances, has shown:

1. That the deeper tissues of the external body wall are sensitive to pain but much less so than the skin.

2. That the viscera are insensitive to stimuli which produce pain in the external body wall, such as pinching and heat.

3. That the layer of loose connective tissue lying immediately outside the peritoneum is exquisitely sensitive to pain although the peritoneum is not.

4, That the tunica vaginalis is the only sensitive serous membrane covering an organ; and, that this sensitiveness is due to the fact that it is supplied by a cerebrospinal nerve, a twig of the genital branch of the genitocrural nerve which arises from the 1st lumbar segment.

In considering these observations, we must not forget that while pinching and tearing, which are unnatural stimuli, might not cause pain, distention of a hollow viscus, which is the natural stimulus, might cause it; so the last word on this subject may not yet be said.

One must also bear in mind that there is a marked difference between the nerve cell which receives impulses from a normal organ, and a nerve cell which receives impulses from an inflamed organ. Inflammation produces a hyperirritability, varying according to the degree of the stimuli coming from the inflamed organ; so while pinching and tearing of viscera might not produce pain under normal conditions, one can conceive of pain arising when the nerve cells are rendered hypersensitive by inflammation.

Head[10] recognizes three types of sensibility*, epicritic, protopathic, and deep*. He describes them as follows:

"I. *Deep sensibility*, capable of answering to pressure and to the movement of parts, and even capable of producing pain under the influence of excessive pressure, or when the joint is injured. The fibers, subserving this form of sensation, run mainly with the motor nerves, and are not destroyed by division of all the sensory nerves to the skin.

"II. *Protopathic sensibility*, capable of responding to painful cutaneous stimuli, and to the extremes of heat and cold. This is the great reflex system, producing a rapid widely diffused response, unaccompanied by any definite appreciation of the locality of the spot stimulated.

"III. *Epicritic sensibility*, by which we gain the power of cutaneous localization, of the discrimination of two points, and of the finer grades of temperature, called cool and warm," Adequate Stimulus. — One must always bear in mind the condition which is known as *adequate stimulus* when considering visceral reflexes. Stimuli are continuously passing centralward, from the viscera, which neither produce reflexes nor disturb the consciousness of the patient, because the stimuli are not adequate. Every reflex that is registered indicates that a stimulus adequate to carry the nerve force through all components of the reflex is present. This is discussed fully on page 161.

Variable Sensibility of Different Tissues. In order to account for the reflex pains which are expressed on the surface of the body when internal viscera are diseased, it is assumed that the continuous bombardment of sensory cell bodies in the cord produces in them a state of hyperirritability which is transferred to other sensory cells adjacent to them, thus producing in the cord on the part of many sensory cells a condition of increased excitability. The result of this is that stimuli which might even under ordinary circumstances be unrecognized either by consciousness or by a reflex act, produce pain or other expressions of altered sensibility in the sensory nerves arising from those sensory cell bodies in the cord which show increased irritability. There are certain structures in the internal viscera which are far more sensitive than others. The serous membranes in general are extremely sensitive when inflamed.

In the gastrointestinal tract, the stomach is much more sensitive than the intestines, while the sensibility in the rectum and anal orifice is much greater than that of any other part of the intestinal tract. The nasal and laryngeal structures arc the most sensitive of all portions of the respiratory tract. Of the genitourinary tract, the urethral canal, and particularly the prostatic or membranous portions, are the more sensitive. Excretory ducts in general are highly sensitive. Of the genital glands, the testicle and ovaries and their appendages are extremely sensitive. Luciani[12] in discussing the observations and experiments which have been made up to the present time on the sensibility of internal organs, sums up the results as follows:

“(a) Only the tissues provided with nerves are sensitive to pain stimuli: the epidermis, the horny tissues in general, the cartilages and fibro-cartilages are totally insensitive, because they have no nerves.

"(b) The organs, tissues, and internal membranes innervated by the sensory roots of the nerves of the cerebrospinal axis are more or less sensitive to painful stimulation.

“(c) The organs and internal tissues innervated exclusively by the nerve-fibers of the sympathetic system are little sensitive to pain stimuli under normal anatomical and functional conditions, but in a state of inflammation they may acquire an exquisite sensibility to pain.

"There are no exceptions or comments for the first proposition; the second and third, on the contrary, must be examined. The connective tissues, ligaments, tendons, and aponeuroses have, under normal conditions, an indefinite sensibility to pain. The periosteum is very painful, as shown on scraping the bones in certain surgical operations; but bone itself, particularly the compact substance, is insensitive, as proved in amputation without chloroform. The pain sensibility of bone-marrow under physiologic conditions is doubtful.

"The muscles in the normal state are but little sensitive to pain. During amputations without anaesthetics they give no pain. Strong compression gives rise to a specific dull pain; intense faradization is very painful. This sensitiveness to pain is not due to excitation of the cutaneous nerves, because Duchenne observed it with direct electrical stimulation of the pectoralis major muscle exposed during excision of the breast. The feeling of muscular fatigue presents every gradation from a simple sense of heaviness to acute pain, which may last 24 to 48 hours, and is accentuated on the slightest pressure. But in this case the state of the muscle is evidently altered, owing probably to the accumulation of fatigue products, which act as an irritant poison. Similar abnormal conditions underlie the muscular and articular pains of a rheumatic and gouty character. On the other hand, the sharp pain that accompanies the cramp caused by violent and involuntary contracture of the muscles is transitory. It has been attributed to the compression of the cutaneous sensory nerves that traverse the muscles, but this is a fallacy, because in that case, in accordance with the law of peripheral projection, the pain would be perceived in the skin and not in the contractured muscle.

"Serous membranes in general, as the peritoneum, pleura, cerebral and spinal dura mater, and the synovium, are believed to be sensitive to pain even under normal conditions, and when inflamed become much more 80.

"The pain sensibility of the mucous membrane of the digestive tract is generally very acute near its junction with the skin (oral and pharyngeal cavities), but it diminishes in the oesophagus. The painful sensation of choking produced when an alimentary bolus that is too large or too hard sticks near the cardiac aperture of the stomach is not due solely to the sensibility of the mucous membrane, but rather to the cramp that compresses the nerve fibers that surround the canal. The pain sensibility of the stomach is moderately acute, that of the intestine low, but it increases again in the rectum and at the anal orifice. Puncture, section, cauterization (as shown by experiments on rabbits and dogs, and surgical operations in man), do not produce the sensations of pain in any part of the intestinal canal under normal conditions. But in a pathological state, the intestine may become the seat of severe pains, such as those of colic.

"The mucous membrane of the respiratory apparatus is sensitive to pain in the nasal and laryngeal tracts, but insensitive throughout the bronchial ramifications.

"The mucous membrane of the uretogenital system is very sensitive along the urethral canal, particularly in the prostatic or membranous part; that of the bladder, on the contrary, has little sensibility. Even large calculi may remain unperceived for some time until inflammation sets in. The vulva is sensitive, but the vagina, cervix of the uterus, and the uterus itself arc only moderately sensitive. As long as they are normal they can be cut or cauterized without producing pain. Pain in these parts undoubtedly depends on compression or traction of the sensory nerves that lie in the depth of the tissue, or in the uterine appendages and the vaginal canal.

"The excretory ducts of the glands are usually very sensitive to distention. The intense pain of hepatic and nephritic colic is well known.

"The heart, arteries, and veins are insensitive to pain in the normal state. The same may be said of the hepatic parenchyma, spleen, pancreas, kidneys and lymphatic glands. The genital glands, the testicles, the ovaries and their appendages are, on the contrary, highly sensitive. Compression of these parts causes acute pain, and may even induce syncope.

"From all these facts it is clear that the internal tissues and organs have as a rule a lower sensibility to pain than the surface of the body ; and that the deep organs innervated by the sympathetic normally feel little pain, but they have a very high latent pain sensibility which may became apparent under abnormal conditions, particularly in inflammation."

Visceral Versus Somatic Pain. While the viscera may be insensitive to many stimuli which would cause pain if applied to the skeletal sensory nerves, yet they are capable of expressing pain through the skeletal sensory nerves when irritated, as is frequently seen in disease. The mechanism by which somatic pain is felt when injury is done to a sensory nerve is by the harmful impulse being carried central ward and being transferred through intracentral paths in the cord and brain until the perceptive centres are reached. Not only is the individual made aware of the pain, but he also locates it in the area supplied by the sensory nerve which receives the irritation. *Visceral pain, on the other hand, is a pain, which, while produced in an internal viscus, is referred and felt in the areas supplied by the skeletal (somatic) sensory nerves. The perception centres are made aware of it in the same manner as they are made aware of somatic pain, but instead of perceiving the pain as occurring in the viscus, they recognize it (W being in the sensory skeletal nerve or nerves whose cell bodies are so arranged in the central nervous system as to be rendered irritable by the stimuli which are transmitted over the afferent sensory nerves coming from the viscera in question. The referred pain from the viscera is produced by transference of the sensory impulse from the sympathetic sensory to the spinal sensory neurons and from the vagus sensory neurons to the sensory neurons of the Vth cranial nerve (trigeminus).*

Visceral pain thus expresses itself at the periphery of sensory spinal nerves or of the Vth cranial nerve. This method of expressing visceral pain, together with the fact that the body in early embryonic life, during the period of the formation of the nervous system and differentiation of the viscera, is a segmented organism, explains the fact that pain which is caused by inflammation of a viscus expresses itself in definite skeletal zones but is not always expressed over that viscus. This is well illustrated in the pain which arises from the various divisions of the gastrointestinal canal. The abdominal wall is supplied with sensory nerves from the lower six thoracic spinal segments. The stomach, small intestines and ascending and transverse colon are supplied with connector nerves from the 5th to 12th thoracic and 1st to 3rd lumbar segments. The innervation of these various intestinal segments is such that the supply for the upper portion of the gut comes mainly from the upper segments of the cord, the middle from the middle, and the lower portion from the lower. This shows in the location of the reflex pain when different segments of the digestive tube are stimulated. When the stomach is inflamed, the pain is in the epigastrium; when the small intestine, the pain centres lower about the umbilicus; and when the colon, the pain is still lower between the umbilicus and pubis, as shown in Fig, 16.

Neither does this express all of the truth, for there are two types of pain to be considered; one, the superficial pain which follows the sensory skin zones (dermatomes) in its distribution, and, another the deep pain, a sense of pain or pressure which affects the deep structures such as muscles and tendons which follow the muscles (myotomes) in its distribution. These are often located in different areas.

While each spinal sensory nerve sends fibers to certain skin areas corresponding to the segment from which the nerve arises which accounts for the superficial pain felt in those areas, it also sends fibers out which join the corresponding motor nerve and which be- come responsible for the pain felt on pressure over the deep structures. The difference in the areas of distribution of the superficial and the deep pain may be judged from Figs. 4, 5, 6, and 7, pages 31 - 34.

One must comprehend that pain is due to stimuli which are more severe than those which are usually flowing centralward during normal conditions of activity. The sensory sympathetic nerves are continuously carrying stimuli to the cord which are transferred to the spinal sensory nerves, but are not of sufficient strength to cause the perceptive centres in the brain to take cognizance of them; consequently, no painful sensations are perceived. It is only under fairly strong stimulation or when the neurons are hyper- irritable that the cortical sensory centres are made aware and pain is felt.

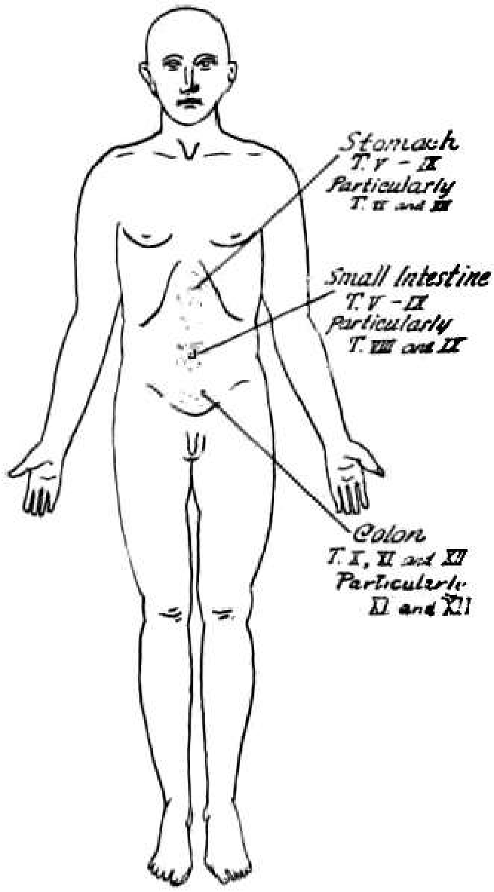

Figure 16. Diagrammatic representation of location of pain when different portion of the gastrointestinal tract are involvement. The stomach – 6th and 7th thoracic zones; small intestine – 8th and 9th thoracic zones; colon 11th and 12th thoracic zones

Mackenzie" is averse to calling the afferent sympathetic neurons "sensory" because he feels that he has fully established the fact that the viscera are not sensitive. He relates his findings in a conscious subject in whom he resected a portion of the small intestine, without giving any anaesthetic, either local or general. He says: "There were numerous peritoneal adhesions, and while I cut and tore these, the patient was unconscious of any sensation. I cut and stretched the serous surfaces of parietal and visceral peritoneum, I tore adhesions from the liver, I cut and sutured the bowel and mesenteric and no sensation was felt."

The afferent neurons from the viscera belong to the vegetative nervous system and have all the anatomic characteristics of the spinal sensory nerves which arise from the posterior horn, and so physiologists call them "sensory," without intending to imply that they carry painful stimuli. While the term is confusing, it might be more confusing to endeavour to change it.

Referred Character of Visceral Pain. In considering pain as a symptom of disease of the internal viscera, it is usually taken for granted that the pain is in the organ the same as we find the pain at the seat of inflammation of structures on the surface of the body. That this cannot he true is clearly shown by a study of the innervation of those internal organs which have travelled far from the area in which they were found in early embryonic life, such as the lungs and the diaphragm. When the pulmonary tissue is inflamed, the pain is usually reflected over the shoulder and neck in the sensory zones supplied by the 3rd and 4th cervical segments of the cord. The diaphragm commonly reflects its pain in case of central diaphragmatic pleurisy in the 3rd and 4th cervical sensory zones. The heart gives sensation in the 1st, 2nd and 3rd thoracic zones, and inasmuch as these arc found both on the surface of the chest and the arm, the pain may appear as either a chest or an arm pain.

Most visceral pain, at least, seems to be of a referred nature, not in the organ itself.

The viscera are not endowed with epicritic sensibility, but only with deep and protopathic. By this fact Head[14] explains the referred nature of visceral pain, for when a part is once endowed with epicritic sensibility the pain is no longer referred. He says "We believe that this condition {protopathic sensibility) is due to the uncontrolled passage of a set of impulses, which normally undergo modification of inhibition before they reach the highest centres. This view is supported by the existence of a normal protopathic surface, such as that of the glans penis.

"Most of the characteristic reactions obtained from a part in a condition of protopathic sensibility undergo modification with the return of epicritic impulses; reference alone is completely abolished. It may be asked why a function apparently so useless remains, though in a condition of permanent suppression. The answer to this question is given by the existence of referred pain in disease of the internal organs. These parts are probably innervated, like the glans penis, from the deep and protopathic systems. But, unlike the glans, their sensibility is extremely low; heat- and cold-spots most be scanty or even absent from most parts of the stomach and intestines. Moreover, pain cannot be produced by such stimuli as the prick of a pin, sufficient to evoke sensations from protopathic parte on the surface of the body. Internal surfaces cannot respond to artificial stimuli, to which they have never been exposed during the life of the individual or the race.

"Even if a stimulus is able to evoke impulses from these sheltered parts of defective sensibility, it does not usually produce a sensation, in consequence of the concurrent activity of the sensory organs of the skin. But a sensation may be produced, whenever these visceral impulses become sufficiently strong to overcome this inhibition, or when the central resistance to their passage is in any way lessened. Once the path has been opened, the resistance to potentially painful impulses is lowered, and a weaker visceral stimulus will evoke a sensation. To this diminished resistance is probably due the production of pain by otherwise inadequate stimuli in eases of long-continued visceral irritation.

"Since the internal organs are totally devoid of epicritic sensibility, a sensation produced within the visceral area will tend to show the same peculiarities as one evoked from a part supplied with deep and protopathic sensibility only. If the stimulus consists of pressure or of the movement of muscles, the patient will recognise to some extent its true locality, in proportion as the part is supplied with end-organs from the deep afferent system. "When, however, the stimulus evokes pain the sensation will tend to be referred into remote parts.

"Now, just as one part of the affected area on H's hand seemed to be linked with some other remote portion, so visceral sensory surfaces seem to be closely associated with somatic segmental areas. When pain is evoked, it is not localized in the organ stimulated, but is referred to some area on the surface of the body.

"Thus, the retention, on the primary level, of afferent impulses, which if not inhibited, would lead to incorrect localization, has a protective object. To the normal organism they would be worse than useless, but in disease they underlie widespread pain and uncontrollable muscular reflexes."

Referred pains can only be understood when the organ is carefully studied with reference to its embryologic development, in which case it will be seen that the usual visceral pain follows the segmental relationship which determined the innervation in early developmental life as discussed in Chapter IV. The cells of the visceral nerves originally were found in the neural canal; and, while during the development of the individual they wandered far from it, yet they have preserved their segmental relationships through the connector fibers which nm from the spinal segments to the motor cells of the ganglia, lateral, collateral and terminal, in case of the sympathetic system; and from the nuclei in the midbrain and bulb, and the cells in the sacral segments of the cord, to the motor cells in the organs themselves in case of the parasympathetics as shown in Chapter XXX. Visceral pain is expressed by afferent sensory sympathetics and para- sympathetics transferring the impulse to sensory segmental spinal nerves and the Vth cranial nerve; and the location of the pain depends upon the segments of the body which stand in reflex relationship with the afferent sympathetic or parasympathetic nerves; because the pain is expressed in the peripheral distribution of those nerves, either spinal or Vth cranial, whose cells lie adjacent to them.

Mackenzie's[15] discussion of visceral pain, should be read by all who are interested in this subject. He says with reference to the referred nature of visceral pain: "In putting forward the view that the pains arising from the viscera are not felt in the organ, hut are referred to the peripheral distribution of cerebrospinal nerves in the external body wall, I have opposed to me the practically unanimous opinion of all people, whether they have studied the subject or not."

The reasons given for the belief in pain being felt in the inflamed organ arc fully discussed by Mackenzie. The fact that pain is often felt on pressure over the organ he attributes to the hyperalgesia which often affects the soft tissues covering the body wall, due to the viscerosensory reflex. He also calls attention to the fact that the pain remains stationary though the organ shifts its position; and further, the pain often extends beyond the limit of the organ. This I have discussed above and illustrated by the pain in inflammation of the lungs, diaphragm and heart.

Hyperalgesia. In considering so-called deep pain, it must be remembered that all skeletal structures are supplied by the sensory spinal and cranial nerves; and, while pain is most acutely developed in the skin, it is also present in subcutaneous tissue and muscle. Hyperalgesia of the soft tissues is not uncommon in the areas which have been the seat of reflex sensory pain. Mackenzie cites the severe pain felt by John Hunter in his arm after an attack of angina pectoris. Soreness of the shoulder and upper arm muscles is often complained of by patients who suffer from inflammatory diseases of the lungs; so also, at times, is pain felt in the broad chest muscles.

Hyperalgesia of the skin is also common in visceral diseases. Not infrequently do we find patients suffering from pulmonary tuberculosis and pleurisy in whom the skin becomes very sensitive, even a very slight stroke causing pain. In studying hyperalgesia of the muscles, it is important to bear in mind that the sensory innervation of the muscles follows their motor innervation and not that of the cutaneous zones. This is especially necessary in order to understand the pain in the muscles where the muscle and skin areas are not coextensive as in diseases of the lungs as noted on page 144.

No study of hyperalgesia and other forms of visceral pain can be complete without recognition of the great work done by Head. Head, contrary to Mackenzie, recognizes two types of pain in internal viscera, one in the organ itself, which is more that of discomfort and uneasiness, and one on the surface of the body which is a true painful sensation. Head has formulated the following law of the location of visceral pain:"

"When a painful stimulus is applied to a part of low sensibility in close central connection with a part of much greater sensibility, the pain produced is felt in the part of higher sensibility rather than in the part of lower sensibility to which the stimulus was actually applied."

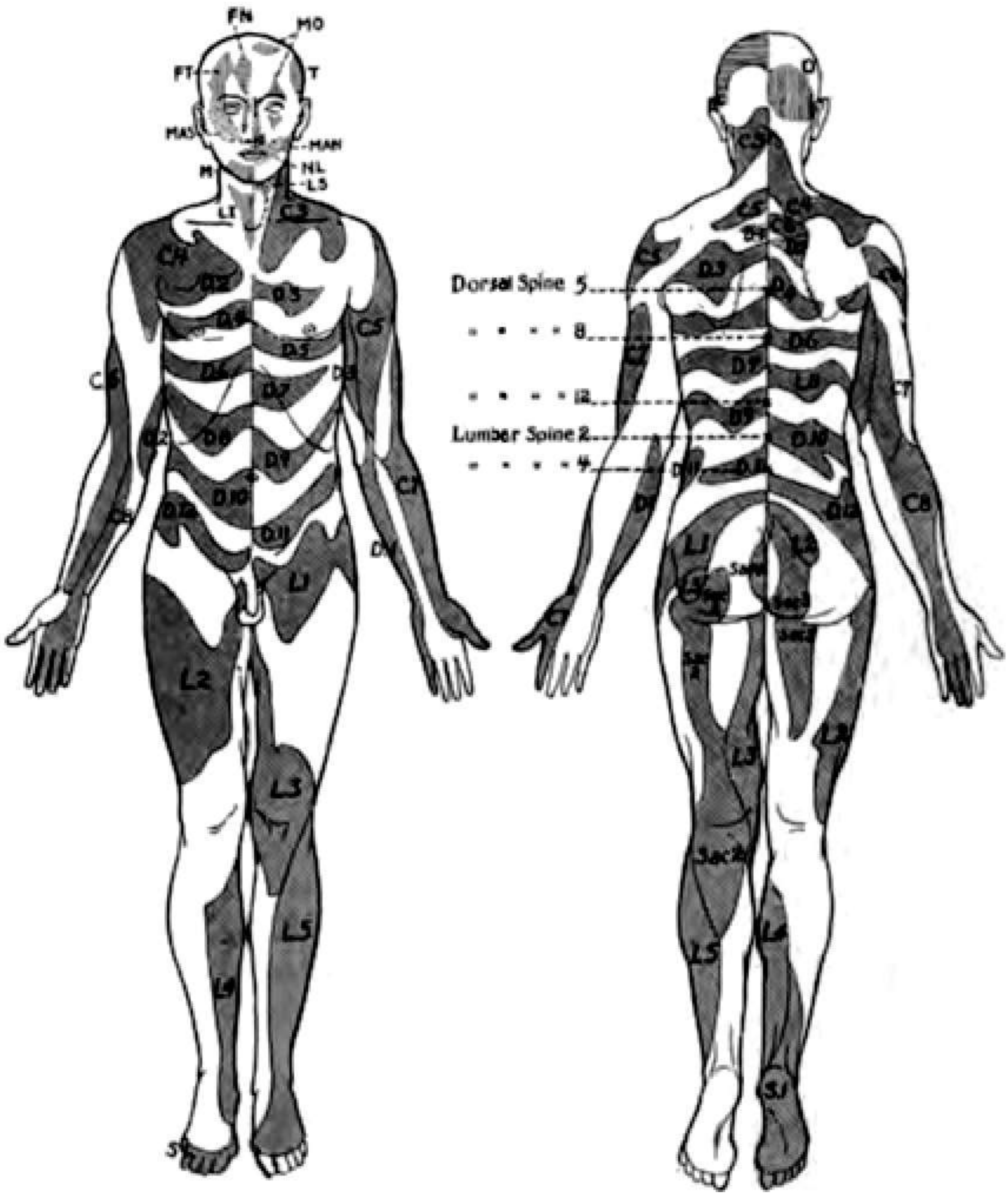

Figure 17. Diagram of zones and hyperalgesia after the clinical researches of Head (anterior and posterior view). The 8 cervical segments by C1 and C2 to C8; the twelve dorsal or thoracic segments by D1, D2 – D12; The 5 lumbar segments by L1, L2 – L5; and the 4 sacral segments by Sac1, Sac2 – Sac4.

The areas of the head are denoted as follows: N – nasal or rostral; FN – frontonasal area; MO – medio-orbital area; FT – fronto-temporal area; V – vertical area; P – parietal area; O – occipital area; NL – nasolabial area; Max – maxillary area; Man – mandibular area; M – mental area; LS – superior laryngeal area; LI – inferior laryngeal area; TO = hyoid area (Luciani).

The position of sensory zones on the surface of the body is lower is lower than the emergence of the corresponding sensory nerves from the cord. In order to show this relationship the spinous processes of the 5th 8th and 12th dorsal and the 2nd and 4th are shown in the figure.

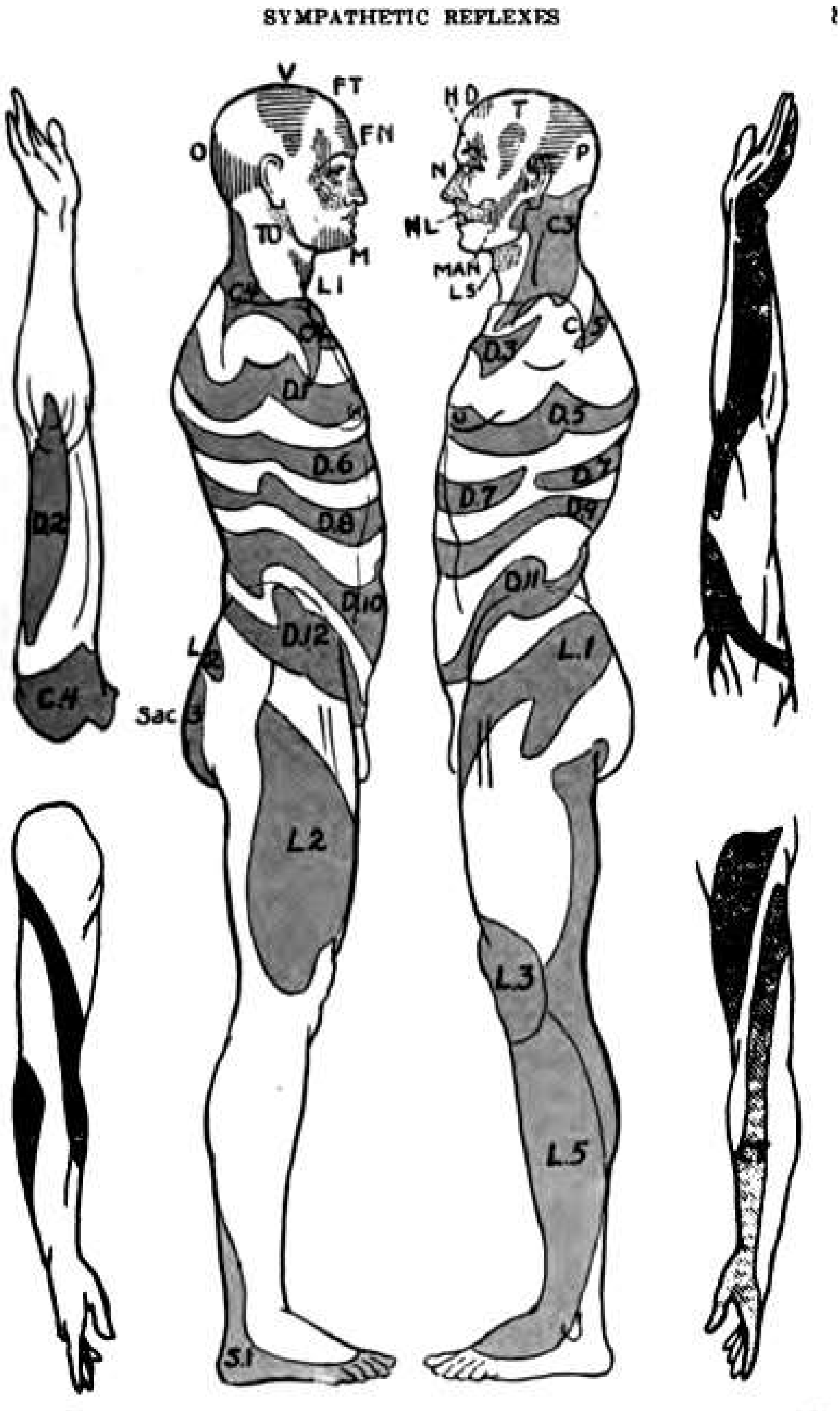

Figure 18. Diagram of the zones and hyperalgesia after the clinical researches of Head (lateral view). For description, see figure 17

The fact that the internal viscera are less sensitive than the skin areas supplied by sensory nerve cells, which lie adjacent in the same segments of the cord, according to this rule, would account for the pain being felt in the more sensitive nerves of the skin. In the presence of disease of the internal viscera, where the sensory cell bodies in the cord become highly excitable, the mere touch or pinching of the cutaneous surface or slight pressure over deeper structures gives evidence of pain, when the same degree of stimulation would not produce any sensation more than that of being touched, if the cell bodies in the cord had not been bombarded by the stimuli coming from the viscera. After much careful study, Head mapped the body in zones which show hyperalgesia when internal viscera are inflamed. This is well presented by Luciani:"

"Head's clinical investigations have such great practical importance that it is desirable to reproduce the following diagram and table, which sum up his results.

"Figs. 17 and 18 show the segmental cutaneous areas of the trunk, extremities, and head. The form and extent of these were arrived at:

"(a) By mapping out the areas in a number of cases of cutaneous hyperesthesia with coincident visceral affections;

"(b) From the topography of the eruptions in 52 cases of herpes zoster;

"(c) By mapping out the analgesic areas in organic diseases of the spinal cord and roots.

"The following table shows the relations between the cutaneous areas and the internal organs:

Areas in the trunk and limbs		**Areas in the head**	
Heart	C3, C4 – D2 – D8	Ventricles and aorta	N, FN, MO, FT
Lungs	C3, C4 – D4 – D9	Auricles	FT, T, V, P,
Stomach	D7 – D9		N, FN, MO, FT, T, V, P
Intestine	D9 – D12		FN, MO, T, V, P
Rectum	Sac2 – Sac4		V, P, O
Liver	C3, C4 – D7 – D10		
Gall bladder	D8 – D9		FN, MO, T, V, P, O
Kidneys and urethra	D11 – L1		T, V
Bladder (mucous membrane and neck)	Sac3 – Sac4		
Detrusor vesicae	D11 – L2		
Prostate	D10 – D12, Sac1 – Sac3		
Epididymis	D11 – D12		
Testicle	D10		
Ovary	D10		
Ovarian appendix	D11 – L1		
Uterus	D10 – L1		
Neck of uterus	Sac2. Sac4		
Mammae	D4 – D5		
Spleen (from Signorelli)	D6		

Figure 19 Table showing relations between cutaneous area and the internal organs
The areas of the head are denoted as follows: N – nasal or rostral; FN – frontonasal area; MO – medio-orbital area; FT – fronto-temporal area; V – vertical area; P – parietal area; O – occipital area; NL – nasolabial area; Max – maxillary area; Man – mandibular area; M – mental area; LS – superior laryngeal area; LI – inferior laryngeal area; TO = hyoid area (Luciani).

This table should be studied carefully by all students of visceral neurology.

Recurrent Pain in Sensory Spinal Nerves Resulting from Visceral Disease. A troublesome symptom of chronic visceral disease is recurrent aching or pain expressed in those somatic sensory zones which are supplied by neurones whose cell bodies lie adjacent to the cell bodies of the afferent neurones from a viscus which is or has been the seat of disease. Its presence disturbs and discourages the patient and its explanation confuses the physician. This pain may come when there is no exacerbation of the disease. Different causes excite pains which are associated with different viscera. For example: A patient who has previously suffered from pulmonary tuberculosis experiences pain under many conditions in the zones in which the sensory reflex from the lung is expressed, — the neck and shoulders. These may appear at the time of chants in the weather, when tired, or when the patient is physically or nervously below par, regardless of whether the disease is active or not. Pain arising from chronic inflammation of the pleura is influenced in much the same manner. Pain arising from stomach and intestinal diseases will often appear when the patient is tired or nervously exhausted, or suffering from other depressive conditions without there being at the time active disease in the organs themselves. Pain from the kidney and uterus will be experienced by patients who have previously suffered from chronic illness of these organs when the patient tires or becomes depressed. And so it is with other important viscera. The neurons which carry the impulses which call forth the viscerosensory reflexes, become hypersensitivity to such a degree that aching or pain is expressed in the respective sensory zones as a result of stimuli which would be insufficient to cause reflex action in normal nerve cells. Mackenzie speaks of this as being a persistent hyperirritability of the nerve cells in the areas of the cord which receive the impulses from the diseased organ.

The explanation of this pain is furnished by the fact that nerve cells under normal conditions will stand a certain amount of stimulation without producing action. Afferent stimuli continuously pass centralward from all viscera, but they only cause reflex action when the stimulus becomes adequate to overcome the resistance between the cell body which receives the impulse and the cell body which effects the action whether it be a contracture of muscle, a stimulation of secretory activity or a change in sensation such as is often noted as pain. When for a long time harmful afferent stimuli pass to the cord, the threshold of response for the nerve cells to which these stimuli are transferred is lowered and they respond to a stimulus below that which they would withstand during normal conditions. In other words, these cells become hyperirritable and reach a state where a lesser stimulation produces an *adequate stimulus*. In case of the pain or aching which is often experienced by patients who have previously had an inflamed lung, pleura, intestinal tract, kidney or uterus, or other organ as mentioned above, the threshold of response in the cell bodies of the sensory spinal nerves becomes lowered to such a degree that when these patients experience any unusual condition which affects nerve cells generally those cells whose threshold of response has not been previously lowered withstand the stimulation, while those in whom the threshold for stimuli has been lowered respond with pain.

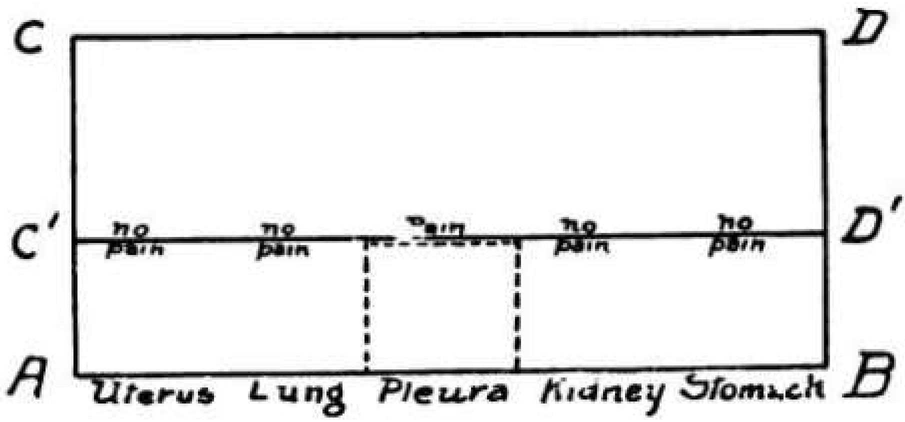

Figure 20. Graphic illustration of causes of chronic pain in sensory neurons, the cell bodies of which have been rendered hyperirritable by disease.
Line AB represents the point at which the sensory neurons connecting with the uterus, lungs, pleura, kidney and stomach, normally discharge when stimulated. Line CD represents the stimulus and AC the strength of the stimulus which the nerves cells will normally withstand. If the degree of irritability of the nerve cells of all the organs mentioned is normal, no pain would occur until CD has reached AB. The dotted lines in the figure are drawn so as to illustrate that the neurons connected with the pleura have attained a state of hyperirritability, so that they discharge with a lesser stimulus that the neurons connected with other organs, and when CD has reached the point of C'D', pain is felt in the neurons connected with the pleura, although it does not occur in the neurons connected with the other organs

This idea is expressed graphically in Fig. 20, in which AC, the distance between lines AB and CD, represents the strength of stimulus which can be withstood by the nerve cells of the body, generally, without discharging energy, — producing pain, muscular contraction, or altered secretion. When inflammation is present, or has been long present in organs, the cells in the central nervous system which receive stimuli from that particular organ, take upon themselves a condition of increased irritability, and discharge on being irritated by stimuli of a lesser degree than that required under normal conditions. They would be discharged by a stimulus less than AC, for example, AC; consequently, when factors appear which produce a marked general nerve stimulation such as toxemia, disease, tiring, worry, overwork, malnutrition and weather changes, the line CD representing general stimulation approaches AB, which is the normal point of general nerve discharge. Such nerve cells as have taken upon themselves a condition of increased irritability as a result of preceding harmful stimulation will discharge somewhere before the line AD is reached as, for example, at CD'.

For example: Patients who have had pleurisy often suffer pain in the chest on tiring, or because of weather changes, or when depressed by worry and other harmful influences, although they are comfortable at other times and have no other pain during the action of these depressive conditions, except that expressed in the somatic sensory zones which are connected with afferent pleural nerves. Tiring, worrying, changes in weather, etc., cause the line CD to approach AB, and if AB should be reached there would be a general discharge of nerve energy shown from many of the organs of the body. But long before CD reaches AB, for example, at CD', the pleural pain is felt, because the pleural sensory neurons are in a state of hyperirritability and the line AC, which represents the strength of stimulus which the nerve cells of a given organ, the pleura in this example, should normally withstand is reduced to AC, Other organs show no pain, as is shown in the illustration, because the excitability of the cell bodies of the neurons which receive stimuli from them is not increased.

3. Viscerotrophic Reflex. While the visceromotor and viscero- sensory reflexes have been considered by others I have failed to find a satisfactory discussion of the "viscerotrophic reflexes" in the writings of other observers. This is probably because most study along the lines of clinical visceral neurology has heretofore been directed toward acute visceral inflammation. While acute inflammation of the viscera provokes the "visceromotor" and "viscero- sensory" reflexes, the trophic changes[18, 19, 20] which depend upon reflex visceral stimulation are dependent upon a chronicity of the inflammation to bring them about.

Cause of Trophic Reflex. So far as physiologists are able to determine, there are no special trophic nerves, but nutrition of tissue depends upon the sensory and motor nerves which supply it. The skin and subcutaneous tissue depend upon the spinal and cranial nerves for their nutrition, consequently these are the nerves which are responsible for the "viscerotrophic" reflex in these structures. The function of body cells and their nutrition are inseparable. Therefore, trophic change must be looked upon as a disturbance in the innervation of the part affected, and degeneration as a condition in which the nerve cells which supply nutrition to the part, are not able to fully care for the nutritional requirements of the cells.

Nerve cells may be injured in many ways. Certain poisons may come in contact with them and alter their stability; they may be the recipients of powerful chemical or mechanical stimuli which prove harmful; or they may be abnormally stimulated by harmful irritation of their peripheral sensory filaments, or the injury may result from malnutrition. While they may even be able to endure a moderate number of harmful stimuli for a short period of time with- out harm resulting, yet, if long continued, the cells will be injured, and the tissues supplied will suffer nutritional change.

Injured cells show in an increased irritability and a reduction of their functional capacity. Since the nerves that supply motor activity and sensation to the skeletal structures have control over the nutrition of these .tissues, therefore a prolonged injury to the cells which give origin to the spinal nerves is followed by a reduction in motor power, or alteration in sensation and in a failure to maintain the nutrition of the structures, — degeneration.

Whenever an organ is the seat of a chronic inflammatory process, the nerve endings in that organ are irritated. Many harmful stimuli are sent centralward which continue as long as the inflammation lasts. If the nutrient cells which give origin to the afferent sensory fibers are bombarded by harmful stimuli over a long period of time, they and the cells adjacent become injured, and manifest an inability to properly functionate. This injury affects all components of the reflex, one result of which is trophic change in the tissue. In case of the sympathetic and vagal (parasympathetic) afferent nerves and the efferent spinal and the Vth cranial nerves in reflex connection with them, a degeneration of skeletal soft tissues — muscles, subcutaneous tissue, and skin, — results.

Examples of Trophic Reflex. This reflex degeneration, for which I would suggest the term "viscerotrophic reflex" in harmony with the terms "visceromotor" and "viscerosensory" is well illustrated in the trophic changes which are so commonly found in chronic pulmonary tuberculosis and pleuritis," In pulmonary tuberculosis the skeletal tissues which are supplied by the cervical spinal nerves, particularly the 3rd, and 4th, are affected by this trophic reflex. The musculi, sternocleidomastoideus, scaleni, pectoral is, trapezius, levator anguli scapulae and diaphragm, and the skin and subcutaneous tissue supplied by the same segments, areas included in the neck and shoulders down to the 2nd rib anteriorly, and the angle of the scapula show trophic changes, as shown in Fig, 48 A and B, page 134, In chronic pleuritis, the trophic disturbance is expressed through the thoracic spinal nerves, so the musculi intercostales and the broad muscles of the back and the skin and subcutaneous tissue over the thorax below the second rib, degenerate. Sometimes the degeneration is general, at other times, it is localized. Only such areas of soft structures are affected as are supplied by neurons whose cell bodies receive stimuli from the afferent neurons from the pleura.

Other examples of the trophic reflex are seen in the degeneration of the lumbar tissue in such chronic inflammations of the kidney as tuberculosis and multiple abscess; in the soft tissues of the abdomen when the gut is the seat of chronic tuberculosis; or when a chronic peritonitis is present.

It is in chronic diseases of the lungs and pleura, however, where the trophic reflex is best observed, and where it is of greatest diagnostic worth. Chronic inflammation of the lungs and pleura is suggested at once when localized degeneration of the neck and chest muscles and the skin and subcutaneous tissue over them is observed. Inasmuch as these two viscera cause reflexes in different segments of the cord, the location of the denegation is of differential value. This is discussed in Chapters XVI and XVII.

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Chapter VII

Reflexes Whose Afferent Impulses Course In The Parasympathetic Nerves

Distribution of Parasympathetic Reflexes

In order to comprehend the parasympathetic reflexes, it is necessary to understand the relationship which exists between the cranial, bulbar, and sacral nerves. As is discussed on page 299 and emphasized in the preceding chapter, there is a very close relationship between afferent sensory impulses coming from the viscera through the sympathetic nerves, and the spinal nerves. There is also a close relationship between impulses which originate upon the surface of the body and travel centralward through the spinal sensory nerves, and the sympathetic motor nerves which supply the internal viscera.

It is necessary to bear in mind that the medulla oblongata is but an expanded portion of the spinal cord, and while the relationships are distorted because of the ventricles and other structures which are made from it, nevertheless there is much the same relationship between the nerves which take their origin in this part of the nervous system as there is between the sympathetic and spinal nerves lower in the cord. The vagus nerve contains both sensory and motor nerves to the viscera, and sensory stimuli coming centralward over one division of this nerve arc capable of producing reflexes in other divisions of the same nerve ; also in other cranial motor nerves, both those having vegetative and voluntary functions; and in the sensory portion of the Vth cranial nerve. A great many of the common so- called "functional visceral disturbances," will be recognized as reflexes connected with the parasympathetic nerves, particularly the vagus. The relationship of the sensory and motor roots in the medulla are shown in Fig. 21.

Relationship of Trigeminus Nerve to Parasympathetic Reflexes

To further explain parasympathetic reflexes which take place in the internal viscera as a result of afferent impulses from the eye and the mucous membranes of the nose and accessory sinuses, it is necessary to bear in mind that the sensory fibers of the Vth cranial nerve (trigeminus) bear the same reflex relationship to the motor neurons of the VIIth, IXth, and Xth cranial nerves as the fibers of the sensory spinal nerves do to the motor neurons of the sympathetic system. Many of the headaches which accompany diseases of internal viscera are probably parasympathetics-sensory reflexes through the Vth cranial nerve. The sensory somatic neurons of the Vth cranial nerve also have the same property of carrying sensory stimuli centralward to join with the motor neurons of the VIIth, IXth and Xth cranial nerves in the production of reflexes, as is possessed by the sensory fibers of the spinal nerves in joining with the motor neurons of the sympathetics. On this point I desire to quote from Gaskell:

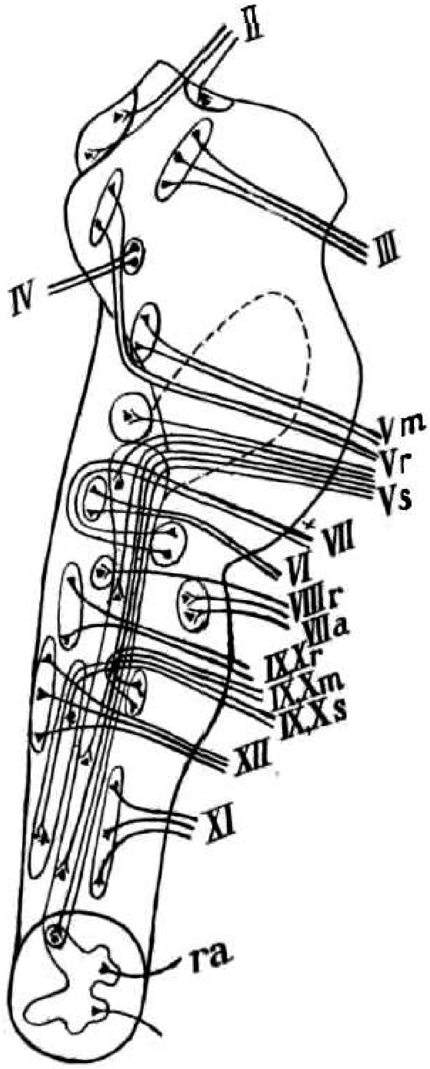

Figure 21. the sensory and motor nuclei of the medulla. M – motor; s – sensory; r – reflex roots. VIIa – nervous cochlearus; VIIIr – nervus vestibularis. The remaining Roman numerals represent the remaining cranial nerves. (Bechterew)

"Similarly, in the mesosomatic region (Fig. 22 [Plate II in this text]) the groups of motor cells, known as the facial nucleus and the nucleus ambiguus, represent the motor neurone of the splanchnic segmentation, and represent therefore the motor neurons of the muscles of the mesosomatic appendages; they are quite separate from the nucleus of the Abducens, which supplies motor fibers to the only remaining dorso-ventral muscles, a pair of which originally existed in each segment, and from the hypoglossal nucleus containing the motor cells of the longitudinal somatic muscles. These mesosomatic groups also extend down the cord; the splanchnic group being represented by the nucleus accessorius or the lateral horn of the cervical region, which is formed from the lateral cell groups of the anterior horn ; the somatic group by the cells of the anterior horn, supplying motor fibers to the longitudinal trunk muscles.

"Thus the cells of the motor neurons of the voluntary system, form two well-defined groups in accordance with the double segmentation of the striated musculature in the cranial region.

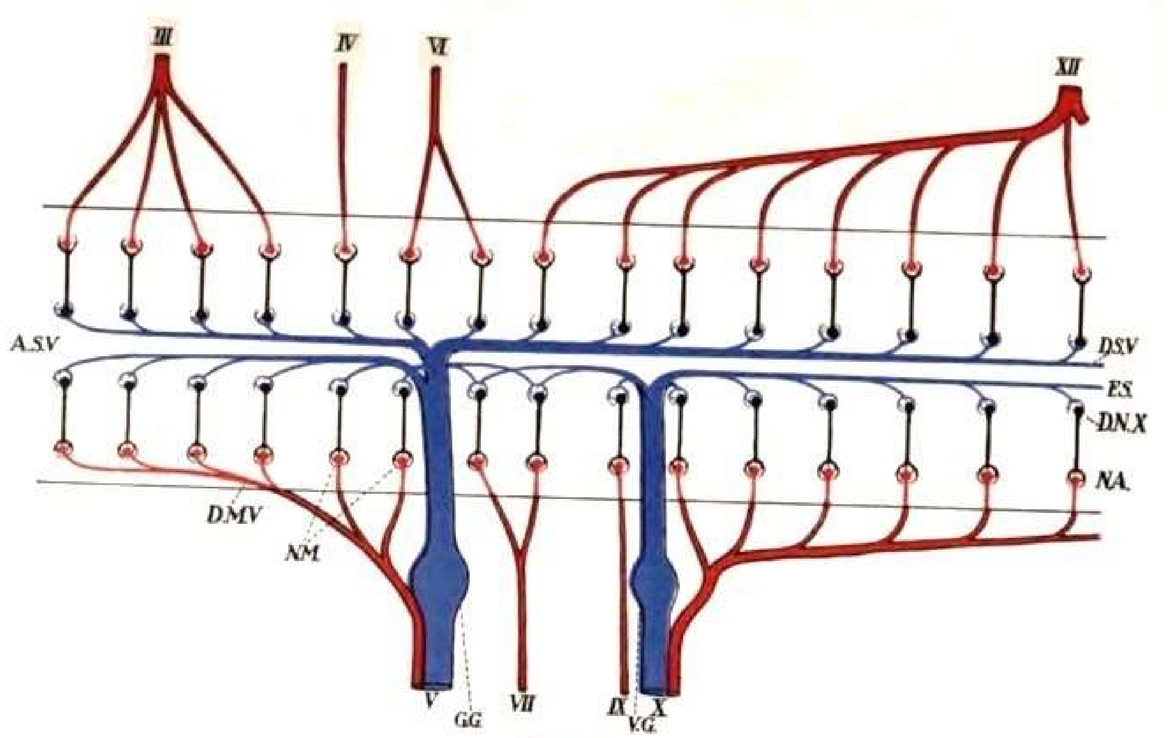

PLATE II

Figure 22. Plate II - The reflex paths of the voluntary system in the cranial region. The afferent receptor neurons are shown in blue, the connector neurons in black and the efferent excitor neurons in red
The splanchnic excitor neurons are shown in the lower part of the diagram; the somatic excitor neurons in the upper part. The receptor neurons for both systems all run in the fifth and tenth nerves which are shown in the lower part of the diagram.
The neurons in the horizontal line all belong to the same segment, the first six lie in the prosomatic segments, and the remainder in the mesosomatic.
The receptor fibers of the somatic system all run in the fifth nerve, their nuclei lying in the Gasserian ganglion, G. G.
The ascending sensory root, A.S.V., supplies the connector neurons of the pro- somatic segments of the somatic system. These connector neurons, which lie close against the ascending root, communicate with the excitor neurons of the four segments comprising the nucleus of the third nerve, with the nucleus of the fourth nerve, and with the anterior portion of the nucleus of the sixth nerve in the respective segments. The descending sensory root, D.S.V., communicates with the connector neurons of the mesosomatic segments of the somatic system. The connector neurons connect in the first mesosomatic segment with the more posterior portion of the excitor nucleus of the sixth nerve and the others with the series of nuclei which form the excitor nucleus of the twelfth nerve.
The receptor fibers of the splanchnic system in the prosomatic region all run in the fifth nerve. They form part of the ascending sensory root and connect in each segment with connector neurons which in their turn connect with the nuclei of the descending motor root of the nerve. D.M.V. The nuclei of the two posterior segments form the nucleus masticatorius, N.M. Some afferent fibers of the fifth nerve probably connect also with the connector neurons of the seventh nerve as shown in the diagram.
The afferent fillers of the mesosomatic segments of the splanchnic system all run in the sensory portion of the tenth nerve, their cells lying in the vagus ganglion, V.G.
A small ascending root connects with the connector neurons of the first three segments; the connector neurons in their turn connect with the motor nuclei, the first two of which give origin to the seventh nerve and the third to the ninth nerve.
The descending root, the fasciculus solitarius, F. S., connects with the connector neurons of the remaining segments which lie in the dorsal nucleus of the vagus, D.N.X. The motor neurons of these segments form the motor portion of the tenth nerve, the segmental nuclei lying in the nucleus ambiguus, N.A. (Gaskell.)

The afferent receptor neurons are shown in blue, the connector neurons in black and the efferent excitor neurons in red

The splanchnic excitor neurons are shown in the lower part of the diagram; the somatic excitor neurons in the upper part. The receptor neurons for both systems all run in the fifth and tenth nerves which are shown in the lower part of the diagram.

The neurons in the horizontal line all belong to the same segment, the first six lie in the prosomatic segments, and the remainder in the mesosomatic.

The receptor fibers of the somatic system all run in the fifth nerve, their nuclei lying in the Gasserian ganglion, G. G.

The ascending sensory root, A.S.V., supplies the connector neurons of the pro- somatic segments of the somatic system. These connector neurons, which lie close against the ascending root, communicate with the excitor neurons of the four segments comprising the nucleus of the third nerve, with the nucleus of the fourth nerve, and with the anterior portion of the nucleus of the sixth nerve in the respective segments. The descending sensory root, D.S.V., communicates with the connector neurons of the mesosomatic segments of the somatic system. The connector neurons connect in the first mesosomatic segment with the more posterior portion of the excitor nucleus of the sixth nerve and the others with the series of nuclei which form the excitor nucleus of the twelfth nerve.

The receptor fibers of the splanchnic system in the prosomatic region all run in the fifth nerve. They form part of the ascending sensory root and connect in each segment with connector neurons which in their turn connect with the nuclei of the descending motor root of the nerve. D.M.V. The nuclei of the two posterior segments form the nucleus masticatorius, N.M. Some afferent fibers of the fifth nerve probably connect also with the connector neurons of the seventh nerve as shown in the diagram.

The afferent fillers of the mesosomatic segments of the splanchnic system all run in the sensory portion of the tenth nerve, their cells lying in the vagus ganglion, V.G.

A small ascending root connects with the connector neurons of the first three segments; the connector neurons in their turn connect with the motor nuclei, the first two of which give origin to the seventh nerve and the third to the ninth nerve.

The descending root, the fasciculus solitarius, F. S., connects with the connector neurons of the remaining segments which lie in the dorsal nucleus of the vagus, D.N.X. The motor neurons of these segments form the motor portion of the tenth nerve, the segmental nuclei lying in the nucleus ambiguus, N.A. (Gaskell.)

"On the sensory side (Fig. 21 [Plate II this text]) there are also two distinct sets of sensory fibers represented in the double segmentation, belonging respectively to the somatic and splanchnic segments. In the prosomatic region the sensory neurons for both segmentations are found in the Gasserian ganglion; but in the mesosomatic region the somatic sensory neurons belong mainly to the trigeminal and were also found in the Gasserian ganglion, while the splanchnic sensory neurons are found in the sensory ganglia on the facial, glossopharyngeal, and vagus nerves. So also there must be corresponding connector neurons for these two sets of segments, in order to carry out the primary or segmental reflexes, similar to those in the trunk region. These primary connector neurons are situated in the spinal region in the posterior horns (Fig. 22. [Plate III in this text]). We must look for the corresponding cells in the cranial region in two situations corresponding respectively to the posterior horns belonging to the somatic and splanchnic segmentations. The posterior horn cells of the cord arc characterized by the presence of the substantia gelatinosa Rolandi close to them, and the characteristic of the descending sensory root of the trigeminal (Fig. 23 [Plate IV in this text]) is the presence of the substantia gelatinosa Rolandi along its whole length. In this substance are found cells with which the fibers of this root continuously make connection, called by Edinger the end nucleus of the 'ascending' root. Such cells clearly correspond to a series of connector nuclei of the same kind as those be- longing to the voluntary nervous system in the segments of the spinal cord, and form in my opinion the primary connector neurons of the somatic segmentation. I imagine therefore that, as far as the somatic segmentation is concerned, the primary or segmental reflexes, which must take place in each cranial segment as well as in each spinal one, are effected through these connector neurons, as represented diagrammatically in Fig. 23. [Plate IV in this text]. With respect to the splanchnic segmentation (Fig. 23. [Plate IV in this text]) in which the motor neurons are found in the nucleus of the facial, nucleus ambiguus and the accessory nucleus, and the sensory neurons in the ganglia on the roots of the corresponding nerves, we must look for the connector neurons in that part of the grey matter of the medulla oblongata which continues into the spinal cord as the posterior horn.

"The posterior horn cells belonging to the vagus segments in the medulla oblongata have become part of the mass of cells in the floor of the fourth ventricle, known as the dorsal nucleus of the vagus, and according to Edinger the sensory roots of the vagus terminate in many of these cells and in their continuation as a cell column close along the 'descending' root of the vagus (the fasciculus solitarius). In fact this group of cells forms the connector neurons belonging to the splanchnic segmentation in exactly the same manner as the corresponding group of cells in connection with the sensory trigeminal fibers form the connector neurons belonging to the somatic segmentation.

"I imagine therefore that, so far as the splanchnic segmentation is concerned, the primary or segmental reflexes, which must take place in each cranial segment as well as in each spinal one, are effected through these connector neurons, as represented diagrammatically in Fig. 24. [Plate IV in this text]."

Examples of Parasympathetic Reflexes

In our clinical experience for a long time we have had our attention called to some of the motor and sensory reflexes whose afferent impulses course through the sympathetic nerves. Particularly have we known the visceromotor reflex in appendicitis, cholelithiasis, peritonitis, and ulcer of the stomach; and the viscerosensory reflex in appendicitis, cholelithiasis, cholecystitis, gastric ulcer, diaphragmatic pleurisy, and angina pectoris. Later we have been able to describe both motor and sensory reflexes for the lungs, kidney and portions of the intestinal canal other than those above named, as well as many others.

With our increased knowledge we are warranted in assuming that every internal viscus having sympathetic fibers is connected with spinal nerves through its afferent sensory sympathetic fibers; and that, if these afferent sensory fibers in the viscus are sufficiently irritated by conditions which arise during disease of the viscus, they will produce their own "visceromotor" and "viscero- sensory" reflexes; and if the disease becomes chrome, their "viscerotrophic" reflexes.

There is another group of reflexes which, aside from a few very definite instances, such as the slowing of the heart in certain abdominal lesions, are recognized even less, although they are met in every disease of consequence affecting important viscera, * I refer to the reflexes which take place from one viscus to another through the parasympathetic division of the vegetative system. This is well illustrated by the slowing of the pulse, as it is frequently observed when some part of the gastrointestinal canal is inflamed. It is at times seen in appendicitis, and cholecystitis. I have frequently observed the same reflex bradycardia, in clinical pulmonary tuberculosis, also in tuberculous enteritis.

Functional Disturbances and the Parasympathetic Reflex
Physiologic study of parasympathetic reflexes gives us a basis for explaining innumerable so-called "functional disturbances" in organs other than the one inflamed. This I shall attempt to illustrate fully in the clinical sections of this monograph. As each organ is connected reflexly through sympathetic afferent verves and spinal efferent nerves with the superficial structures in the body wall, so is each organ supplied by parasympathetic nerves co7inecled reflexly through afferent parasympathetic fibers and efferent parasympathetic fibers with other organs supplied by the parasympathetic system; and each organ when inflamed influences other organs reflexly; and, if the reflex action is sufficiently strong, function is perverted and symptoms on the part of that organ are produced. Organs and tissues innervated by the Vth, VIIth, IXth, XIth and XIIth cranial nerves also show parasympathetic reflexes.

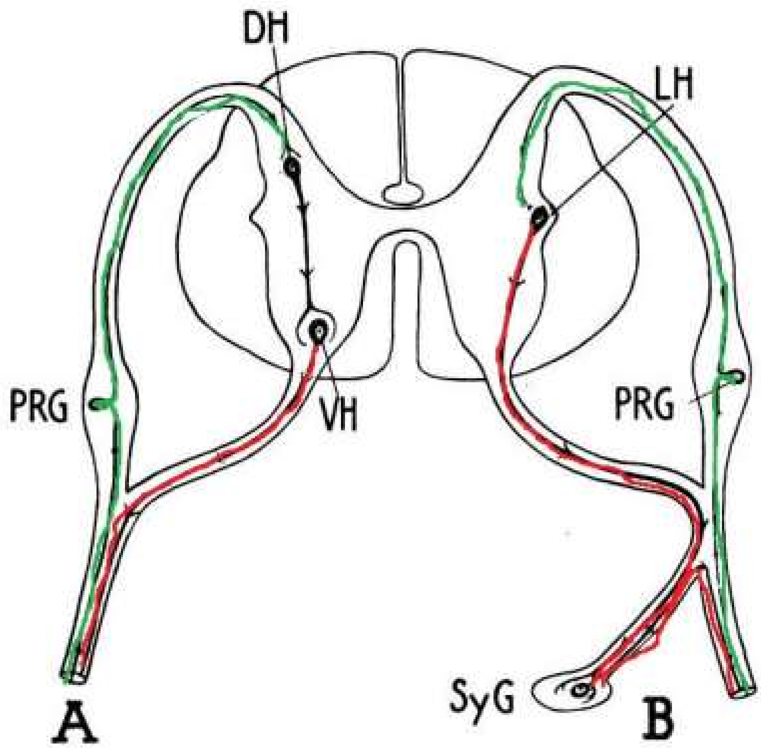

PLATE III

THE REFLEX PATHS IN THE CORD

Figure 23. Plate III. The reflex paths in the cord.
Green – sensory nerves, receptor neuron; black – connector neuron; Red – motor neuron – excitor neuron.
A: Of the voluntary system. The receptor neurons run in the posterior root, their cells lying in the posterior root ganglion PRG. The connector neurons lie in the dorsal horn, DH, and connect with the excitor neurons lying in the ventral horn, VH, whose processes run in the anterior root.
B: Of the involuntary system. The receptors run in the posterior root, their cells lying in the posterior root ganglion, PRG. The connector neurons lie in the lateral horn, LH, and their processes running out in the anterior horn with the excitor neurons lying in the sympathetic ganglia, SyG, The processes of the excitor neurons form the grey ramus communicans and run out of the spinal nerve (Gaskell)

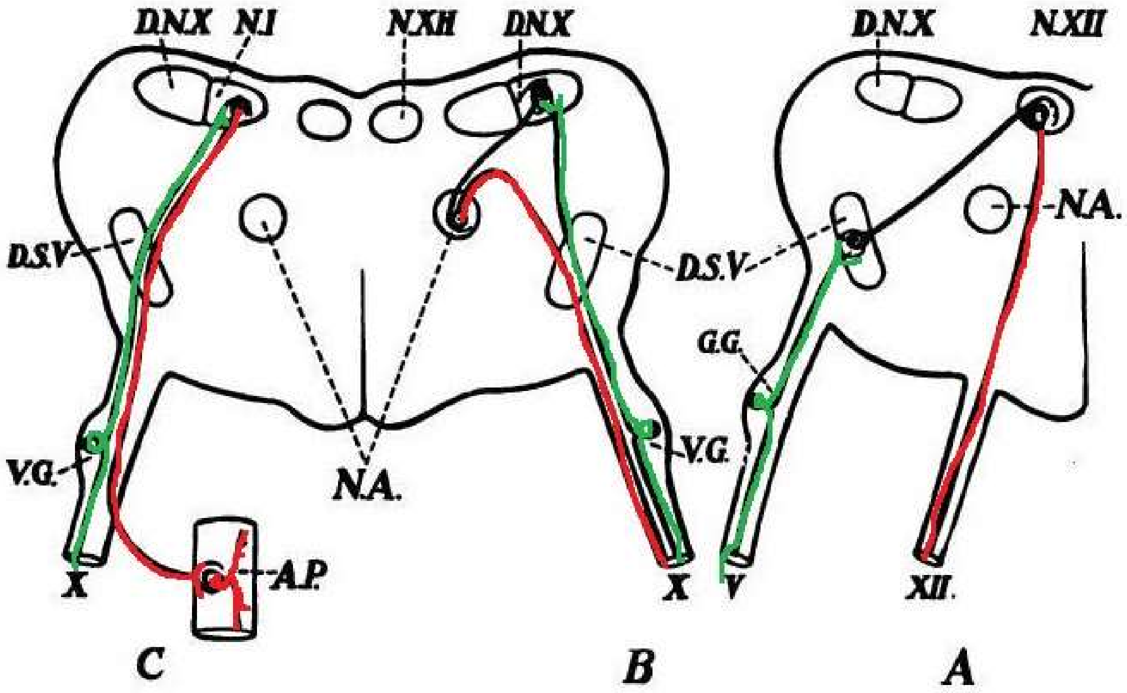

PLATE IV

Figure 24. Plate IV. Reflexes in the bulbar region. (Green – sensory nerve, neuron, Black – connector neuron, Red – motor nerve, excitor neuron).
A - Of the somatic system. The afferent fibres run in the fifth nerve V, their cells lying in the Gasserian Ganglion, GG. These connect with the connector neurons lying close against the descending root of the fifth nerve, DSV. The connector neurons, in their turn, connect with the excitor neurons which lie in the nucleus of the twelfth nerve NXII.
B – Of the splanchnic system. The receptor neurons lie in the tenth nerve, X, with the cells lying in the ganglion of this nerve, VG, and connect with the connector neurons which lie in the dorsal nucleus of the vagus, DNX. Processes of the connector cells connect with the excitor neurons which lie in the nucleus ambiguus, NA, their processes form part of the tenth nerve, X.
C – Of the involuntary system. The receptor neurons run on the tenth nerve, X, with their cells in the ganglion of this nerve, VG, and connect with the connector neurons which lie in the nucleus intercalatus of Standerini, NI which forms part of the dorsal nucleus of the vagus, DNX. The processes of these connector neurons run out in the vagus nerve, X, and finally connect with the excitor neurons which lies on some peripheral organ; e.g. in the case of the intestine, lying in Auerbach's plexus, AP. (Gaskell)

The Nature of Parasympathetic Reflexes

We expect two groups of important reflex symptoms whenever an important thoracic or abdominal organ is involved in a severe inflammatory process: *(1) a group through the sympathetics which express themselves largely as motor, sensory and trophic reflexes in the skin, subcutaneous tissues and muscles, (2), a group through the parasympathetics which express themselves for the most part as motor, sensory, secretory and probably later as trophic reflexes in other viscera. This does not preclude the many vasomotor changes that probably result from sympathetic stimulation and the many reflexes in the tissues of the head and face which result from parasympathetic stimulation.*

There are probably innumerable vasomotor phenomena of a reflex nature which are caused by both afferent and efferent impulses coursing over the sympathetics, could we but recognize them. Prom a theoretical basis we suspect these and cannot help feeling that they account for some of the obscure symptoms which are met with in visceral disease.

In the preceding chapters I referred to the reflexes which take place between the sympathetic and spinal nerves as "visceromotor," "viscerosensory" and "viscerotrophic." following the nomenclature as suggested by Mackenzie for motor and sensory visceral reflexes. It would clarify the discussion if we prefixed the term "Sympathetic" to all such reflexes occurring in the tissues of the neck, chest, and abdomen, because they all originate from afferent stimuli which course over sympathetic sensory nerves. Likewise we should prefix the word "parasympathetic" to all such reflexes as express themselves in the skin, subcutaneous tissue and muscles of the face and head, because they all originate from afferent impulses which course over the parasympathetic nerves (vagus).

The importance of bearing the distinction between sympathetic and parasympathetic reflexes in mind is self-evident, for we also have reflexes arising in the parasympathetic sensory nerves of a motor, sensory and trophic, and still others of a secretory nature. These are for the most part, reflexes which arise in one organ and are expressed in another, and might with greater propriety than those arising in the sympathetics, be called visceromotor, viscerosensory and viscerotrophic. In order to avoid confusion, however, I shall suggest that they be called: "parasympathetic motor," "parasympathetic sensory," "parasympathetic trophic," and "parasympathetic secretory." It will thus be seen that we have one common reflex arising from parasympathetic afferent stimuli which occurs less often as a result of sympathetic stimuli, — a "secretory reflex."

Importance of the Parasympathetic Trophic Reflex

The trophic reflex of parasympathetic origin is not as readily recognizable as the trophic reflex of sympathetic origin. Yet its importance must be evident to anyone who studies the effect of continuous harmful stimuli upon nerve cells. To my own mind the parasympathetic trophic reflex becomes a very important factor in influencing the tissues so as to become receptive for the implantation of causative micro- organisms in such diseases as chronic pulmonary tuberculosis. I have suggested^ that the probable explanation of the fact that a tuberculous infection in the larynx is nearly always secondary to a long- time existing infection of the lung, is that it is a result of continuous reflex stimulation of the laryngeal nerves which supply this organ with trophic as well as motor and secretory impulses. This results in trophic changes in the tissues, causing them to become less resistant. In support of this suggestion, I would cite the commonly recognized fact that the laryngeal lesion is most apt to appear on the side which corresponds to the more chronic and greater inflammatory process in the lungs. I would further call attention to the importance of this parasympathetic trophic reflex in preparing the soil for implantation of bacilli in the intestinal tract. Infection in the intestine and larynx both manifest themselves as an implantation which takes place late in the disease, usually coming on after it has existed in the pulmonary tissue for a prolonged period of time. Its existence and peculiarities indicate that it is often a surface infection. Such a .surface infection would be facilitated by lowered resistance due to such trophic changes as result from the reflex parasympathetic stimulation.

Common Parasympathetic Symptoms and Syndromes

Many of the common symptoms which have been looked upon as being of a nervous type, the so-called "functional disorders," will be readily recognized as belonging to this group. Many of the cases of Hyperchlorhydria, nausea, spastic colon, bradycardia, asthma, hay fever, epiphora, cough, hoarseness, so-called nasal and nasopharyngeal catarrh, are due to reflex irritation of the parasympathetic fibers which activate the organ or structures involved, the afferent stimulus coming through the parasympathetics from the same or some other organ or organs. Other types are due to general parasympathetic irritability and are precipitated by either physical or psychical stimuli. In this class are included the phobias of the neuropath, so well described by Dejerine.[4]

The importance of these reflex symptoms may be inferred from the nerves which make up the parasympathetic group of the vegetative system. The system comprises all vegetative fibers in the IIIrd, VIIth, IXth, and Xth cranial nerves, and the pelvic nerve. All smooth muscle structures and all secreting glands supplied by these nerves as well as all structures supplied by the Vth, VIlth, XIth, and XIIth cranial nerves may be affected by parasympathetic reflexes. The closeness with which various organs are bound by reflexes seems to vary greatly; so does the direction, in which the reflex travels, vary. These is a close relationship, for example, between the various portions of the gastrointestinal canal; and it would seem from our clinical observation that the reflexes travel almost with equal facility in either direction. Next, there seems to be a close association between the gastrointestinal canal and those organs which belong to it embryologically, the respiratory tract, liver and pancreas. The heart is also closely bound to all of the above organs. In other words, all organs innervated by the vagus (Xth cranial nerve), are intimately bound together and are capable of readily transmitting reflexes to, and of receiving reflexes from, each other. In ease of the eye, the reflex influence on other organs is well established in case of eye strain. Many years ago Gould wrote voluminously on this point; but unfortunately the truths which he uttered were not well received. The eye is also unquestionably influenced by visceral disease, but here the data at hand do not make the point certain. The larynx seems to be influenced more than it influences other organs. These relationships will be made more definite in the clinical portion of this study.

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Chapter VIII

Sympathetic and Parasympathetic Syndromes

As is shown in the chapter dealing with the physiologic activity of the sympathetics and parasympathetics, and again in the discussion of the innervation of each particular organ and system of smooth musculature, the syndromes indicative of sympathetic and parasympathetic stimulation are wholly different.

Syndrome of Sympathetic Stimulation

If we consider the more important structures of the body, we send that stimulation of the sympathetics, either general or local, is followed by some of the following common symptoms met in disease:

Dilatation of the pupil ; protrusion of the eye ball ; lessened lachrymal secretion ; lessened salivary secretion ; lessened mucous secretion in the nose and throat; lessened secretion in the gastrointestinal tract, showing particularly as a hypochlorhydria and retarded digestion; lessened motility in the gastrointestinal tract, showing as a slowness in the peristaltic wave, contraction of sphincters of the gut, and a general relaxation of the intestinal musculature leading to limited dilatation and to the common type of constipation found in the acute infectious diseases ; rapid pulse and at times rise of blood pressure, al- though vasoconstriction in one area is usually accompanied by compensatory vasodilatation in others ; increase in glycogen content of the blood, its being forced from the liver; increase in body temperature due to (1) an increased production of heat resulting from increased chemical action,' and (2) decreased elimination due to vasoconstriction in superficial vessels; diminution in the amount of urine; contraction of the ureter; contraction of the uterus; goose flesh and increased sweating. Increased adrenal and thyroid secretion also follow sympathetic stimulation; and this in turn produces symptoms varying in degree according to the amount of extra secretion formed.

Syndrome of Parasympathetic Stimulation

Stimulation of the parasympathetics produces some or many of the following common symptoms: Contraction of the pupil; widening of the eye slits; increased lachrymation; increased secretion of the nasal, oral and pharyngeal mucous glands, conditions commonly known as catarrh ; increased salivary secretion ; contraction of the laryngeal muscles such as is met in laryngospasm ; increased bronchial secretion such as is met in bronchitis; spasm of the bronchial musculature as found in asthma; hypermotility and hypersecretion of the gastric glands including that of hydrochloric acid; hypersecretion and hypermotility of the intestine, leading to colicky pains and states of either spastic constipation and stasis or diarrhoea, depending much on the degree of stimulation and whether the circular or more longitudinal fibers are the recipients of the increased stimulation; irritable bladder; and incontinence of urine and faeces. Sweating is also found in conditions which are accompanied by the above group of symptoms, as well as those belonging to the sympathetic syndrome.

Special Service Rendered to the Organism by the Sympathetic and Parasympathetic Nerves

The sympathetic and parasympathetic nervous systems have separate and distinct functions to perform for the organism. Various phases of this question have been discussed by Cannon (2), Crile (3-4) Brown (5), the writer (6), and others. In this discussion I shall partially follow one of my recent papers (6). The sympathetic system, which includes, aside from the sympathetic division of the vegetative nervous system, those endocrine glands which are particularly strongly sympathicotropic, the adrenals and thyroid, governs man's defence. This is the system which reacts against such conditions as pain, shock, fear, anger, rage, injury and infections. It protects the individual against outward enemies; prepares him for resistance or flight and sustains him during the effort. It provides the nonspecific defence in case of infection. It is the protective and energy expending system of the body. It also presides largely over the genital system although erection of the penis is due to parasympathetic stimulation.

The parasympathetic system, on the other hand, provides sustenance for the individual. It presides over the ingestion and digestion of food; the ejection of the waste from the alimentary canal, and regulates respiration. Its function is to maintain the organism as an individual. It controls the food preparatory to storing it in the form of potential energy or incorporating it in the tissues while the sympathetics control the actual building up and tearing down processes.

There are also certain products of glands of internal secretion which are parasympathicotropic, among them may be mentioned, the internal secretions of the pancreas and parathyroids, and secretin which is produced by the duodenal glands near the pylorus.

Of the two divisions of the vegetative system the sympathetic is the more widely distributed, consequently sympathetic action is more general than parasympathetic. If we conceive of the body as a tube of which the skin, and structures allied to it embryologically, make up the outer surface; the gastrointestinal tract and the structures embryologically related to it, the inner surface; and the walls as being filled with vessels; then we are in a position to understand the relative extent of sympathetic and parasympathetic activity. The smooth musculature of the skin, the pilomotors and sweat glands; most of the urogenital structures, and the blood vessels of the body are innervated alone by the sympathetics. The sphincter muscles of the bladder and gastrointestinal canal are activated by the sympathetics and inhibited by the parasympathetics; while action of the muscles and glands of the enteral system is inhibited by the sympathetics. On the other hand, the parasympathetics furnish the appetite and carry on digestion. They supply all of the necessary juices, salivary, gastric, intestinal, pancreatic and biliary, for the digestion of food; and motor power to the intestine for mixing it with the secretions and propelling and ejecting it from the body. They also send inhibiting fibers to the sphincters, and some fibers to the urogenital system. In conjunction with the voluntary system they control the oxygen supply of the body through respiration, al- though the amount of oxygen required depends upon the double need for both anabolic and catabolic processes. It might be said that the parasympathetics control the intake and digestion of food and help provide the oxygen for its oxidation and then hand it over to the sympathetic control for distribution and utilization.

The sympathetic system presides largely over the reproductive organs of the animal, and protects him from harm; while the para- sympathetic system provides nourishment and energy which is stored to be utilized in his behalf in case of need.

This conception of the vegetative nerves and endocrine glands, points to four purposes which they are intended to fulfil; procreation, growth, nourishment and defence. These are factors of the greatest importance to the organism, when considered in its animal status.

Those functions performed by the sympathetic and parasympathetic systems necessarily dovetail somewhat into each other; for both food and oxygen must be carried to the tissues where oxidation takes place, and various waste products resulting from tissue action must be carried to their respective points of elimination by the blood vessels which are sympathetically activated structures.

It might at first thought seem strange that a protective mechanism which provides the individual with the means for escape from, or combat with, an enemy; or, for resisting an infection; or, for overcoming an injury; should have an inhibitory action upon the functions of the gastrointestinal canal which provides the nourishment which is the basis of the energy used for protection. But if we go way back in the stage of evolution we find that the life of the individual was short and that a suspension of its digestive activity was of little importance in comparison with its preservation from its enemies. A heroic effort was often immediately necessary; and it was all important that the entire energy of the body be directed toward the supreme task of defence, otherwise the animal would perish.

The parasympathetics have little opportunity to interfere with sympathetic action in the defence program, because their action is so limited in the sympathetically activated structures. They have no connection with the sweat glands and pilomotor muscles; little with the genitourinary system; and come into play in the circulatory system chiefly in their inhibitory action upon the heart. They seem further to play no part in the innervation of the adrenals, pituitary or thyroid, and probably have no control over glycogen when it has once been stored in the tissues for use. So, while the organism is provided with food and oxygen by the parasympathetics, they seem to have no veto upon its use when once provided.

There are stages in the development of animal life in which the organism is provided with energy only by means of internal secretions; and others in which they are supplied by both internal secretions and nerves of simple and comparatively rudimentary action; as the organism becomes still more complex, however, a complicated central nervous system is developed which is presided over by the will, whose particular function it is to correlate and integrate the function of all parts of the body.

"When this stage of development has been readied, the vegetative system, composed of the glands of infernal secretion and the sympathetic and parasympathetic nerves, is no longer an independent system. While these are still able to carry on the functions of the body, for a time and after a fashion, even though separated from the central nervous system; yet, as long as they are connected with it, they are subject to stimuli which arc transmitted to it through the central nervous system, and to ideas and emotions which arise in the psychical centres.

It is a long way, developmentally speaking, from the opening and closing of the oscula' of the sponge in response to the movements of sea water, or the response of the earthworm, with its simple nervous system, to outward stimuli, to the fine adjustments and responses of man with his well-developed and finely adjusted central nervous system, and his psychical centres. Yet, throughout all this gap the same vegetative functions have been cared for in the same general way. The vegetative nervous system and the glands of internal secretion of man serve him in the same manner, only more elaborately, than they served organisms way down in the scale of evolution.

General Sympathetic Responses

We shall now discuss briefly some of the functions which are performed by these systems.

Defence Against an Enemy. Tt is now evident that stimuli which affect the human body may be either of physical or psychical origin. A man sees a source of danger, he is imbued with fear and decides to either defend himself or make his escape. Whichever course he decides upon he wills to bring the necessary muscles into action.

But this decision would be entirely useless if it were not for the vegetative nerves and endocrine glands, muscles cannot perform work except they are provided with glycogen and oxygen for its oxidation. Six or eight times as much blood must pass through muscles, which are in action as when at rest, in order to supply the needed energy. A certain amount of glycogen is stored up in the tissues, particularly the muscles and the liver, ready to be used at any time. When the struggle comes, if it is of short duration this stored supply may be sufficient for the purpose; if not, more must be provided by the ingestion and digestion of food or by transforming the body tissues into glycogen. All of this requires oxygen and the tissues at a given time have only about enough oxygen for their actual needs; so pulmonary ventilation increases from a normal of 5 to 8 litres to 30 or 50 litres per minute; or if the struggle is exceedingly severe to 100 litres or more per minute. Much of this preparation is accomplished by the vegetative systems.

It may be necessary that this defence be called into action at once. This is accomplished through the higher centres. The emotion of fear and the desire for self-preservation cause psychical impulses to be transmitted to the proper centres in the brain and cord, and, even before the individual moves a muscle in the struggle, impulses are sent by way of the sympathetic centres in the brain through his sympathetic system (nerves, adrenals and thyroid) ; as a result of which his heart beats rapidly carrying more blood to the muscles and brain, the glycogen is forced from the liver so it can be delivered to the muscles, the blood pressure rises to insure a more rapidly flowing stream, the coagulation power of the blood increases, ready to check the flow of blood in ease of injury, his pupils dilate, his hair stands on end, his sweat glands become active in order to eliminate the excess of heat produced in the struggle; and at the same time there is an inhibition of action in the gastrointestinal tract so that all energy may be directed for the time being to the brain, heart and muscles which require all possible energy for the conflict. When the struggle begins, these conditions are maintained as long as is necessary or until the mechanism of defence is exhausted and the individual is overcome. As energy is used up and acids are formed in the blood they stimulate the respiratory center and cause pulmonary ventilation to keep pace with the demand for oxygen. This last function is the only one of all the important phenomena connected with the struggle against outward foes in which the parasympathetics seem to take any considerable part.

Infections. — So is it in infections; the struggle for the destruction of toxins as it effects vegetative structures is manifested through the sympathetic system — a dry skin, lessened elimination with increased production of heat resulting in a rise of temperature, rapid pulse, increased thyroid and adrenal action, and an inhibitory effect on the gastrointestinal tract as shown in a loss of appetite, and a decrease in secretory and motor power of the stomach and intestines, producing slow digestion and constipation. It is thus seen that those phenomena which arc most evident in the normal defence of the organism against infections prior to the production of specific cellular reaction belong to the syndrome of sympathetic action. The phenomena attendant upon the condition of anaphylaxis, however, are recognized as belonging to parasympathetic syndromes.

The combat of infections is also accompanied by psychic stimuli, but these are of little or no importance in starting action in the defensive mechanism.

It will be appreciated that there is a marked difference between the body's reaction to the severe acute infections and the more chronic and milder ones. In both of these the defence may eventually break down, but in the acute cases we can sometimes study it more readily, where the patient goes into collapse with rapid, inefficient heart muscle, low blood pressure, sweating and falling temperature. In some severe infections recovery is followed by marked asthenia. This was seen often following influenza during the recent pandemic. It is evidence of general nerve injury but particularly of the sympathetic system. There is also probably a hypoadrenia, the glands failing to recover quickly from the injury. This same condition of condition of the mechanism of defence is a part of the picture in chronic infections like tuberculosis.

Shock. — Shock is another condition which shows marked disturbance of the sympathetics. This is favoured by the person receiving an injury when his defensive mechanism is already injured by such conditions as fatigue, excitement, exposure and infection. The condition of the control of the vessels in shock is such that it seems like a sympathetic paralysis. Blood pressure falls, fluid transudes into the tissues, and the capillaries are found dilated and filled with corpuscles.

Injury and Asphyxia — In conditions of injury and asphyxia it is the sympathetic system that bears the brunt of the struggle.

High Blood Pressure. — There is a high blood pressure which is commonly met, particularly in women, which is due to sympathetic stimulation; and, it is quite possible that prolonged harmful stimulation of the sympathetics might result in arterial degeneration.

General Parasympathetic Responses

Anaphylaxis affords an example of a general stimulation which affects the parasympathetics,' Mild anaphylaxis shows the following symptoms: Bronchial spasm and increased bronchial secretion, nausea, vomiting, diarrhoea, and itching of the skin. Severe anaphylaxis shows increased motility of the intestinal tract with relaxation of the anal sphincter resulting in involuntary discharge of faeces; increased activity of the bladder musculature with relaxation of the sphincter, causing incontinence of urine; perspiration; low blood pressure; fall in temperature and collapse. From this we conclude that the symptoms of anaphylaxis, except those of severe anaphylaxis in which the higher centres are predominantly affected, belong to the parasympathetic syndrome.

Local Parasympathetic Syndromes

Local syndromes of parasympathetic stimulation are common; such as hay fever, due to hyperirritability of the Vth and VIIth cranial nerves; asthma, due to hyperirritability of the pulmonary branches of the vagus; hypermotility and hyperchlorhydria which may be due to hyperirritability of the gastric vagus, and increased motility and secretion in the intestine, and spastic constipation, due to hyperirritability of the sacral innervation of the colon.

It must also be remembered, however, that hyperchlorhydria may be due to a marked stimulation of the sympathetics controlling the pylorus which causes a contraction of the sphincter muscles, thus interfering with the emptying of the acid contents. .

Antagonism of Sympathetic and Parasympathetics

In order to make the antagonistic action of the sympathetics and parasympathetics in the important structures of the body more apparent, I append the table on page 113.

The antagonistic action of the sympathetics and parasympathetics is evident in all structures where these two components of the vegetative system meet. Their normal action maintains physiological equilibrium in these structures the same as antagonistic nerves maintain balance in the voluntary system. This has been described by Meltzer,[8] as the law of *contrary innervation*.

Effect of Stimulation or Sympathetic and Parasympathetic of Important viscera

	Sympathetic	**Parasympathetic**
Pilomotor muscles	Stimulate	No effect
Musculature of sweat glands	Contracts muscle and forces sweat out of gland	No effect
Sweat glands	Stimulate	Possibly stimulate
Vasomotor system	Contract or dilate according to strength of stimulus	No general effect, dilate in a few structures
Heart	Increase rapidity	Slows
Eye	Dilate pupil, contract Mullerian muscle	Constrict pupil
Lachrymal glands	Decrease secretion	Increase secretion

Mucous membrane of nose and throat	Decrease secretion	Increase secretion
Respiratory tract	Relax musculature and decrease secretion	Stimulates musculature, increases secretion
Salivary glands	Decreases watery component of secretion	Stimulates watery component of secretion
Intestinal tract	Relax musculature and decreased secretion and control blood vessels	Stimulate musculature and increased secretion
Sphincters	Contract	Relax
Ureters	Constrict	No effect
Uterus	Constrict	No effect
Bladder	Contract muscles of trigone and sphincters, relax musculature of body	Relax muscles of trigone and sphincters and stimulates musculature of body

Figure 24 Effect of Stimulation or Sympathetic and Parasympathetic of Important viscera

We meet disturbances in the working of this law in many clinical syndromes, such as pylorospasm, cholecystitis, and inflammation of the biliary passages, patulous iliocaecal valve and other sphincter disturbances. We also see it in hay fever, asthma, and the various changes in motility and secretory activity of the gastrointestinal tract. This contrary innervation is taken into consideration in the treatment of spastic constipation by enemas of magnesium sulphate and in transduodenal lavage in cholecystitis and diseases of the biliary passages in which the same salt is used.

Degenerations

From our study of reflexes, it can be seen that a reflex action continuing for a prolonged period of time, has deleterious influences upon the nerve cells which are active in producing the reflex. In the skeletal tissues this is shown in such trophic reflexes as I have described in connection with inflammation of the lung and kidney. We may also infer that the same trophic change occurs in the internal viscera when nerve cells or the nerve components of a reflex are kept in continuous action over a long time. This I have mentioned on page 102 ill connection with the reflexes in the larynx and in the intestinal tract causing degenerative changes and preparing the soil for the implantation of the tubercle bacillus. It seems to me perfectly rational to consider that degenerative processes result from interference with the normal trophic stimuli to a part or organ.

With this in mind I would suggest the possibility of the thickening of the arterial walls, such as we see in amyloid degeneration in the presence of chronic suppuration, and in general arterial degeneration, being due to the action of toxins upon the sympathetic neurons. It is not at all improbable that continuous action of toxins upon sympathetic nerve cells would result in injury to them and in trophic changes in the tissues which they supply; and inasmuch as the entire vascular system is innervated by the sympathetics, it is probable that such changes should result from toxins acting upon the vasomotor neurons. This .suggestion would include amyloid and atheromatous degeneration as a part of the sympathetic syndrome. I do not make these assertions as facts, but only for the purpose of stimulating thought along this line.

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Part II

Innervation of Important Viscera With a Clinical Study of the More Important Viscerogenic Reflexes

Chapter IX

Introductory

In Parts I and III of this monograph, I have endeavoured to lay the foundation for the application of known physiologic facts pertaining to vegetative or visceral neurology, to the everyday practice of clinical medicine. While I realize fully that all clinical phenomena expressed in tissues supplied by visceral nerves cannot be satisfactorily explained alone by the study of their relationship to the nerves which supply these tissues, yet such a study will greatly simplify many of our clinical pictures, facilitating diagnosis and aiding in the application of therapeutic measures. By bearing in mind that the visceral nerves are supplemented in action by various chemical substances, such as the normal products of the endocrine glands, and disturbed by pathology substances resulting fi-om normal and abnormal metabolic activity; and that visceral nerves are markedly influenced by physical and psychic states; and further that the relative irritability of the cell bodies of the sympathetic and parasympathetic systems differ in different individuals, and that this irritability may van' in the different organs of the same individual; one has before him the chief variants which account for the variability of symptoms in diseases of internal viscera. One must not expect visceral neurology to explain everything. If only it is accepted for what it will explain, it will well repay most careful study.

Grouping of Structures Supplied by the Vegetative Nerves

Before proceeding to the clinical discussion, it is well to call to mind the classification of the tissues supplied by the vegetative nerves according to their embryologic formation; for this makes clear their innervation. This has been discussed in Part III, page 198, but I shall repeat the salient facts here. A study of Plate I, p. 50, will acquaint one with the innervation of the principal structures supplied by the vegetative nerves.

The structures which are supplied by the vegetative nerves are numerous and scattered throughout the body, yet they may be classified in few groups, thus:

1. The Subdermal Musculature. A group known as the subdermal musculature, because it is situated immediately under the akin. It consists of the pilomotor muscles and the muscles of the sweat glands. It is innervated by the sympathetic nerves alone.

2. The Vasodermal Musculature. The smooth muscle in the walls of the blood vessels and the muscle of the heart, which Gaskell believes is related to the skin muscles, hence calls the vasodermal musculature. This is activated throughout by the sympathetics. In the heart there are parasympathetic fibers which have an inhibiting influence upon the heart muscle. Some parasympathetic dilator fibers exist also in the vessels in certain structures, as noted on page 99.

3. The Sphincter System. The sphincter system of the genitourinary and gastrointestinal tracts are supposed by Gaskell to have originally been a part of the dermal musculature which has slipped into the gut in the same way that the parasympathetically controlled musculature has gained access to the heart. The sphincters are activated by the sympathetics and receive inhibitory fibers from the parasympathetics, the opposite; from the other structures in the gastrointestinal canal.

4**. The Urogenitodermal System**. This system consists of most of the structures belonging to the genitourinary system. It is formed from the segmental duet. Its name as suggested by Gaskell shows its relationship to the dermal tissue. This system is activated by sympathetic nerves; and most of the structures belonging to it arc void of parasympathetic fibers, as described in Chapter XXVI.

5. The Enteral System of Musculature. While those tissues in Group 1 to 4 belong to the dermal system, are formed from the ectoderm, and are activated by the sympathetics, the enteral system is derived from the endoderm and activated by the parasympathetics. The former consist of musculature which lies or originated immediately under the skin; the latter, of a musculature lying or originating immediately under the surface of the gut. The enteral system is activated by the parasympathetics and receives inhibitory fibers from the sympathetics. This system consists of the entire gastrointestinal canal, with the exception of the sphincters; the respiratory system; liver; pancreas; and bladder, except the trigone.

6. Smooth Musculature of the Head. There is a group of muscles belonging to the structures of the eye which receives its innervation from the vegetative system, and which is important because of its reflex relationship with other nerves; likewise the lachrymal gland and certain Structures in the nose, accessory sinuses, pharynx and larynx, which are vegetative in character.

In our clinical discussion I shall preserve the grouping of the viscera as accurately as possible, according to the systems to which they belong. The chapters shall follow, however, without mention of the transition from one system to another. Since the enteral system is of the greatest interest from the standpoint of the study of reflexes, and can be used to greatest advantage in illustrating the physiologic relationship which exists through both divisions of the vegetative nervous system, I shall discuss it first.

The Enteral System

It will be noticed that practically all structures belonging to this system are innervated by both parasympathetics and sympathetics,

I mention parasympathetics first because all of these structures except the sphincters are activated by the parasympathetics. Muscular contractions are produced by stimulation of the parasympathetics, and the activity of the secretory glands is increased by stimulating them. Stimulation of the sympathetics on the other hand, produces an inhibitory effect both upon all muscles except the sphincters, and upon the secreting glands. When these two systems of nerves equalize each other, normal physiologic function results, but when either system is stimulated at the expense of the other, then the physiologic balance is disturbed and symptoms result.

It will be further noticed that nearly all structures belonging to this system, the oesophagus, stomach, small intestine, (ascending and transverse colon, according to some authors) liver, pancreas, pharynx, larynx and lungs, are activated by the vagus nerve. It will be noticed further that the enteral system is the system which is *particularly* activated by the vagus nerve. The only other real important structure which is cared for by it is the heart. Because of this close relationship in innervation, there is a very close reciprocal relationship between the various organs making up the enteral system; also between them and the heart; and a disturbance in one of these organs causes reflex disturbance in other organs supplied by the vagus nerve more readily than it does in organs supplied by the parasympathetic fibers coursing in other nerves. This relationship is shown in Plate V (Fig 26) from Gaskell.

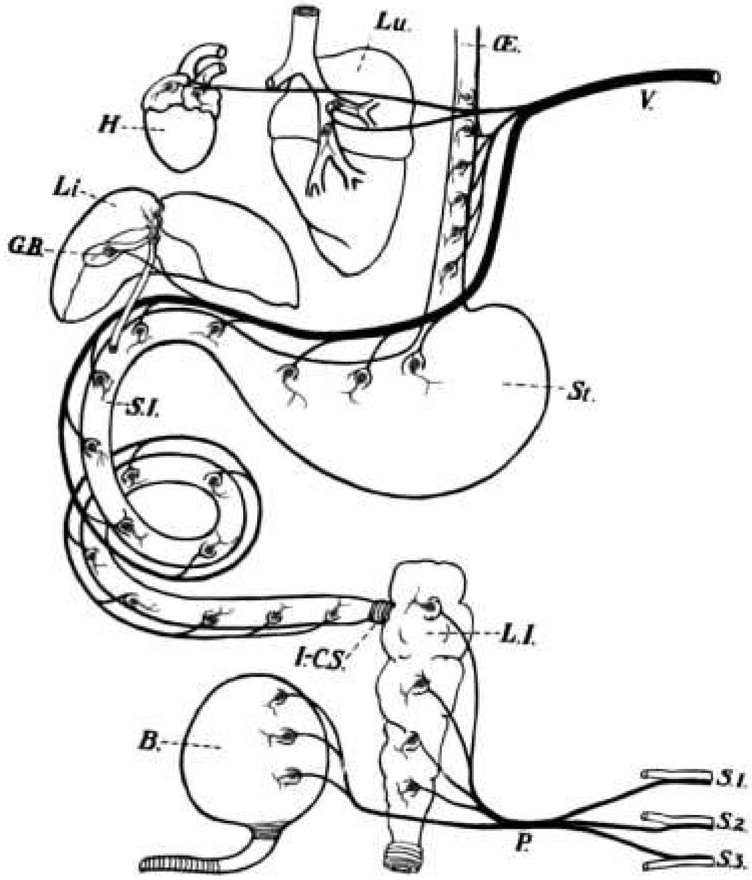

Figure 25. Plate V. Distribution of the connector fibres (black) and excitor neurons (red) in the bulbo-sacral or enteral system.
The vagus nerve, V, contains the connector nerves of the excitor nerves of the main viscera, I.C.S. The motor neurons lie in all the organs themselves.
The pelvic nerve, P., contains the connector fibers of the sacral outflow and connects with peripheral excitor neurons on the large intestine and bladder.
The vagus nerve thus contains the connector neurons to the motor cells of the heart, H., which have to do with the slow nave-like contraction which is only found in certain tortoises, such as Kmya Europea, and does not appear to exist in higher forms. The vagus nerve also contains the connector fibers to the excitor neurons on the bronchi in the lung, Lu., and also the connector fibers to the exciter neurons on the gall bladder end bile duct lying on the liver, LI.; it also contains the connector fibers to the excitor neurons of the oesophagus, OE.; the stomach, St.; and the small intestine, S.I.; which here lie between the muscle layers in Auerbach's' plexus.
The Pelvic nerve, P, which arises from the three sacral roots, S1, S2, S3, also contain the connector nerves of the excitor nerves to the small intestine, L1, and also the connector fibres of the excitor neurons of the body of the bladder, B
Many physiologists describe the variation as supplying the colon as far as the descending portion as mentioned in the text. (Gaskell)

The interrelationship of the various portions of the enteral system, also the interrelationship of the organs of the enteral system and the heart and lungs, may be inferred from Fig. 28, page 93. This shows the vagus extending from the oesophagus to the descending colon although Gaskell teaches that the vagus supplies the small intestine only and the sacral nerve the entire colon. In all tissues supplied by the vagus it furnishes the activating fibers. In each organ, however, with possibly the exception of the oesophagus and the cardiac end of the stomach, it is opposed in its action by inhibiting fibers which belong to the sympathetic system, shown in the figure as arising from the semilunar, aorticorenal and superior mesenteric ganglia. These latter are shown as one large ganglion in the figure. It will also be noted that the descending colon, rectum, and bladder are cared for by the lumbar and sacral portions of the cord. The parasympathetic fibers arising in the sacral portion of the cord, and coursing in the pelvic nerve, activate these structures. The sympathetic fibers whose cells lie in the superior mesenteric ganglion and which are connected to the central nervous system by connector neurons arising in the lumbar portion of the cord, furnish the inhibiting fibers to the descending colon, rectum, and bladder.

The preganglionic fibers from the thoracic and upper lumbar segments of the cord representing the sympathetic system are indicated by solid lines, which end in ganglia. These are the "connector neurons" of Gaskell. They are medullated. They end in motor cells in the ganglia; and the fibers emerging represented in the figure by broken lines, are nonmedullated. These latter are the true sympathetic motor fibers.

The fibers of the pelvic and vagus nerves, representing the parasympathetic system, are indicated by solid black lines ending in cells which lie within the organ innervated. No ganglia interrupt the parasympathetic fibers until they enter the organ supplied.

The genuine parasympathetic system of nerves for the enteral system lies within the walls of the organ. In the intestine it is represented by the plexuses of Auerbach and Meissner. The motor cells to the bronchi, liver, pancreas, colon, and bladder also lie within their walls. The vagus and pelvic nerve which connects these motor cells with the medulla and cord are not in reality the motor nerves to them but only "connectors."

The innervation of the sphincters is not illustrated in this figure. The ileocecal, rectal, and vesical sphincters are activated by the sympathetic fibers and receive their inhibiting fibers from the vagus and the pelvic nerve, as shown in Plate VI.

The symptoms which arise on the part of the organs belonging to this system may be grouped cither around the sympathetic nerves or the parasympathetic nerves. This holds for both organic and so- called "functional diseases." An alteration in either muscular action or secretory function is an expression of disturbance in nerve equilibrium. This may result either from a disease in the organ itself, disturbance of nerve equilibrium through central stimulation, or a reflex from some other organ which is bound to it through its nerve supply. It is important for the clinician to learn to think in terms of visceral neurology.

As a matter of differential diagnosis between organic and functional disturbances, it may be stated broadly that a 7nofor or secretory disturbance in any important organ belonging to the enteral system, unless accompanied by sensory, motor, or trophic reflexes in the skeletal structures, is not due to inflammatory organic change in the tissues of that organ. The only exception to this statement which occurs to me would be found in conditions where the amount of tissue involved in the organic change would be so small in extent or the irritation so mild in degree that the reflex action would involve so few efferent neurons as not to be detected; or it might be the stimulation would be so mild as not to be able to overcome the resistance in the nerve cells and make itself evident in reflex action. It cannot be assumed however, that all disturbances accompanied by pain are due to organic changes in the viscera, as, for example, pylorospasm is sometimes accompanied by some pain and yet not due to organic change, so are colicky pains often present which are not dependent upon organic lesions in the gut.

We can now approach the various reflexes which manifest themselves upon the part of the stomach, intestines, liver, pancreas, respiratory tract and bladder in a manner to make them intelligible. In these reflexes we often have a definite help in differentiating organic from inorganic lesions. One must not forget, however, that there are many complex conditions which arise, and many complex causes of symptoms which must be considered. One is safe in assuming, in discussing diseases of the viscera belonging to the enteral system, that a parasympathetic stimulation tends to produce reflexes in both the organ in question and in other organs; and that they are prone to show moat markedly in other organs belonging to the same (enteral) system. A sympathetic stimulation, on the other hand, tends to cause reflex action comparatively easy of recognition, principally in those tissues supplied by spinal nerves which mediate with the afferent sympathetic nerves in the cord; and that such stimulation produces the visceromotor, viscerosensory and viscerotrophic reflexes, which are expressed in the skeletal tissues, as described in Chapter VI.

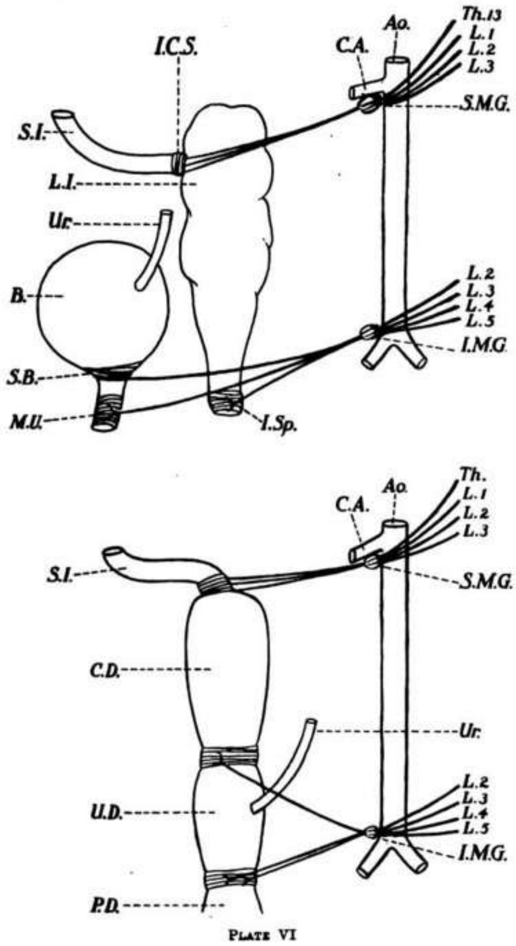

Figure 26. Plate VI. The connector fibres and excitor nerves of the sphincter system of the involuntary muscles. The upper figure shows their arrangement in the mammal and the loner figure their arrangement in the reptile (young crocodile). The connector neurons form two groups: an upper group rising from tbc last dorsal and first three lumbar roots and all running to the superior mesenteric ganglion, S.M.G., which lies at the point of origin of the celiac axis, C.A., from the aorta, Ao,, and a lower group rising from the second to fifth lumbar roots, L.2 to L.5, and running to the inferior mesenteric ganglion, I.M.G., which is situated just above the bifurcation of the aorta. The excitor neurons from the superior mesenteric ganglion innervate the ileocolic sphincter muscle, I.C.S., which lies at the junction of the small intestine, .S.I. and the large intestine, L.I.. The excitor neurons in the inferior mesenteric ganglion supply in the mammal the internal sphincter muscle, I.C.S., the sphincter of the bladder, SS., and the muscle of the urethra, M.V.

The cavities of the bladder and large intestine are hero entirely separate, but have been evolved from the arrangement shown in the lower figure. In the reptile the cloaca is composed of a continuous tube divided into three portions. 1. The coprodeum, CD, which corresponds to the large intestine of the mammal. 2. The urodeum, U.D., which corresponds to the bladder cavity of the mammal and into which the ureters, Ur., open, and 3, the proctodeum, P.D., which is the hindmost chamber. A muscle corresponding to the internal sphincter of the mammal separates the coprodeum from the urodeum, and is innervated by excitor neurons in the inferior mesenteric ganglion. A similar muscle also separates the urodeum from the proctodeum; this corresponds with the sphincter muscle of the bladder and the muscles of the urethra, and is innervated by exciter neurons in the inferior mesenteric ganglion. (Gaskell.)

Parasympathetic reflexes will be recognized as an increased muscular and secretory activity throughout the structures of this system with the exception of the sphincters of the gut which will be relaxed.

Sympathetic reflexes will show as spasm of the skeletal muscles, as in appendicitis, gall bladder diseases and pulmonary inflammation; as pain in the skin areas and muscles which are reflexly bound to the organ inflamed, through the spinal sensory nerves; and in atrophy of the soft tissues when the inflammation of the viscus becomes chronic.

Familiarity with these reflexes must not cause the observer to think that the study of symptoms is so simple a matter as tracing the paths of reflexes. Sometimes a reflex action which should he expected will not be present; and at other times action will be due to causes which are not reflex in character. When an important organ is inflamed *there is a tendency* for the different impulses to cause reflex action although such action may not materialize in symptoms which are recognizable.

Tissues Activated by the Sympathetics

It is evident that the tissues belonging to Groups 1, 2, 3 and 4, will not present the same number of reflexes as are met in the enteral system. The fact that some of the structures, such as the blood vessels, pilomotor muscles and muscles of the sweat glands, consist of small amounts of muscle widely scattered, makes the reflex from them less important. The nerves supplying the tissues arise from segments widely scattered, hence there is not sufficient concentration of afferent stimuli to produce recognizable reflexes. In other structures, notably the urogenitodermal tissues, the organs again, in part, become more important, have an innervation which comes from a more limited area of the cord, hence show reflexes on the part of the sympathetic and spinal nerves in much the same manner as the organs of the enteral system.

The Eye

The eye is in relationship with both sympathetics and parasympathetics, and shows symptoms dependent upon both sets of nerves.

The Lachrymal Glands and the Vegetative Fibers in the Nose, Accessory Sinuses, Pharynx and Larynx

These structures are important from both the standpoint of originating impulses which cause reflexes in the viscera, such as asthma resulting from nasal and sinus affections; and as being tissues which are influenced reflexly by stimuli arising in other viscera, such as cough and hoarseness produced by stimuli originating in the pulmonary and pleural tissue and the increase in nasal and pharyngeal secretion (catarrh) caused by stimuli arising in the lung and gastrointestinal tract.

In my description of the various organs and systems, I shall make no attempt to exhaust the number of reflexes that may occur, but only to describe those which are most evident and thus make plain the paths through which they travel. Those dealing with the respiratory system will be found more complete than the other systems, because my opportunities for observation have been greater in this line.

The clinical discussion of each organ will be preceded by a brief description of its innervation, believing that this will increase the interest in the anatomic and physiologic aspects of the subject, as well as add to the clearness of this discussion.

Chapter X

Oesophagus

I. Innervation of the Oesophagus

The upper third of the oesophagus is composed of striated muscles. The lower two-thirds is composed of unstriated and is innervated by the vegetative system.

Swallowing is a reflex act. It is partially voluntary and partially involuntary. The oesophagus is composed of both circular and longitudinal fibres. The sensory fillers in the soft palate (trigeminal) are the starting point for the swallowing reflex. Stimulation of the glossopharyngeal inhibits swallowing; central stimulation of either the superior or recurrent laryngeal, promotes it. The most important part in the act of swallowing as parried on in the oesophagus, is performed by the recurrent laryngeal which sends four branches to the oesophagus. The oesophagus, like the other parts of the gastrointestinal canal, possesses ganglia of its own, which form plexuses on the surface of the smooth muscle, instead of between the layers as in other parts of the intestinal tract. Fig. 18 shows the innervation of the muscles of deglutition.

It is generally accepted that no sympathetic fibers go to the oesophagus, hut that tonus is maintained by both activating and inhibiting fibers belonging to the vagus. The movement of the bolus in the oesophagus is performed by n reflex excited by its presence, which consists of a relaxation of the muscular fibers below and a contraction of those above. This we know as the law of the intestines.

II. The Oesophagus: Clinical Consideration

When passing through the oesophagus, fund excites a reflex which causes the muscular lone of the stomach to relax. Hurst' describes the relationship of this reflex to the sensation of fullness, either in normal or dilated stomachs.

The tonus of the stomach remains fairly constant no matter whether it contains little or much. This tonus is maintained probably through the vagus alone in the cardiac end of the stomach while in the pyloric portions it results from the activity of the vagus and sympathetic nerves balancing each other. Pressure in the stomach calls forth a sensation of fullness.

The oesophageal reflex performs a very important function, each time that a holus of food goes through the oesophagus, an inhibiting impulse is sent to the stomach musculature through the vagus, which decreases its tonus and causes the walls to relax, and enlarge the stomach cavity to the extent necessary to receive the additional food. A sensation of fullness indicates that the muscles are taut and gives the individual the feeling of satiety. The oesophageal reflex then is one whose purpose is to prepare the stomach for the incoming food.

This action is exerted upon the cardiac end of the stomach where the vagus alone controls the muscle tonus.

The oesophagus furnishes one common sensory reflex, that of head or brow ache which accompanies the rapid eating of very cold substances, such as ice, ice cream and water ices. Hurst[2] accounts for this as being a referred pain in which the afferent sensory impulse courses from the lower end of the oesophagus through the vagus and the efferent impulse passes out over the sensory fibers of the Vth nerve. This relationship is evidence of the fact that the vagus and the sensory portion of the Vth cranial nerve have the same relationship to each other as the sympathetics and the spinal sensory nerves.

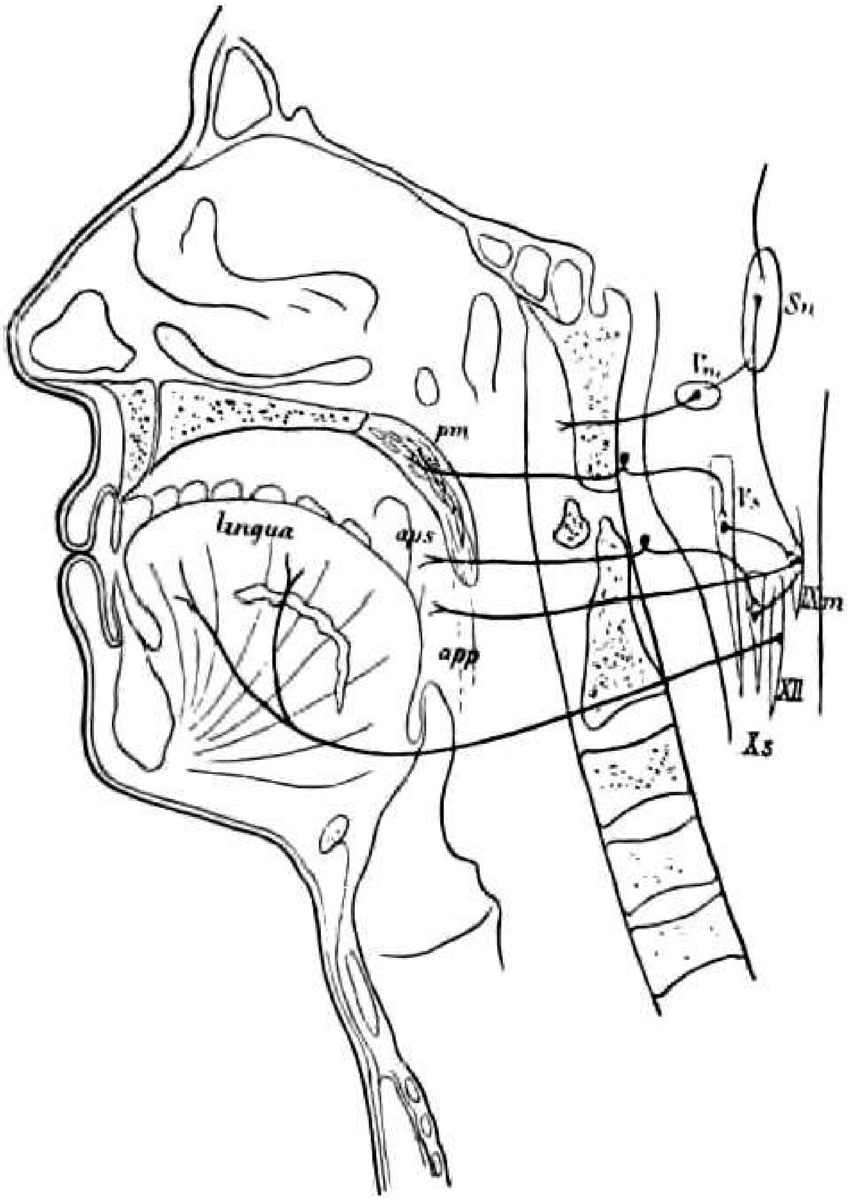

Figure 27. Showing the innervation of the muscles of deglutition. Sn – substantia nigra; I'm – Motor centre for trigeminus; I's – sensory root for trigeminus; IXm – motor centre for glossopharyngeus; XII – centre for hypoglossal; Xs = sensory centre for vagus; pm – soft palate; aps – arcus palatoglossus; app – arcus palatopharyngeus. (Bechterew)

Stricture of the oesophagus may be dilated with little pain; and cancer of this organ is often comparatively painless. These clinical facts may be taken as proof of the paucity of sympathetic fibers in the oesophageal wall. The fact that some pain is present, however, might be taken to indicate that there is not a total absence of sympathetic nerves, but that a few stray fibers are distributed to this organ. From the usual location of the pain over the sternum, one might infer that such fibers probably arise from the 2nd, 3rd, 4th and 5th segments of the cord, just above those which supply the stomach. In harmony with sensory reflexes in other portions of the intestinal canal, sensory sympathetic fibers arising from these segments would carry impulses back to the cord and transmit them to the 2nd, 3rd. 4th, and Vth sensory spinal nerves which would transfer the pain to the periphery, in this case to the area over the sternum. In a case of cancer of the oesophagus, the details of which were recently given me by a friend, the patient suffered from pain in the upper left chest and down the inner aspect of the arm. This is further evidence of the probability of the oesophagus having sympathetic fibers, and further indicates that they belong to the upper thoracic segments of the cord. This pain occurred in the same area as that from cardiac affections.

If there are no .sympathetic afferent fibers in this organ, then this pain must be considered as being, contrary to Mackenzie's rule, in the oesophagus itself.

Bibliography

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Chapter XI

The Stomach

I. Innervation of the Stomach

The stomach is a part of the great enteral system of the body, which comprises the entire gastrointestinal tract and all structures which are embryologically derived from it, such as the respiratory system, the liver, pancreas, and part of the genitourinary system. Its innervation is shown in Plate V, Fig 26, also in Plate VI (Fig 27) from Gaskell, page 118.

The gastrointestinal tract offers a splendid opportunity for studying the antagonistic action of the sympathetics and parasympathetics. The innervation of all of these tissues is alike in that both musculature and glandular structures are activated by the parasympathetics, and all receive inhibitory impulses from the sympathetics, with the exception of the sphincters and the possible exception of the cardiac end of the stomach and oesophagus. An equilibrium of action is maintained when the excitability of the parasympathetics and sympathetics equals each other, or when the excessive excitability in the one is still short of overcoming the excitability of the other.

Parasympathetics. The stomach receives its motor fibers from the vagus, the principal nerve of the parasympathetic system. Stimulation of the vagus has a tendency to produce two distinct actions:

1, An increased tone in or a contraction of the musculature of the stomach; 2, increased activity of all the glands of the stomach. Abnormally increased vagus stimulation results in hypermotility, and an increase of gastric secretion including hydrochloric acid.

The motor cells which supply the stomach lie in the walls of the organ itself, while the connector neurons well as medullated fibers from the visceral nucleus of the vagus to connect with them after entering the organ.

The fibers of the vagus supply the entire stomach, pylorus and cardia, and the lower third of the oesophagus.

Sympathetics. The sympathetic nonmedullated fibers going to the stomach have their motor cells in the semilunar ganglion the same as those to the liver and spleen. The medullated connector fibers which run from the spinal cord arise from the 5th to the 9th thoracic segments. While these are the same segments which supply the small intestine, we assume that the upper segments, particularly, supply the stomach; and the lower ones the intestine; because the reflex pains from the two are reflected in this order. See Fig. 10, page 48.

Sympathetic fibers are distributed freely to the pyloric end of the stomach, but fail to appear or arc found only sparingly in the cardiac end.

The sympathetics have the property of inhibiting the activity of both musculature and secreting glands, and when markedly stimulated decrease both motility and secretory activity. When the sympathetic fibers of the stomach are markedly stimulated, the musculature relaxes, and hypomotility with a decrease in the normal acidity may result.

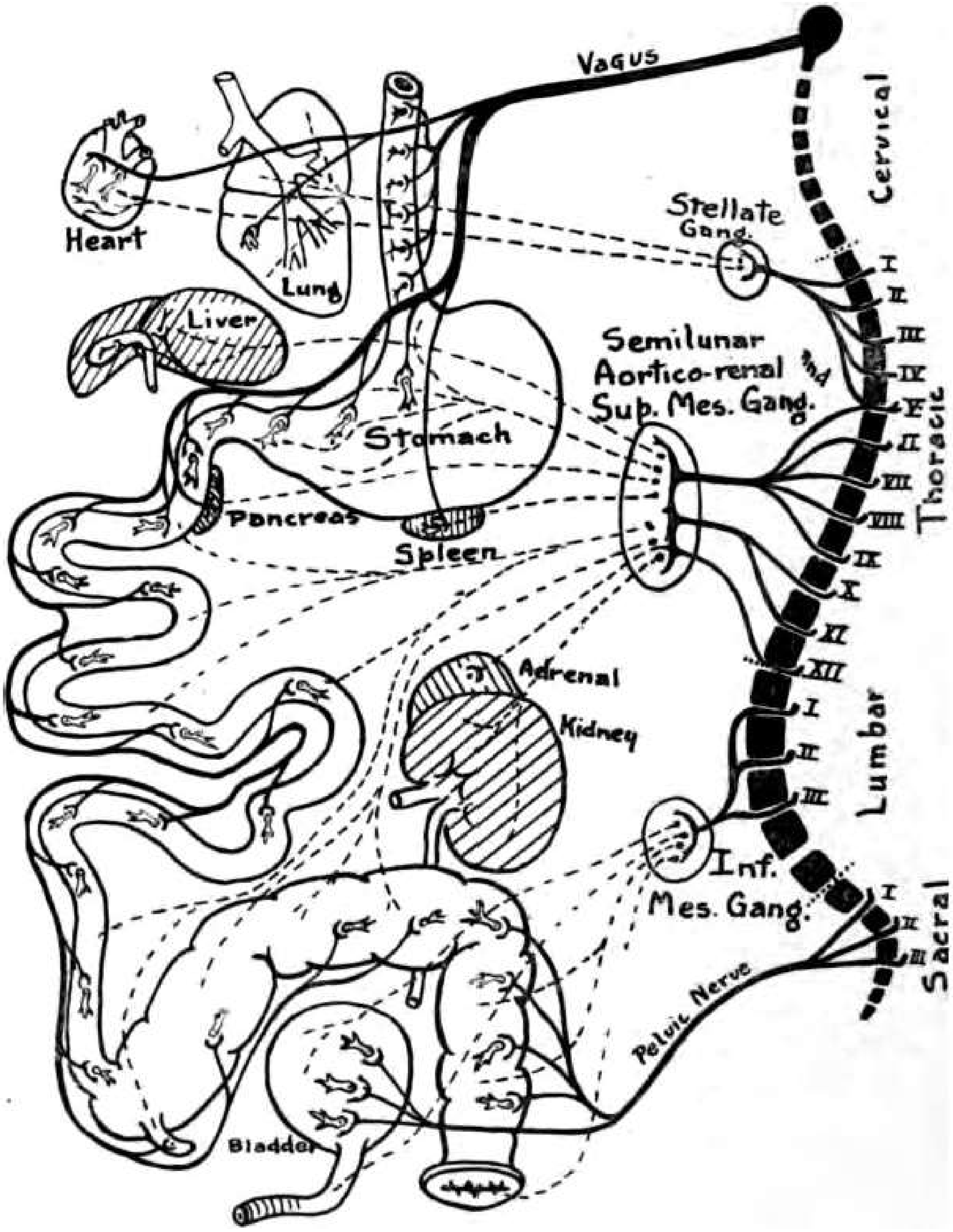

Figure 28. Innervation of the double innervation of the enteral system.
The Vagus and pelvic nerves are represented by solid black lines with the ganglia in the walls of the organs themselves. These furnish parasympathetic fibres to all the organs of the enteral system.
The black lines running from the thoracic and upper lumbar segments of the cord to the ganglia represent connector neurons of the sympathetic system; the broken lines running from the ganglia to the organs represent the non-medullated fibres which furnish the sympathetic supply to all the various organs. All the organs here represented, with the exception of the adrenal gland and the iliocaecal, vesical and anal sphincters, are activated by the parasympathetics and received inhibitory fibres from the sympathetics. These latter are activated by the sympathetics, and with the exception of the adrenal gland, receive inhibitory fibres from the parasympathetics

Digestive Control Both Nervous and Chemical. The control of digestion is partly chemical and partly nervous. Hunger is due to contraction of the stomach musculature through stimulation of the vagus "parasympathetic". Hunger calls for food which may, either psychically, or mechanically, through its presence, start the secretion of gastric juice. When once acid appears in the stomach it passes the pylorus and stimulates the secretion of *secretin* which is the chemical substance which stimulates further production of gastric secretion and the production of pancreatic secretion.

When digestion once starts, it can continue to its finish probably without further stimulation of the vagus nerve. Secretin and the plexus of nerves (Auerbach's and Meissner's) lying in the wall of the gut arc sufficient. But it must be understood that the digestion process is not independent of stimuli which travel over the parasympathetics and sympathetics: on the other hand, these systems, when stimulated, carry activating and inhibiting impulses, respectively, which greatly affect the digestive process.

II. The Stomach: Clinical Consideration

The stomach is an organ which has been very much misunderstood in clinical medicine. It is influenced by many pathologic conditions within the body. While it is not subject to many diseases of a truly organic nature, yet its functions are disturbed by diseases differing widely in nature. This is all the more evident because of its function and position at the beginning of the gastrointestinal tract; and also because of its close relationship to the other organs of the enteral system, maintained through its innervation. It is not only a reservoir for food, but it is an organ in which a very important step in digestion takes place. Many symptoms on the part of the stomach are explainable as stimulation of either the sympathetics or the vagus (parasympathetics), and may be profitably studied from this view- point. The cause may lie within the organ itself, or in organs or structures far removed.

If clinicians would familiarize themselves with those conditions which arise within the body and produce general sympathetic stimulation, such as toxemia, fear, anger and pain; and parasympathetic stimulation, such as anaphylaxis; and the psychic states and endocrine disturbances as they affect both sympatheticotonics and vagotonics; and recognize the organs which particularly bring the stomach into reflex relationship with them through the parasympathetics, they would have the foundation for explaining functional disorders which constitute a great percentage of gastric disturbances. If they would study the visceromotor and viscerosensory' reflexes which result from afferent impulses coming from the stomach through the sympathetics and being transferred to the skeletal structures through the spinal nerves, they would have at their command localizing symptoms which are fairly definite.

If we study gastric symptoms from the standpoint of visceral neurology, we can approach such conditions as nausea, vomiting, hypochlorhydria, hyperchlorhydria, hypomotility, hypermotility, and dilatation of the stomach, in a manner which makes many of them intelligible and also in a manner which will often point the way for their relief.

Psychic Influence on Digestion. The digestive tube is particularly influenced by psychic reactions, and if this is borne in mind it will facilitate diagnosis. AH functional disturbances in digestive organs cannot be looked upon as being of reflex origin. There are conditions, such as psychic states, toxemia, anaphylaxis and endocrine imbalance which by acting, either through the sympathetics or parasympathetics, also disturb physiologic activity. The effect of psychic states upon the secretion of saliva and the gastric juice and the inhibitory action of toxins upon these secretions as met in acute infectious diseases, will illustrate this point. The ease with which the digestive balance is upset in the hyperirritable states designated as vagotonia and sympatheticotonia must be considered in a study of the cause of symptoms.

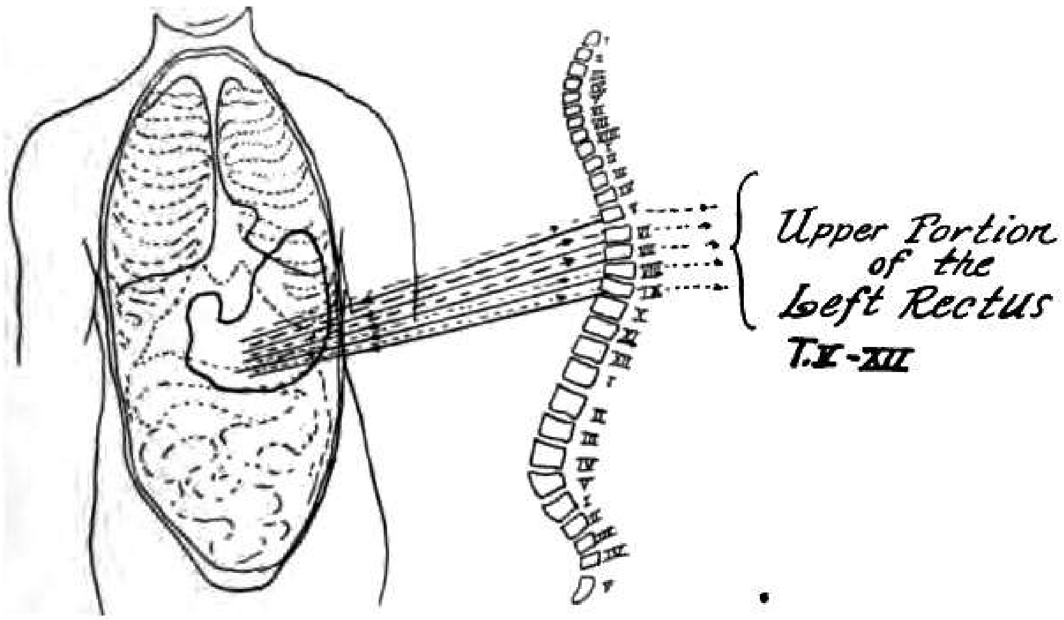

Figure 29. Showing the gastric visceromotor reflex. Line connecting the stomach with the thoracic segments of the cord from the 5th to the 11th represent the sympathetic nerves. Solid lines represent the sympathetic nerves supplying the stomach. Broken lines represent the sensory sympathetic which carry afferent impulses to the cord. Broken lines on the other side of the cord represent corresponding spinal nerves which receive the impulses from sensory sympathetic nerves and transmit them to the muscles shown, producing the gastric visceromotor reflex. The broken lines running from the stomach to the 6th and 7th segments, indicating that these are the principle paths of the impulse.

Gastric Visceromotor Reflex. The visceromotor reflex (Fig. 20) from the stomach is well known to clinicians. The stomach receives its sympathetic nerve supply from the semilunar ganglion which is connected with the spinal cord by connector fibers arising from the 5th the 9th thoracic segments. Afferent impulses, going back to the cord as a result of diseased conditions in the stomach, are transferred most readily to the spinal nerves arising in the same segments (5th to 9th) particularly to those of the 6th and 7th, The gastric visceromotor reflex manifests itself in the upper- portion of the rectus abdominis muscle. This muscle takes its innervation from the intercostal nerves arising from the thoracic segments, 5th to 12th. That portion of the muscle which is particularly affected in the reflex is the upper portion of the left rectus, which is supplied by the 6th and 7th, spinal thoracic nerves. It will thus be seen that while the stomach is supplied by the sensory sympathetic neurons whoso cell bodies lie in the ganglia on the posterior roots of all thoracic segments from the 5th to the 9th, the path of least resistance is in the neurons of the 6th and 7th segments; consequently, structures innervated by the 6th and 7th thoracic nerves are most apt to show the reflex. When the impulse is exceedingly strong, however, as it may be when the organ is severely inflamed, the reflex may affect any of the segments, in the wider area.

Gastric Viscerosensory Reflex. A viscerosensory reflex from the stomach usually shows itself on the left side in the epigastric region and often in the back as shown in Fig, 29 in those skin areas which are supplied by the 6th and 7th thoracic nerves. Sometimes the pain is also felt in other segments, either higher or lower than these, depending considerably upon the severity of the stimulation. Widespread pain is particularly felt in the lower intercostals when the stomach is markedly distended with gas. The natural stimulus of the sensory nerves of hollow viscera is distention of the muscular coat.

Hurst[1] opposes the theory as suggested by Mackenzie that visceral pain does not exist in the organ involved, and believes that the viscera show both a distinctly visceral and a referred or somatic pain expressed reflexly through the spinal nerves.

It will be noticed that both the viscerosensory and visceromotor reflexes from the stomach show in the same structures as those from the pancreas as described in Chapter XIV.

Gastric Parasympathetic Reflexes. As gastric parasympathetic reflexes we understand disturbances in the stomach or in other tissues or organs caused by stimuli arising within the stomach. The afferent impulses travel centralward through the sensory fibers of the gastric vagus, and the efferent impulses manifest themselves in the motor fibers of various parasympathetic nerves, producing increased tone or contraction of the muscles and increased secretory activity in the glands. The parasympathetic reflexes are particularly marked in other organs belonging to the enteral system and less marked in other tissues supplied by the para- sympathetics. When the stomach wall is inflamed, as by ulcer, we should expect increased tonus in the muscle coat of the stomach itself, and hypermotility in the intestines beyond. We should also expect a reflex increased secretion in the stomach, intestines, and probably the liver and pancreas, which arc also closely connected with it. Hurst considers that peristalsis results from the stimulation of the hydrochloric acid. While it may do so, the vagus nerve when stimulated also causes increased secretion, and increased muscular activity. It does not seem probable that the motility should depend wholly on the acid content and be independent of nerve (vagus) influences. The evidence is sufficient to show that vagus stimulation produces peristalsis both under normal and pathological conditions.

As a parasympathetic motor reflex, we now and then find a bradycardia, the efferent impulses traveling through the cardiac branches of the vagus nerve.

The increased flow of saliva which now and then is observed in gastric diseases may be of reflex origin, the efferent impulses coursing in the VIIth and IXth cranial nerves. It may, however, also be of central origin.

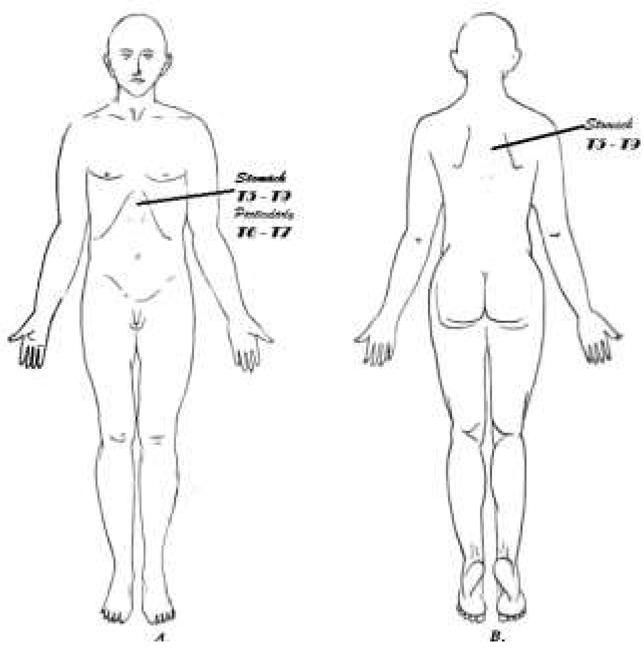

Figure 30. Showing the location of the gastric viscerosensory reflex. A – Anterior view; B – Posterior view. While the stomach is connected by sensory sympathetic nerves with the 5^{th} to the 9^{th} segments of the cord, pain is expressed particularly in the 6^{th} and 7^{th} sensory zones anteriorly. Posteriorly, is felt at times of the entire group of segments from the 5^{th} to the 9^{th} in the median line or to the left of the same.

The Manner in Which the Stomach Is Reflexly Influenced by Other Organs. The stomach shows parasympathetic motor and parasympathetic secretory reflexes as a result of irritation in many other organs. Hyperchlorhydria is usually associated with general hypersecretion of the gastric glands, and with a heightened activity of the gastric muscle.

Hyperchlorhydria. Hyperchlorhydria is not uncommonly noticed in cases of severe eye strain. The afferent impulses are probably transferred centralward through the sensory fibers of the Vth (trigeminus) nerve while the efferent impulses are carried through the motor fibers of the gastric vagus.

The writer has had ample opportunity to test this reflex, having always suffered from eyestrain. Overuse of the eyes has always been followed by nausea, and hyperchlorhydria, as well as headache.

Hyperchlorhydria is commonly found in gall bladder diseases, pancreatitis and appendicitis, particularly in the chronic forms, and in chronic inflammations of the intestines, such as tuberculous infiltration and ulceration and diverticulitis. In such cases the afferent impulses are carried centralward through the respective sensory fibers of the vagus and are transmitted to the stomach through the motor neurons of the gastric vagus.

Hyperchlorhydria is frequently found associated with asthma and hay fever. Whether it is due to a reflex stimulation, the efferent impulse traveling centralward in the sensory fibers of the pulmonary branches of the vagus in case of asthma, and in the sensory fibers of the nasal branch of the Vth cranial nerve in hay fever, and being transferred to the gastric motor neurons; or whether it is part of a general condition in which the excitability of the nerve cells in the parasympathetics seems to predominate (vagotonia) is not quite clear from its clinical manifestations. The latter, however, seems the more probable.

Pulmonary tuberculosis, prior to the stage of marked wasting, is commonly accompanied by hypermotility and hyperchlorhydria, the path of the reflex being the one just mentioned in connection with asthma. These are symptoms commonly found in tuberculosis. This condition, together with other evidences of parasympathetic stimulation in the gastrointestinal tract, as described in Chapter XVI, is often so accentuated in early tuberculosis that the patient has his attention centred on the gastrointestinal tract instead of the lungs. Not infrequently during the stage of marked toxemia with high fever, when under ordinary circumstances the secretion of the stomach should be lessened, a marked hyperchlorhydria is present because the parasympathetic secretory reflex induced through the sensory fibre of the pulmonary vagus and the motor fibres of the gastric vagus, is able to overcome the central inhibiting influence of the sympathetics which results from the toxemia.

Common causes of reflex hyperchlorhydria are chronic appendicitis, gall bladder inflammation, pulmonary tuberculosis and eye strain.

Hypermotility. The parasympathetic motor reflex, as shown in increased muscular tonus and hypermotility, is often present and manifests itself under much the same conditions as hypersecretion of the gastric glands.

Hypochlorhydria. Hypochlorhydria might result from a destruction of the gastric glands as a result of certain degenerative changes in the stomach wall. It is frequently found as an acute condition accompanying acute toxemia. Under such circumstances the sympathetic nervous system is markedly stimulated centrally, and the secretions of, not only the stomach, but the entire gastro- intestinal tract are inhibited because of a preponderance of sympathetic over vagus action. This is frequently prevented, however, by there being at the same time a marked reflex parasympathetic stimulation resulting from inflammation of some important viscus which is capable of maintaining the normal nerve equilibrium or even of overbalancing the action of the sympathetics such as was mentioned in connection with pulmonary tuberculosis above. Hypomotility also results from degeneration of the muscle coat of the stomach. It is present at times during such acute states of toxemia as are accompanied by hypochlorhydria as mentioned above.

Dilatation of the Stomach. Under normal conditions the stomach is prepared for the reception of a bolus of food by a reflex originating in the oesophagus as described in the preceding chapter. A feeling of fullness such as that which marks the satisfaction of hunger results from a distention of the gastric muscle. In eases of dilatation of the stomach, the appetite as a rule is poor, partly because the oesophageal reflex, in preparing the stomach for the reception of a bolus of food attempts to relax muscles of the stomach which are already more or less relaxed. This is the explanation of the common symptom of fullness and inability to take food noted by patients suffering from a dilatation of this organ.

Nausea and Vomiting. While nausea and vomiting may be due to many different conditions, yet in many instances they seem to be direct vagus (parasympathetic) reflexes. They may be precipitated through the centres of sight or smell, and often result from disease within the stomach and intestines. They are common accompaniments of gall bladder disease, other diseases of the liver, pancreatitis, appendicitis, such diseases of the intestines as tuberculosis, and inflammatory conditions of the kidney and ureter, testicle, ovary and uterus. Both may result from eye strain. They are commonly found in pulmonary tuberculosis, particularly at the time when necrosis and caseation are taking place. When a cavity is forming, the patient is at times very markedly nauseated during the height of the inflammation. Nausea is also found in affections of the heart muscle accompanied by dilatation. Nausea is commonly accompanied by a parasympathetic secretory reflex manifested through the efferent motor fibers of the VIIth and IXth cranial nerves. This shows itself in increased salivation, and at times in increased secretion of the nasal mucous membrane; and, if the nausea is severe and accompanied by vomiting, lachrymation may also be present.

Chapter XII

The Intestinal Tract

I. Innervation of the Intestinal Tract

1. Innervation of the Small Intestine. The small intestine is the place where alimentary digestion is completed and absorption be- gins. It is a very important organ, and the health of the individual is either conserved or impaired according to what occurs to the ingesta while passing through it and the colon. This in turn depends largely upon secretion and motility.

Like the stomach, it is supplied by both parasympathetic and sympathetic nerves; the former, activating; the latter, inhibiting action, except in case of the sphincters which are activated by the sympathetics and inhibited by the parasympathetics. The innervation of the intestinal tract is shown in Fig 26, Plate V, page 100, and Fig, 30, page 111

Parasympathetics. The parasympathetic neurons which innervate the small intestine have their motor cells in the plexuses of Auerbach and Meissner, which lie in the intestinal walls. The motor cells in these plexuses are connected with the central nervous system through connector neurons from the vagus.

When the vagus is stimulated, these cells are activated and tend to increase peristaltic action and the secretion of the intestinal glands.

The gastrointestinal tract, in fact, all vegetative structures, possesses a certain degree of independence of the central nervous system, the power to functionate residing in the plexuses of nerves within the, organ walls, but an mentioned in discussing the stomach, this does not imply that the intestine is independent of the vagus. The contrary is true, as shown particularly in diseased conditions.

Sympathetics. The sympathetic fibres to the small intestine arise from motor cells in the superior mesenteric ganglion which receive their connector fibers through the greater splanchnic nerve, which is formed by fibers arising in the 5th to 9th thoracic segments. The same ganglion also supplies vasoconstrictor nerves to the vessels of the small intestine. The fact that the reflex pain from the intestine manifests itself in the umbilical region, while that from the stomach is in the epigastrium, warrants the conclusion that the intestine receives its principal innervation from segments of the cord lower than those of the stomach.

When the greater splanchnic is stimulated, the muscular coat of the intestine is relaxed, the activity of the secreting glands is depressed, and the blood vessels are either constricted or dilated according to the degree and character of the stimulation.

We must also bear in mind that the intestinal mucosa produces chemical substances (hormones) which influence both secretion and peristalsis, as secretin produced in the pyloric end of the duodenum.

The action of the splanchnics, according to Bechterew[1], varies according to the condition of the blood. If the circulation stagnates and the splanchnic vessels become filled with a markedly venous blood, then stimulation of the splanchnic nerves causes increased peristalsis, the reverse of that which normally follows. The explanation is that CO_2 in the blood stimulates peristalsis.

2. The Innervation of the Colon and Rectum. Like other portions of the alimentary canal, the colon receives nerve supply from both the parasympathetics and sympathetics, as shown in Plates I, page 50, and V, page 103, and Fig. 8, page 46.

Parasympathetics. The parasympathetic fibers to the colon and rectum according to some investigators are from two sources; the ascending portion, and probably as far as the descending colon, being supplied by connector fibers from the vagus through the plexus solaria and the remaining portion of the colon proper, the sigmoid and rectum, receiving their connector fibers from the sacral portion of the cord through the pelvic nerve (nervus erigens) and plexus haemorrhoidal is. According to others, among whom are Gaskell, Langley and Anderson, the small intestine is innervated by the vagus and the colon by the pelvic nerve alone. The motor cells for these structures, like those higher up in the gastrointestinal canal, lie on or in the walls of the gut. The rectal reflexes occur largely through the sacral nerves and manifest themselves in the areas shown in Fig. 28,

Stimulation of the pelvic nerve causes both a contraction of the muscles of the colon and also an increase in its glandular activity.

Sympathetics. Sympathetic connector fibres for the colon come through the lower thoracic and upper lumbar segments of the cord. Those which supply the cecum, appendix, ascending and transverse colon, find their motor ceils in the superior mesenteric ganglion, while those which supply the descending colon, sigmoid and rectum are in the inferior mesenteric ganglion. The nerves for the descending colon probably arise from the left half of the cord, for the reflexes are on the left side of the body.

As in other portions of the canal, sympathetic stimulation relaxes the musculature, except the internal anal sphincter which it actuates, lessens the secretion activity of the glands; and produces vasoconstriction or vasodilation according to the character and strength of the stimulus

3. The Innervation of the Sphincters. In the innervation of the gastrointestinal tract, the parasympathetics are the activating nerves for both the smooth musculature and secretory glands, while the sympathetics are the inhibitory nerves. This holds true for all pails of the digestive tract, and those structures formed from it, such as the respiratory tract, the liver and pancreas, and j)art of the genitourinary- tract, with the exception of the sphincter muscles.

The sphincter system is not an intimate part of the general muscular system of the gut. Gaskell[2] considers that it probably represents a part of the dermal musculature; and indicates that probably muscles innervated by both sympathetics and parasympathetics originally extended from the stomach to the anus, but with the elongation of the gut the sympathetically innervated muscles have been left in certain areas to act as sphincters. While, throughout the intestinal musculature, exclusive of the sphincters, the parasympathetics activate and the sympathetics inhibit; in case of the sphincters the sympathetics activate and the parasympathetics inhibit.

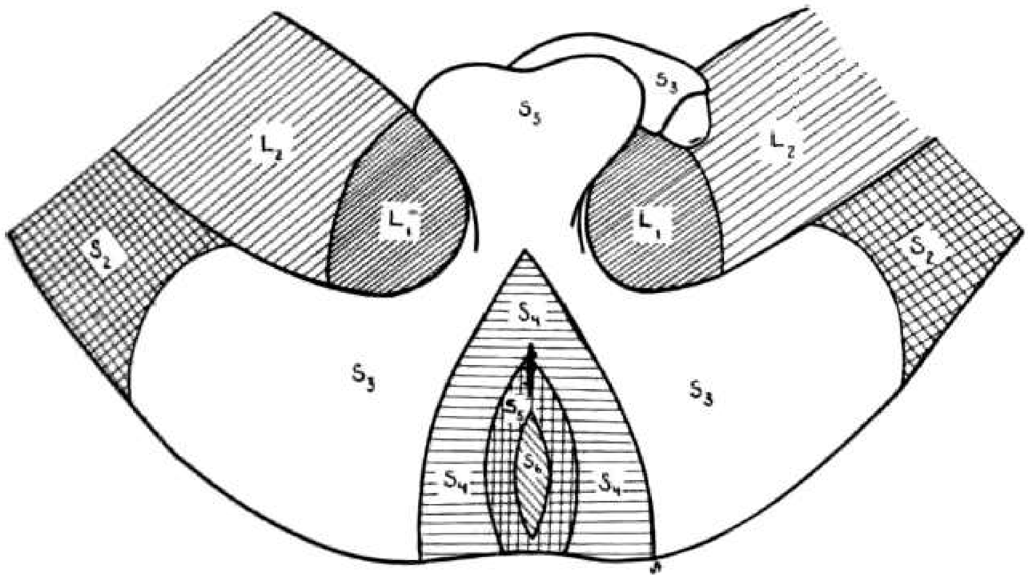

Figure 31. Showing the cutaneous areas supplied by the sacral nerves in the perineal region (after Dejerine). Reflexes in these areas are very common for the organs supplied by the pelvic nerve

Sympathetics. The sympathetic nonmedullated fibers which supply the sphincters arise from two ganglia. Those for the ileocecal sphincter arise from the superior mesenteric ganglion, the connector fibers originating in the last (12lth) thoracic and 1st, 2nd and 3rd lumbar segments, and those for the internal anal sphincter arise from the inferior mesenteric ganglion, their connector fibers coming from the 2nd, 3rd, 4th and 5th lumbar segments. This is shown in Plate VI (page 103) From Gaskell.

The sphincter of the bladder and the musculature of the urethra are also activated by nonmedullated fibers whose motor cells lie in the inferior mesenteric ganglion and which are connected with the spinal cord by connector fibers from the 2nd to 5th lumbar segments. The urethra belongs, embryologically, to the sphincter system.

There is some doubt about the innervation of the pylorus. It is generally believed, however, that it follows the rule of the other sphincters. So far, no vagus influence has been definitely determined for it, although it probably exists.

Parasympathetics. Parasympathetic innervation of the sphincters arises through connector fibers in the vagus (Xth cranial nerve). For the ileocecal sphincter (and probably for the pylorus) the motor cells which give origin to the inhibitory fibers lie in Auerbach's plexus within the gut. Stimulation of the parasympathetics inhibits the sympathetic activity and relaxes the sphincter.

Parasympathetic innervation of the internal anal sphincter arises through connector fibers from the sacral portion of the cord and passes peripheral ward through the pelvic nerve to meet motor cells lying upon the rectal wall in the rectal plexus. Stimulation of these antagonizes the sympathetics in their activation of the sphincter muscle and relaxes it.

The sphincter of the bladder and the urethra belong to this same group but will be considered in connection with the genitourinary structures in Chapter XXVI.

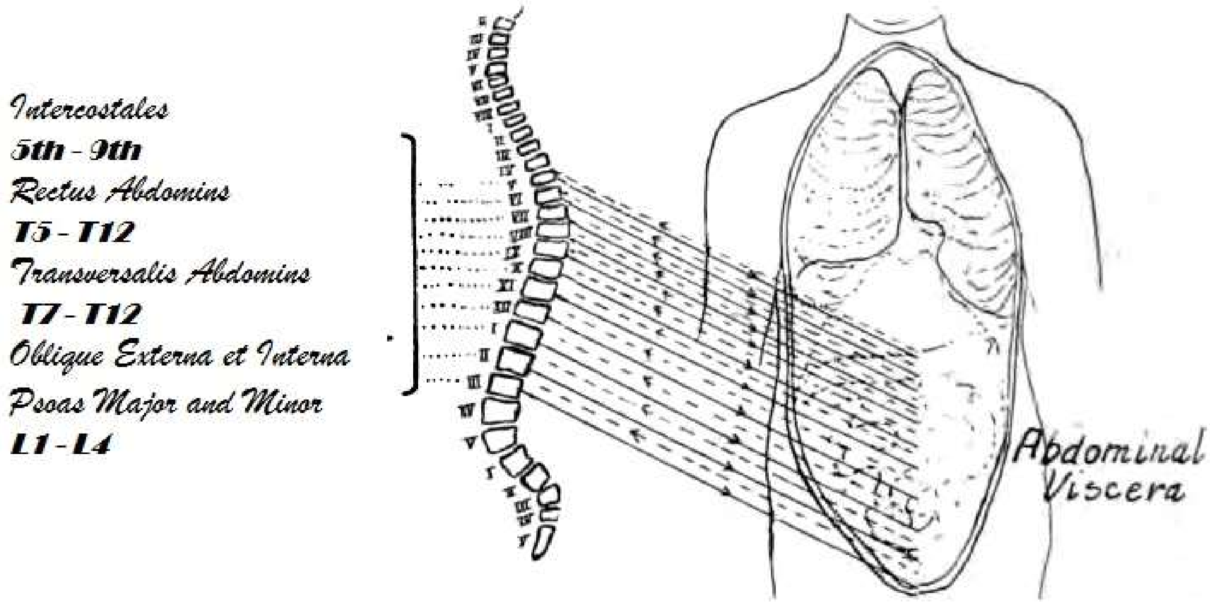

Figure 32. Pathways of the visceromotor reflexes of the abdominal viscera.
Lines connecting to the abdominal viscera with thoracic segments from the 5th to the 12th and lumbar segments from the 1st to the 3rd represent sympathetic nerves. Solid lines represent the sympathetic nerves supplying the viscera. Broken lines represent sensory sympathetic nerves which carry afferent impulses to the cord. Dotted lines on the other side of the cord represent corresponding spinal nerves that receive the impulses from the sensory sympathetic nerves, and transmit them to the muscles shown, producing visceromotor reflexes of the various abdominal organs.
This gives opportunity for many reflexes as may be inferred by fig 7 (page 45).
First the stomach liver and pancreas, supplied by the 5th to the 9th thoracic, the principle reflex being the 6th and 7th segments;
2nd, small intestine, innervation thoracic segments 5th to 9th, principle reflex in 8th and 9th;
3rd colon, innervated from the 9th to the 3rd lumbar;
4th kidney, innervated from the 10th thoracic to the 3rd lumbar, principle reflex in the 11th and 12th thoracic and 1st lumbar

II. THE INTESTINAL TRACT: CLINICAL CONSIDERATION

Sympathetic Reflexes

Intestinal Visceromotor Reflex. The intestinal tract, from the stomach to the rectum receives sympathetic fibers from the lower seven thoracic and upper three lumbar segments of the cord. Apparently, judging from the clinical manifestations of pain and the motor reflexes, there is from above downward a progressive innervation in the gut which corresponds to that in the cord, as mentioned on pages 36 and 57 and illustrated by Figs. 9 and 16.

While the visceromotor reflex from the stomach manifests itself in a spasm of the upper portion of the left rectus, that of the small intestines and ascending colon, so far as we have been able to determine in such cases as tuberculous ulceration, expresses itself oil the right side of the body in spasm of the external and internal oblique muscles innervated by the intercostals 7th to 12th, and the transverse abdominal innervated by the intercostals 7th to 12th. The appendix shows a motor reflex in the transverse abdominal, the oblique and psoas. (See Fig. 16, page 57.)

In this connection we must also mention the diaphragm reflex described by Sale,[3] in the presence of inflammation of abdominal organs, particularly the appendix and gall bladder. The efferent components of these reflexes are the lower intercostal nerves which supply the lower intercostal muscles, the abdominal muscle and the costal portion of the diaphragm. The abdominal diaphragm reflex differs from the pulmonary diaphragm reflex in that the latter is produced through the phrenics, while the former is produced through the intercostals. The stomach, small intestines, upper portion of the colon, liver and pancreas, receiving their sympathetic innervation, as they do, from the 5^{th} to 12^{th} thoracic segments of the cord, send back stimuli to these same thoracic segments, which join with the spinal motor nerves and produce reflex action in the muscles receiving their innervation from these spinal segments. The nerves arising from the lower thoracic segments of the cord, innervate: First, the lower intercostal muscles; second, the costal portion of the diaphragm; and, third, a portion of the muscles of the abdominal wall. Therefore, inflammation of abdominal viscera which are connected reflexly with the lower inter- costal nerves, may produce a diaphragmatic motor reflex which causes a lessening of the respiratory movements of this muscle. For a further description of the diaphragm reflex, see also Fig. 33, page 104.

Intestinal Viscerosensory Reflex, The superficial viscerosensory reflex from the gastrointestinal tract shows itself in pain as a rule in or near the midline of the body, extending from the ensiform to the pubis. When the stomach is involved, the area immediately below the ensiform on the left is the seat of pain; when the small intestine is involved, the point of painful sensation is centred on the umbilicus; and when the colon is inflamed, it is central between the umbilicus and the pubis as shown in Fig. 16, page 57. A deep pain on pressure, or feeling of soreness may be felt over the abdominal muscles at the .same time. Aside from this pain expressed in and near the median line, and the deep soreness we quite often find a pain which is located over some inflamed part. Mackenzie does not recognize this pain over the organ as being in the organ. The pain of appendicitis is one of the best known of all the viscerosensory reflexes. It expresses itself in the right lower quadrant of the abdomen, and is usually accompanied by some degree of boardiness of the underlying muscles. Frequently I have seen a marked hyperesthesia of the akin and hyperalgesia of the muscles under these circumstances. The pain, however, which comes from distention of the gut and which is natural to the intestines, seems to be centred more in the median line. The areas of pain in appendicitis are shown in Fig. 33.

Recently I had an opportunity to observe an attack of appendicitis and ulcerative colitis simultaneously in the same individual, which illustrates the difficulty of differential diagnosis. The patient was a male seventeen years of age. He was suffering at the time from early clinical tuberculosis, and had been undergoing sanatorium treatment for four months. He was in full weight and apparently in perfect physical condition. Suddenly he complained of nausea and vomited his supper. This was followed shortly by severe pain in the lower left quadrant of the abdomen where the skin became markedly hyperalgesia. A disease of the appendix was not suspected at first. He was put on a restricted diet but nausea continued so all food was withheld. He had no rise in temperature. Owing to the fact that he was accustomed to doing much walking and mountain climbing his abdominal muscles were hard. On this account it was difficult to determine the rigidity of the muscles; yet those on the right side seemed to be slightly more rigid than those on the left. There was also slight hyperalgesia on the right side. The patient complained of constipation, much gas in the bowels and colicky pains. A stool, passed the second day after the onset of symptoms, contained large quantities of mucus.

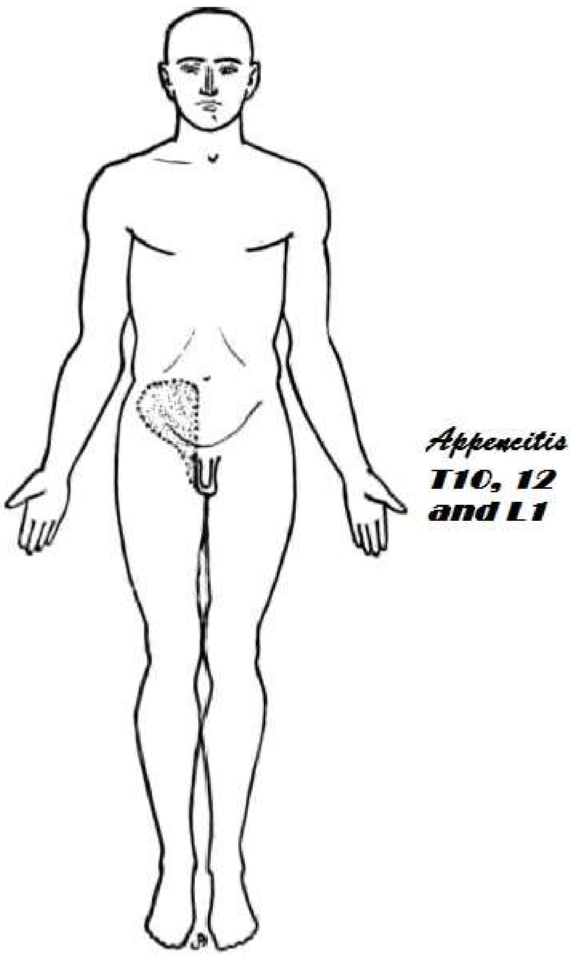

Figure 33. Showing are of pain in appendicitis. Pain may be found anywhere in the lower right quadrant of the abdomen, sometimes extending down into the scrotum

In a second attack, one month after the first, nausea and vomiting were again present. The gas pains were not as marked as in the previous attack. The muscle rigidity was quite marked on the right side. There was also pain on the left side. The temperature reached 99^{o}.

It will be noticed that the patient showed both sympathetic and parasympathetic reflexes. The parasympathetic reflexes were particularly those due to increased motor and secretory action in the intestine, — nausea, vomiting, constriction of gut causing colicky pains, and increased mucus. This, with the hyperalgesia over the lower portion of the abdomen, particularly on the left side, made colitis the most prominent feature of the clinical picture; yet the rigidity of the muscles on the right side afforded localizing symptom which pointed to an appendix as being also an offending organ

The appendix was removed at operation one month after the first attack, and a small ulcer 1 m. long and $^{1}/_{5}$ cm. wide was found which had penetrated to the peritoneal coat. Other portions of the mucous membrane of the appendix were the seat of small haemorrhagic areas. The symptoms in this case were misleading. It was difficult to determine whether we were dealing with a colitis or an appendicitis, or both. All Mas cleared up, however, one month after the operation when the patient was seized with a further attack of pain in the lower left quadrant of the abdomen, similar to that which he had at his first attack. This made it evident that the patient had had two distinct pathological lesions; one, in the appendix which was removed by operation and another in the colon, which produced trouble again later. At the time of the first attack it was difficult to determine whether the pain on the left side was not a transference of the sensory impulse in the cord over to the efferent sensory neurons arising from the left posterior horn and resulting from stimuli coming from the appendix; or whether the stimuli arose from those portions of the colon which naturally reflect in the left lower quadrant. We see this transference at times in angina when the pain is transferred to the right side of the chest.

Surgeons are prone to .say when finding pain on the left side of the abdomen that the appendix is situated on the left side or that the tip bangs over. This is faulty reasoning. No matter where the appendix lies, this does not change the relationship of afferent and efferent neurons which produce the pain; consequently the pain is always transferred in the same way, and the neurons over which it can spread are limited. It matters not whether the appendix be on the left side of the body, or on the right side of the body, or whether it be high or low in the abdomen, the natural place for the pain is in the right lower quadrant of the abdomen. "When the pain extends over on the left side the cause is either a transference of efferent stimuli in the cord, a complicating disease on the part of other viscera which normally produce reflexes on the left or peritoneal involvement.

Peritoneum. — The peritoneum is much like the pleura so far as its innervation and reflexes are concerned. The nerves which supply the abdominal cutaneous zones with sensation send fibers to the underlying parietal peritoneum. This explains the clinical observation that a localized peritonitis which involves the parietal peritoneum gives pain and causes spasm of the muscles in the area overlying. Thus anterior peritonitis is best expressed anteriorly, and posterior, posteriorly. This is of importance in the study of intestinal and other visceral adhesions.

Parasympathetic Reflexes

Parasympathetic Reflexes Shown in the Intestinal Tract Itself and in Other Organs, the Impulse Originating in the Intestinal Tract. There are numerous parasympathetic reflexes ^which may arise from sensory stimuli which originate iii the intestinal tract. Many of these express themselves in the intestinal tract itself. These, how- ever, account for only a small proportion of the disturbance in function met on the part of the intestine. Reflexes which express them- selves in the intestinal tract, the afferent impulses coming from other organs, on the other hand, are extremely common.

The parasympathetic reflexes affecting the gastrointestinal tract which are best known clinically are those which arise from inflammation of the appendix and gall bladder. While the gall bladder is not an integral part of the intestine, embryologically it belongs to it and so should be considered clinically. Afferent stimuli arising from any portion of the gastrointestinal tract, however, may produce the same type of reflex in the tract itself — increased secretion and increased muscle tone. This is well illustrated in diseases which produce inflammation of the intestinal walls, such as tuberculosis, typhoid fever, and dysentery. When an inflammation exists in any part of the gut, afferent sensory impulses travel centralward over the sensory fibers of the parasympathetics and reflect through the motor fibers of the same system, slowing the contents above and hastening them below the point of irritation. Consequently, inflammation in the intestine has a tendency to produce localized or general increased muscle tone and hypersecretion, including an increase of hydrochloric acid, in the stomach; and increased secretion and increased tonus in the muscles of the intestine. This shows itself in several different ways. Sometimes the increased muscular tone produces no recognizable symptoms; again it results in an uneven contraction of the circular muscles of the intestine, producing colicky pains; sometimes, in a general con- traction, particularly of the circular muscles of the colon, producing spastic constipation; and again, if the longitudinal fibers are more involved than the circular in an increased peristalsis, causing loose stools or diarrhoea.

Stimuli applied to any part of the intestine act in much the same manner, according to what is known as the law of the intestine; they slow the action above, and hasten it below. The effect produced depends upon the severity of the stimulation. Sometimes an antiperistaltic action is produced. The nearer the point of irritation to the proximal portion of the intestinal tube, the more apt this is to occur. Thus gastric and duodenal nicer and diseases of the gall bladder are more prone to be accompanied by vomiting than disease farther down the tube, such as appendicitis and diseases of the colon.

As a result of the reflex stimulation when increased muscle tone and hypersecretion are present, several different common syndromes arise as will be noted as the discussion proceeds. Hyperchlorhydria is common in chronic affections of the intestinal tract, particularly appendicitis, and other chronic irritative affections of the intestine such as those of a parasitic nature. Nausea is also common under such conditions, and vomiting sometimes occurs.

All parasympathetic reflexes may fail to appear if the stimulation is slight or if the inhibiting sympathetics are markedly stimulated at the same time by such conditions as toxemia and pain.

A determining factor of great importance, which is particularly well shown in the parasympathetic reflexes in the gastrointestinal tract, whether the stimuli arise in the tract itself or in other organs, is the normal degree of excitability of the nerve cells (tonus — Eppinger and Hess) of the individual. Individuals who are normally vagotonic or those who are pathologically so, as we find in chronic anaphylactic states, hay fever, asthma, are particularly prone to this para- sympathetic reflex in the gastrointestinal tract. It is also marked in many psychic states and in certain conditions of endocrine imbalance such as the vagotonic type of Grave's disease, and in those conditions in which the sympathicotropic secretion of the corpus luteum is temporarily withdrawn as in pregnancy or permanently as in the menopause either artificial or natural.

Colicky Pains. Colicky pains are recognized among the most common symptoms complained of by patients who suffer from increased excitability of the intestinal vagus. This subject has been recently investigated by Alvarez, *• = whose papers are very interesting and instructive. The pains are due to the fact that the stimulation affects the intestinal muscles irregularly, thus producing increased tonus or spasm with constriction of the lumen at irregular intervals.*

Above the constriction, the passage of the contents of the bowel is slowed. As a result of the digestive processes gas develops which is not properly carried off. This results in a distention of the gut and colicky pains. The production of colicky pains is primarily due to parasympathetic overstimulation causing constriction; secondarily, to dilatation which irritates the sympathetics which transfer the impulse lo the spinal sensory nerves producing the intestinal viscerosensory reflex. If constriction exists for a long period of time, distention takes place, the musculature of the intestine becomes thinner than normal and its peristaltic power decreases. This is also accompanied by disturbance in the secretory power of the gut as well. Dilatation, however, occurs most readily in the presence of mechanical obstruction. Some cases of Hirschsprung's disease, however, should be observed from the standpoint of being a sympathetic stimulation.

Spastic Constipation. Spastic constipation is a condition in which the musculature of the intestinal tract, particularly the colon, shows an increased tonus. This tonus may be of any degree, varying from a marked contraction in which the lumen is almost closed and the gut appears as a cord, to that of slight spasm of the muscles here and there throughout the length of the organ. Such a condition is due to either an unusual local parasympathetic stimulation or a generally heightened irritability of the neurons supplying the intestinal musculature. The stimulus is conveyed to the muscles through the parasympathetic motor neurons. This gives a hint for treating conditions of this kind. The intestinal tract should be relieved of all irritating material and such remedies as atropine, which opposes parasympathetic action, should be utilized, also measures which improve the general nerve tone of the patient.

Recently, rectal injections of magnesium sulphate have been recommended to overcome this condition (Soper[6]). This produces the effect of stimulating the sympathetics, but whether it is a sympathetic stimulant or an opponent to the sacral nerve I am not able to say. Its action here, however, is in harmony with its action in the treatment of biliary tract and gall-bladder infections.

Spastic conditions which arise from diseases of the intestinal tract are very often due to chronic appendicitis. They may also be due, however, to any irritative condition throughout the tract, such as tuberculous infiltration and the parasitic diseases of the intestine.

Conditions on the part of other organs which produce spasticity in the gut, such as affections of the liver and gall bladder, and eye strain will be considered later in this chapter.

In conditions accompanied by high fever, even though the seat of the disease be in the intestinal tract, spasticity may not result because the toxemia expresses itself through the sympathetics; and whenever the sympathetics are highly stimulated, they may inhibit the action of the parasympathetics.

Intestinal Stasis. Intestinal stasis may be due to many conditions, such as a general weakness of the musculature of the intestinal tract, conditions which produce marked sympathetic stimulation such as toxemia as is noted so commonly in acute infectious diseases, pain, worry, and mechanical conditions which interfere with the onward movement of the ingesta. It is more commonly, however, due to a disturbance in parasympathetic innervation; either a general cell hyperirritability or a local parasympathetic reflex, the afferent sensory impulses coming from the gastrointestinal tract or from some other organ, such as we shall mention later in this chapter. When the contents of the intestinal tract are delayed in their movement through the intestine, they undergo certain changes which are more or less irritating and injurious to the intestinal wall. Deleterious products which develop are also absorbed. As a result of this, intestinal stasis is usually accompanied by the absorption of more or less toxins. If the condition is a chronic one and the toxemia is not too severe, it may express itself in an irritability and a lowering of the efficiency of nerve cells, acting much the same as the chronic toxins of such diseases as tuberculosis, syphilis and malaria, in lowering the efficiency of the patient. If, on the other hand, the toxemia be greater, then the syndrome of acute toxemia may present. In fact, a very common syndrome in intestinal stasis is that which is usually spoken of as "biliousness." Such attacks are recurrent; the patient will be free for a short period and then will have an acute attack of toxemia. This is usually ushered in by feelings of malaise, headache, and possibly aching of the body, sometimes nausea and vomiting, and often a slight rise of temperature. The condition will last a variable period of time, but can often be relieved by a brisk cathartic which clears out the intestinal canal. If nothing is done, the attack will usually end of its own accord; the irritation of the muscular coat increasing augments peristalsis, or after a time the amount of toxins absorbed acting through the sympathetic nerves, produces an inhibitory effect upon the vagus which causes a relaxation of the spasm of the musculature and permits the passing on of the ingesta. It will be seen readily that since the type of stasis which depends upon the parasympathetic reflex is due to an irritative condition of the parasympathetics, that its successful treatment should depend upon relieving all irritative conditions possible. If the afferent stimuli arise in the intestinal tract, then such things as cathartics, while they may temporarily relieve the conditions, are wrong in principle and other natural methods of relieving the stasis should be utilized.

Diarrhoea. The difference in stimulation which results in the spasticity of the bowel and a diarrhoea, is not well understood. Some authors believe it is a difference in the strength of the stimulus, and others believe it depends upon whether the stimulus affects the circular or more longitudinal fibers of the intestine; but, whatever it is, we know that diarrhoea is a very common result of acute irritative conditions in the intestinal tract. Chronic diarrhoea also results at times from marked injury to the intestinal mucosa, such as occurs in tuberculous ulceration, typhoid ulceration and ulceration due to amoeba. It seems quite probable that diarrhoea may be due to a marked irritation of the nerve cells in the plexuses of Auerbach and Meissner, in which the stimulus arises within the lumen of the gut and is directly applied. Very severe irritation, however, may be present at times without producing diarrhoea. I have seen the entire intestinal tract from the pylorus to the descending colon studded with tuberculous infiltration and ulcers without producing any disturbance in the daily evacuation of the bowel. At other times I have seen it produce a constipation, and still at other times result in diarrhoea. There is no doubt but that many of the attacks of so-called "colitis," in which there are two or three mushy bowel movements a day, often accompanied by considerable gas and colicky pain, arise from sensory stimulation coming either from without or within the bowel itself, although the latter is probably the more common. I feel very sure that I have seen numerous instances of this type of intestinal disturbance produced reflexly by inflammation of the lung in pulmonary tuberculosis.

It will thus lie seen that the more common conditions which we find in the gastrointestinal tract, —nausea, vomiting, hyperchlorhydria, hypermotility, colicky pains, spastic constipation, intestinal stasis and diarrhoea, may all be of reflex origin. It is also probable that they may be produced by direct irritation of the plexuses of Auerbach and Meissner, the stimulus arising within the bowel. They are all expressions of increased parasympathetic irritability or increased irritation. The source of the irritation which causes the reflex may be either within or without the bowel. Successful therapy demands an understanding of their relation to the vegetative nerves.

Bradycardia. Bradycardia is produced very often as a result of stimuli arising in the intestinal tract. This is sometimes seen in typhoid fever, I have called attention to it as being a suggestive symptom of intestinal involvement in pulmonary tuberculosis. In regard to this symptom in tuberculosis, however, one must bear in mind that there is a general tendency toward a slow heart produced by the afferent sensory stimuli which come from the lung. Stimuli coming from the inflammation of the appendix will at times produce a slow pulse, — in fact, stimuli arising in any part of the intestinal tract might reflexly influence the vagus nerve and produce a slowing of the heartbeat.

Whether or not a bradycardia will occur cannot depend entirely upon a reflex vagus stimulation. Other conditions may be present which demand an increased circulatory effort and force an accelerated heart contraction in spite of the vagus stimulation. This is well illustrated in asthma, where the vagus stimulation is overcome by the demand for oxygen, resulting in an acceleration of the heart bests.

Recently a test for the diagnosis of typhoid fever has been proposed by the British Army, the description of which has been given by Marris.' Friedlander and McCord" describe the rationale of the text thus:

"The patient lies horizontally and is instructed to remain completely at rest throughout this test, which is not employed until at least one hour has elapsed from the last meal. The pulse rate is counted minute by minute until it is found to be steady; ten minutes of such counting usually suffices. Atropin sulphate is then injected hypodermically in the dose of $^1/_{33}$ grain, preferably over the triceps region to insure rapid absorption. An interval of twenty-five minutes is allowed to elapse, and the pulse rate is again counted, minute by minute, until it is clear that any rise which may follow the injection has passed off; fifteen or twenty minutes may be necessary for this purpose when the pulse rate is raised at the first count.

"If, for example, a near constant pulse rate of 70 was exhibited at the preliminary counting, and a maximum of 06 was exhibited as the pulse rate subsequent to atropine injection, the inference after this acceleration of twenty-six beats per minute would, under the provisions of the test, be that the condition was not typhoid. If, however, the rate after atropine had attained only to 78 beats per minute as the maximum, the inference is tenable that the existing condition is one of the typhoid group. The test does not discriminate between typhoid and paratyphoids A and B. In Marris' report, the line of demarcation for the interpretation as existing typhoid or nontyphoid is placed at 15; that is, if the acceleration following atropin is less than fifteen per minute, typhoid is indicated. A 'positive' atropin reaction is one giving rise to little or no increased heart rate after atropin administration (fourteen or less per minute), A 'negative' reaction is one giving rise to an increase of fifteen or greater."

In explanation of this test it has been suggested that atropin shows a specific antagonism to the action of the typhotoxin. Such an explanation is not necessary, knowing the action of atropin in antagonizing the action of the vagus nerve, the rationale of this test is easy to explain. "When typhoid fever is present, the inflammation in the intestinal tract produces a marked stimulation of the vagus nerve endings in the intestine which produces a reflex inhibitory action upon the heart, having a tendency to keep the pulse slow in spite of the accelerating action of the atropin. The reason the pulse does not show a marked bradycardia oftener, is because there are other factors present, such as the toxins, which exert an accelerator effect on the heart. The pulse is often relatively slow in such intestinal conditions as typhoid fever, appendicitis and tuberculous infiltration and ulceration. The pulse rate is a resultant of the sympathetic accelerating and the vagus slowing impulses, and therefore varies in different people and in the same individual at different times according to the nerve stimulation and respiratory and circulatory demands upon the body.

If a dose of atropine sufficiently large to overcome the inhibitory action of the vagus is administered to a normal individual, the pulse rate increases very markedly. In ease of the typhoid patient, the reflex stimulation of the cardiac vagus produced by the intestinal inflammation cannot be relieved, therefore the atropine is not able to relieve the inhibitory action of the vagus to so great an extent. The result is that the pulse is not accelerated to the same extent that it is in the normal individual.

It would seem that a test of this kind could be used advantageously if the rationale of its action were properly understood; but the source of error would undoubtedly be great if a given increase in pulse rate would be required for a positive injection. The amount of increase in the pulse rate would depend upon the individual. There are many people who are markedly vagotonic. These, unless cardiac accelerating influences are present, show a slower pulse rate than those who are sympathicotonic. I would like further to suggest that typhoid fever is not the only disease that would show this reaction to atropine. Pulmonary tuberculosis is accompanied by a relatively slow pulse rate when the patient is at rest and observed under the conditions of this atropine test. Tuberculosis and other inflammatory infiltrations and ulcerations of the intestinal tract should give the same reaction. We would also expect it in conditions of inflammation of the gall bladder.

While the test has a definite physiologic basis, it is a test for abnormal vagus stimulation rather than for typhoid fever.

Fig. 35 is a chart taken from a patient suffering from tuberculosis of the intestine. It will be seen that the pulse rate does not increase in proportion to the amount of toxemia present as indicated by the height of the temperature curve. One must not, however, always expect to find the pulse slow in intestinal tuberculosis, for the demands made upon the circulation and the condition of the circulatory apparatus itself differ so greatly that the rate of heart contraction must necessarily vary; but it occurs sufficiently often to show that there is a tendency for this vagus reflex to be present. The heart action must always be considered in connection with the demands which are made by the energy output of the cells. When this is large, the heart contractions must increase in rapidity or more blood must be delivered at each contraction; or both conditions must obtain.

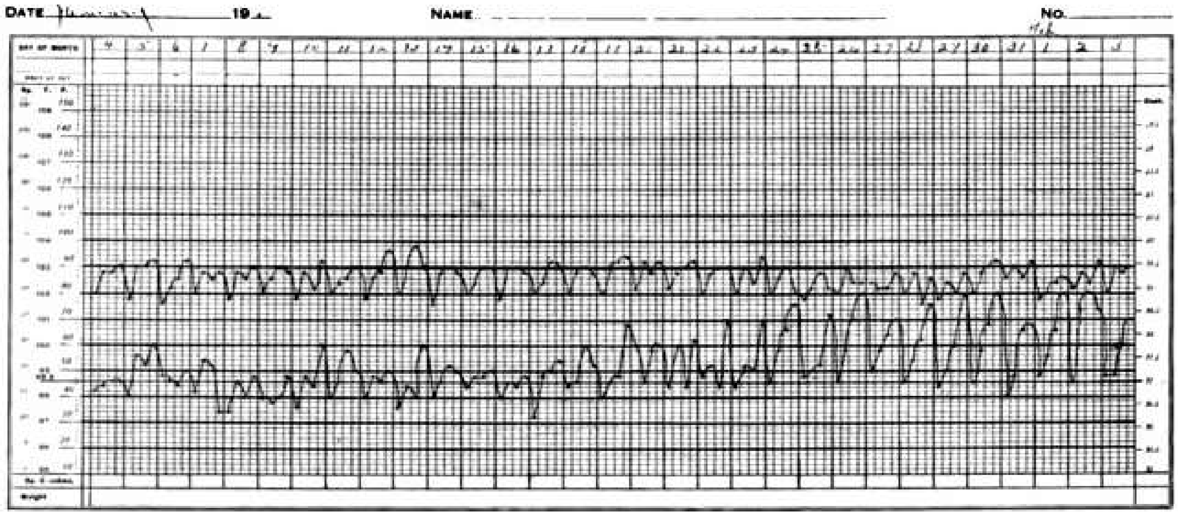

Figure 34. Reflex bradycardia due to tuberculous involvement of the intestine. It will be noted that on the 17th day of January a continuous elevation of temperature started which increased, reaching its maximum of 102°F about a week later and continuing for a number of days. This was associated with definite symptoms of tuberculosis of the intestines. During the first half of the month the temperature was not far above normal and the pulse reached a maximum of about 90 per day. With the increase in temperature to 102°, during the last half of the month, the maximum pulse rate shows a slight decrease, instead of increase. This is a reflex bradycardia from the intestine. The afferent impulses coarse through the sensory fibres of the intestinal branches of the vagus and, mediating in the medulla with the efferent motor fibres of the vagus, produce cardiac inhibition with slowing of the pulse

Hectic Flush. Hectic flush is now and then present as a viscerogenic reflex from the gastrointestinal tract. Hectic flush is better known as a symptom of inflammation of the lung (pulmonary tuberculosis), but patients who suffer from spastic constipation and intestinal stasis often complain of much the same syndrome, although as a rule it is not so marked in character. I have seen a dilatation of the blood vessels occur in the cheek in many cases suffering from intestinal disturbances. This could be accounted for as a parasympathetic reflex, the afferent impulse traveling through the sensory fibers of the vagus, the efferent through the fibers of the Vth cranial nerve which exert a dilator effect upon the blood vessels of the mouth and cheek.

Increased Nasal and Pharyngeal Mucus (Catarrh). It has also been long noticed that patients suffering from intestinal disturbances are prone to have catarrh. We have always thought there was some relationship but could not explain it. The study of the parasympathetic reflexes shows how this may occur. Sensory stimuli originating in the intestine may travel centralward over the vagus and be transmitted through the motor neurons of the VIIth cranial nerve and result in the increase in secretory activity of the mucous glands of the nose and nasopharynx, giving an increase in catarrhal symptoms. In other cases the symptoms on the part of the two structures are to be considered as part of a general parasympathetic hyperirritability.

Herpes. Herpes is sometimes met in infection of the intestinal tract, the afferent impulse coursing over the vagus, the efferent over the Vth cranial nerve. While it is most common in pneumonia, I have seen it in intestinal infections as well.

Headaches. The headache which accompanies intestinal disturbances is often of a reflex nature. The impulse arising in the gastrointestinal tract passes centralward over the sensory fibers of the vagus and is transferred to the trigeminus producing pain in different areas of its distribution.

Parasympathetic Reflexes. Shown on the Part of the Intestinal Tract, the Impulse Originating in Other Organs. — Aside from the many reflex disturbances in the normal function of the intestinal tract above described, which originate from stimuli coming from the intestinal tract, there are many instances of the same reflexes on the part of the intestinal tract, which originate from stimuli arising in other organs. The intestinal tract is influenced by stimuli which act upon the skin. The splanchnics which control the blood vessels of the intestinal tract are stimulated by many impulses which come from the surface of the body, some of these producing vasoconstriction, others producing vasodilatation. The amount of blood in the splanchnic area is directly influenced by cutaneous stimuli. This fact probably supplies an explanation for the well-known clinical observation that chilling of the surface of the body is detrimental in eases of diarrhoea. Chilling produces constriction of the surface vessels, driving the blood inward to the splanchnics which become congested. It also suggests that the benefit of hot applications to the abdomen in treatment of such conditions may be due to relieving the irritation of the plexuses of Auerbach and Meissner by withdrawing the blood from the splanchnics and directing it to the vessels of the skin. The intestinal parasympathetics are reflexly stimulated by impulses coming from many other organs, — in fact, any organ whose afferent sensory stimuli are in reflex connection with the motor neurons of the intestinal parasympathetics, is able to produce reflex action in the intestinal tract.

Eye strain is frequently accompanied by nausea, hyperchlorhydria and spastic constipation, particularly in patients in whom the excitability of the nerve cells of the parasympathetics is naturally high. This is probably caused by afferent stimuli traveling from the eye through the sensory neurons of the Vth cranial nerve, the motor impulse coursing in the motor neurons of the intestinal branches of the vagus.

Inflammation of the lungs, stomach, liver, gall bladder and pancreas is very prone to produce the same group of intestinal symptoms as is described above as originating from stimuli originating in the intestinal tract. These organs are particularly closely bound to the intestinal tract by reflexes, — so much so, that increased parasympathetic excitability as presented by hyperchlorhydria, hypermotility throughout the gastrointestinal tract, spastic constipation, colicky pains, and intestinal stasis, have as their most common reflex cause, inflammatory conditions in the lungs, gall bladder and appendix. All such reflex parasympathetic stimulation results in two different actions: 1, an increased motor stimulus tending to increase the normal contraction of the intestinal musculature; 2, increased secretory stimulation tending to alter the normal activities of the glands of the mucosa.

The common result of the parasympathetic motor reflex as expressed in the intestinal tract is an unequal contraction of the muscles of the intestine, resulting in disturbed rhythm and in an interference with the normal movement of the ingesta within the intestinal canal. The result of this increased muscular tonus depends upon whether it is expressed mainly in the circular or in the more longitudinal muscles. If the former, the ingesta is delayed; if in the latter, peristalsis is increased. Whenever the muscle tonus of the intestinal tract is reflexly stimulated, the secretion from the glands may also be increased.

In the everyday clinical observation of disturbed function on the part of the intestinal tract, the cause of such disturbance is more often found in other organs than in the intestinal tract itself. While, as mentioned above, the reflex may come from the eye or from any of the structures which belong strictly to the enteral system, we must not forget that the kidney and many of the other urogenital organs are also reflexly connected with the intestinal tract, and a reflex disturbance in the normal physiologic function might occur from them.

Action of Toxins on Motility and Secretory Activity of the Intestinal Tract. Toxins, no matter from what source, produce a general stimulation of nerve cells, and peripherally, express a general wide spread stimulation of tissues supplied by the sympathetic nervous tem. Consequently, in all eases of toxemia, and particularly those oi acute toxemia, we find a tendency to sluggishness of action of the intestinal tract. There is a tendency to deficiency of secretion and a deficiency of motility in the gut proper, brought about through the inhibitory influence of the sympathetics in overcoming the action of the vagus; and a stimulation of the sphincters due to the activating influence of the same sympathetic stimulation.

Action of Such States as Anger, Fear and Pain upon the Motility and Secretory Activity of the Intestinal Tract. The effect of such emotional states, as anger, fear, and pain upon the process of digestion has long been known to physiologists and clinicians. The subject, however, has recently come in for careful study by Cannon and his co-workers. They have shown how these various emotional states inhibit the action of both motility and secretory activity of the intestinal tract. All clinicians meet this action in their everyday practice. The reason the gastrointestinal musculature is relaxed and the secretory activity is inhibited, is that states of this type act centrally upon the sympathetic nervous system and, stimulating it, inhibit the normal activating influence of the parasympathetics. Tt has been my observation that such general nerve stimulants as worry and psychical disturbances precipitate action through the neurons of that vegetative system which shows the greatest degree of irritability; in one preponderance of effect is in the sympathetics in another the parasympathetics.

Endocrine glands. Whenever there is a marked disturbance in the equilibrium of the endocrine system, this reacts upon the vegetative nerves and may produce effects in the gastrointestinal system; now of one type, now another.

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Chapter XIII

The Liver and Gall Bladder

I. The Innervation of the Liver and Gall Bladder

The liver, embryologically, is formed from the alimentary canal and consequently has the same innervation. The secretion of bile varies according to the character of the food ingested. It is greatest on a meat diet, somewhat less on carbohydrates, and least on an exclusive fat consumption.

The secretion depends upon nerve activity, and seems to be further influenced by certain products of internal secretion. It is thought that secretin formed in the duodenum acts upon the liver as well as the pancreas.

The gall bladder and ducts arc surrounded by unstriped musculature.

This musculature is arranged about the papilla of Vater in the form of a sphincter. Like the urinary bladder, the activation of the sphincter and the bladder differs.

Parasympathetics. The parasympathetic supply comes from the vagus. The vagus supplies activating fibers to the -sphincter of the common duct and inhibitory fibers to the muscles in the wall of the gall bladder.

Sympathetics. The sympathetics oppose the parasympathetics. They inhibit the action of the vagus in its control of the sphincter and when stimulated cause contraction of the body of the gall bladder.

The sympathetic supply to the gall bladder comes from motor cells in the semilunar ganglion which receives connector fibers from the thoracic segments from the 5th to the 9th.

Not only are the sympathetics inhibitory to the action of the vagus in the liver and gall bladder, but they furnish vasomotor control for the organ. Stimulation of the sympathetics contracts or dilates the vessels according to the degree and character of the stimulation thus altering the secreting power of the gland. It also mobilizes the glycogen found in the liver (Cannon).[1]

Spinal Nerves. The liver and gall bladder receive nerve fibers from the phrenics. This becomes exceedingly important at times in symptomatology, for the afferent impulses are carried back to the 3rd and 4th cervical segments of the cord through the sensory fibers of the right phrenic and thus produce reflex pain in the right shoulder.

II. Liver and Gall Bladder: Clinical Consideration

Hepatic Visceromotor and Viscerosensory Reflexes.— The liver and gall bladder receive their sympathetic innervation from the semilunar ganglion, the connector fibers running from the 5th to 9th thoracic segments of the cord. These are the same segments that supply the stomach. The visceromotor reflex, however, which results from inflammation of the liver and gall bladder, shows itself in the right rectus instead of the left rectus (Fig. 35). One viscerosensory reflex (Fig. 36 A and B) expresses itself in the epigastrium in much the same way as the sensory reflex from the stomach, but more to the right of the median line. It may follow the costal margin and at time (is found in the back in the zones of the 5th to 9th intercostal nerves. Another important viscerosensory reflex from the liver is that which takes place through the spinal (phrenics) nerves. The phrenic nerve sends filaments to the capsule of the liver. Consequently an inflammation of this organ often sends afferent stimuli centralward through the phrenics which express action through the sensory spinal nerves with which they come in contact in the cervical segments of the cord. This reflex is shown strongest above the clavicle and spine of the scapula, in those surface areas over the neck and shoulders which are supplied by the

3^{rd} and 4^{th} right cervical sensory nerves, the same as are involved in right diaphragmatic pleurisy and in tuberculosis of the right lung. This is shown in Fig, 36 A and B.

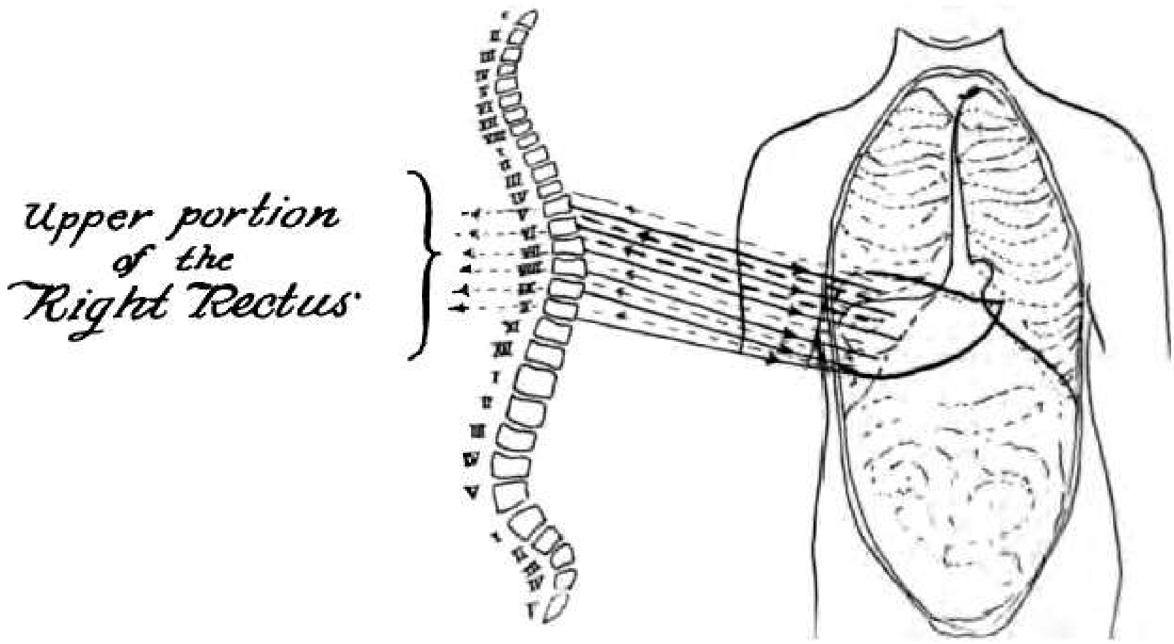

Figure 35. Showing the hepatic visceromotor reflex. Lines connecting the liver and gall bladder with the thoracic segments of the cord from the 5^{th} to the 9^{th} represent the sympathetic nerves. Solid lines represent sympathetic nerves supplying the liver and gall bladder. Broken lines represent the sensory sympathetic nerves which carry afferent impulses to the cord. Broken lines on the other side of the cord represent spinal nerves which receive impulses from the sensory sympathetic nerves and transmit them to the upper portion of the left rectus, producing the hepatic visceromotor reflex. The broken lines running form the liver to the 6^{th} and 7^{th} segments of the cord are heavier, indicating that these are the principle paths of the impulse.

Hepatic Parasympathetic Reflexes. The liver and gall bladder aside from the visceromotor and viscerosensory reflexes in the superficial body structures, just described, show parasympathetic motor and secretory reflexes in other organs. These may be particularly well recognized in the stomach and intestinal tract, in hyperchlorhydria and gastric hypermotility, spastic constipation, colicky pains and intestinal stasis. The two best known conditions for producing reflex colicky pains, hyperchlorhydria, spasticity and stasis in the intestinal tract, are gall bladder disease and chronic appendicitis. To these I would add a third which, to my mind, is equally important, that is, inflammations in the lung, represented by pulmonary tuberculosis. (See page 129).

Gall bladder disease at times is followed by bradycardia. This has been explained as being due to the action of absorbed bile. When an inflammatory condition of the gall bladder is accompanied by bradycardia, a motor reflex through the vagus must be considered as one of the probable causes.

Not only are the gall bladder and bile ducts organs which stand in very close reflex relationship with the stomach and intestines, producing increased motility and increased secretory activity in them; but likewise they at times are affected by reflexes from the stomach and intestines. A spasm of the bile duct is now and then described, which seems to be of a reflex nature, resulting from an inflamed condition in the adjacent stomach or intestines. Such conditions are sometimes relieved by an injection of atropin through its relaxing effect upon the vagus nerve; and I would also softest that adrenin be employed in such eases.

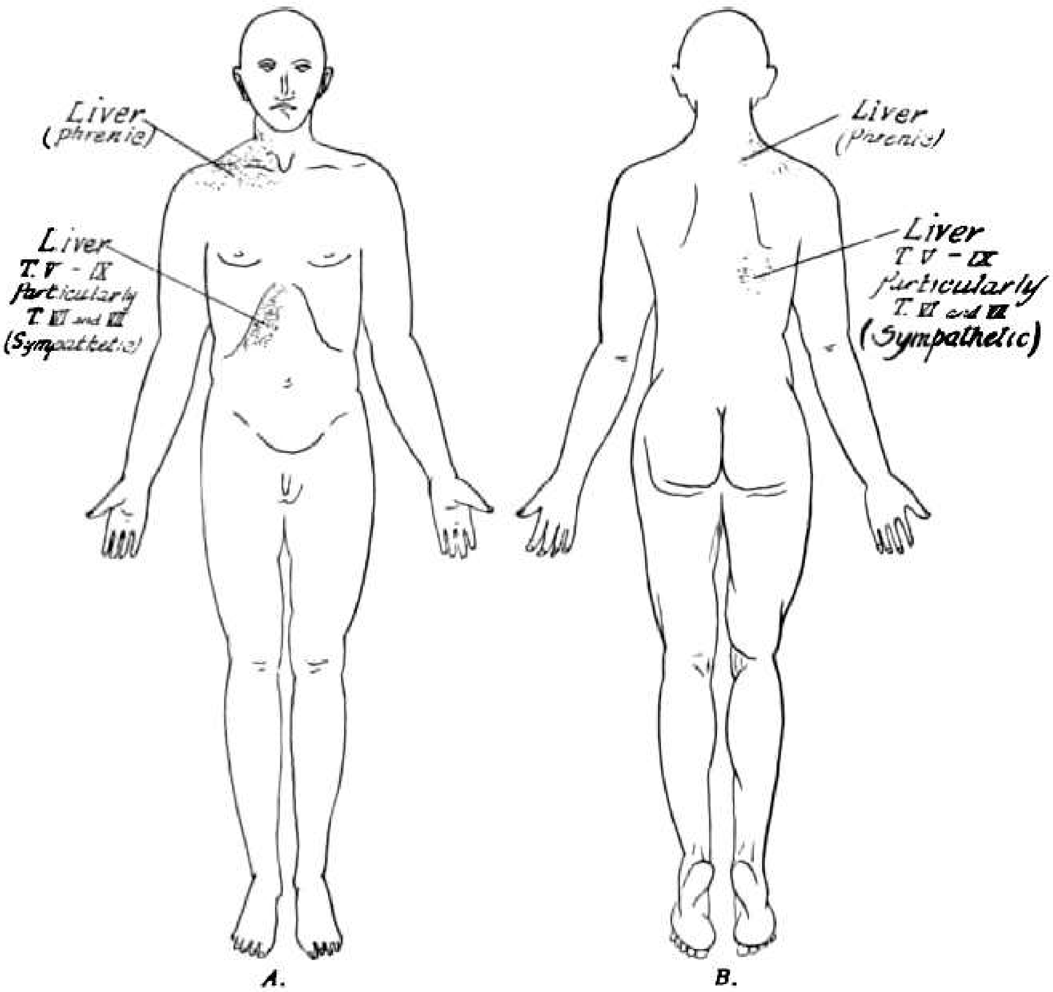

Figure 36. Hepatic viscerosensory reflex.
Lower through the sympathetics, upper through the phrenics. A – anterior. B – posterior.
The hepatic viscerosensory reflex shows itself on both anterior and posterior surfaces of the body. The shaded area in the lower portion of the figure represents pain due to afferent impulses which travel from the liver to the cord through sympathetic neurons.
The efferent impulses express themselves in the 6th and 7th right thoracic cutaneous zones. The upper area of pain is due to afferent impulses that travel from the liver to the cervical portion of the cord through the sensory fibres of the phrenics, where they connect with efferent neurons which express pain in the 3rd and 4th cervical sensory zones

Spasm of Sphincter of Common Duct. Sometimes a spasm of the sphincter of the common duct occurs and simulates gallstone colic- It may be relieved by atropin which antagonizes the vagus which activates the muscle or by adrenin which opposes the vagus through stimulating the opposing sympathetics.

Cholecystitis and Inflammation of the Bile Ducts. Recently a treatment for cholecystitis and inflammation of the biliary duels based upon their innervation has been suggested by Meltzer[1] and Lyon[2]. It consists of introducing a quantity (25cc) of a 25 per cent solution of magnesium sulphate into the duodenum through a duodenal tube. This process has been called transduodenal lavage. The action of the magnesium is to dilate the duodenum and the sphincter and thus favour an outflow of bile. Whether the magnesium acts by inhibiting the action of the vagus directly or by stimulating the sympathetics and causing them to overcome the vagus is not clear. But whichever it is, a sympathetic stimulant or a vagus inhibitory force, it produces the same effect — dilates the sphincter and contracts the gall bladder, thus causing a free flow of bile. It also causes a free flow of bile from the biliary passages in the liver. This practical application of the knowledge of the antagonistic action of the vagus and the sympathetics in the innervation of the gall bladder and biliary duets is another illustration of the practical value of the study of visceral neurology.

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Chapter XIV

I. Innervation of the Pancreas

The pancreas has two very important functions which depend upon: 1, a secretion which is poured into the intestinal canal through the pancreatic duct; and, 2, one which is poured into the veins which leave the organ. The former has to do directly with intestinal digestion, the latter with carbohydrate metabolism.

In its relationship to the two divisions of the vegetative nervous system, the pancreas resembles the salivary glands. Stimulation of the vagus produces an increased flow of thin secretion, while stimulation of the sympathetics produces a secretion which is thick and tenacious. The vagus, however, is the chief secretory nerve of the pancreas. Aside from the vagus, pancreatic secretion is activated by the hormone, secretin.

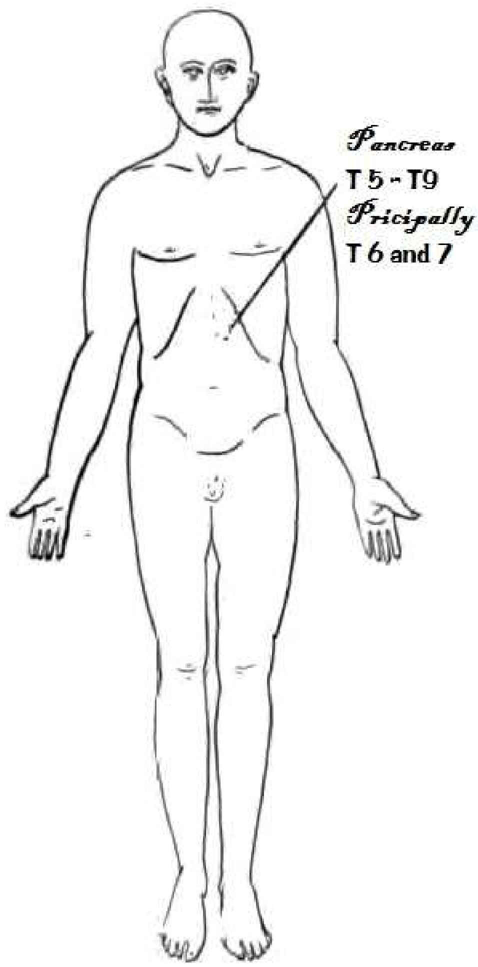

Figure 37. Pancreatic viscerosensory reflex. This reflex is in the same cutaneous sensory zone as the gastric viscerosensory reflex shown in Fig 31

Parasympathetics. The parasympathetic connector fibers arise from the visceral nucleus of the vagus and connect with motor cells within the pancreas. When stimulated, secretion is increased.

Sympathetics .The sympathetics which supply the pancreas have their motor neurons in the semilunar ganglion along with those of the stomach and liver; and the medullated fibers which connect these cells with the spinal cord arise from the 5^{th} to 9^{th} thoracic segments of the cord.

Stimulation of these motor cells decreases pancreatic secretion and causes cither contraction or dilatation of the blood vessels.

The pancreas produces a particular internal secretion which is poured into the veins, and, circulating through the body, comes in contact with and acts upon other organs of internal secretion. This secretion seems to be antagonistic to both thyroid and adrenal activity, and has much to do with maintaining the normal carbohydrate balance in the body.

A secretion of pancreatic juice is stimulated by the hormone, secretin (Bayliss and Starling) which is formed in the duodenal glands adjacent to the pylorus. The glands are stimulated to the production of secretin by the acid contents of the stomach, coming in contact with them on entering the intestine.

II. Pancreas: Clinical Consideration

Pancreatic Visceromotor and Viscerosensory Reflexes. As far as reflex disturbances in the pancreas itself are concerned, taking place through the sympathetic and vagus nerves, our study, as yet, is very meagre. We do know, however, that a stimulation of those sympathetic motor cells which arc in connection with the thoracic segments from the 5th to 9th will inhibit the secretion of the pancreas. We further know that when the pancreas is acutely inflamed, there is a viscerosensory reflex, (Fig, 37) which manifests itself in the epigastrium, being located on the left side of the median line in such a way that it is very difficult to differentiate it from the viscerosensory reflex from the stomach. If the inflammation is very severe the pain is sometimes also found on the right side in the epigastrium. A visceromotor reflex also appears in the upper portion of the left rectus the same as when the stomach is inflamed as shown in Fig. 38.

Pancreatic Parasympathetic Reflexes. The parasympathetic reflexes from the pancreas, as best observed, express themselves mainly in the stomach, producing nausea and vomiting, but also produce other motor and sensory disturbances in both stomach and intestines.

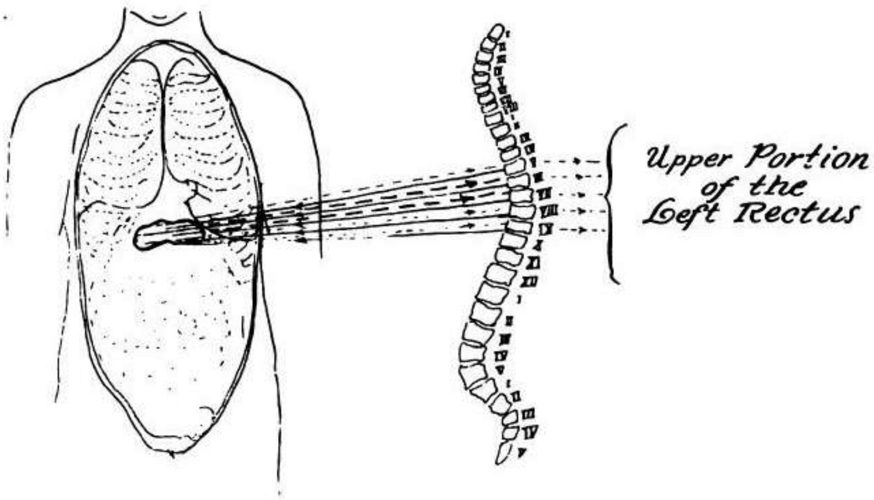

Figure 38. Showing the pancreatic visceromotor reflex.
Lines connecting the pancreas to the thoracic segments of the cord rom the 5th to the 9th represent the sympathetic nerves. Solid lines represent the pancreas which supply the pancreas. Broken lines represent sensory sympathetic nerves which carry afferent impulses to the cord. Broken lines on the other side of the cord represent corresponding spinal nerves which receives impulses from the sensory sympathetic nerve and transmit them to the upper portion of the left rectus producing the pancreatic visceromotor reflex. The broken line from the pancreas to the 6th and 7th segments of the cord are heavier, indicating these are the principle paths of the impulses

Chapter XV

The Diaphragm

I. Innervation of the Diaphragm

The diaphragm is a very important muscular organ. It belongs more to the skeletal than it does to the visceral structures; consequently it receives its nerve supply more from the spinal nerves than from the vegetative system. The upper surface of the diaphragm is covered by the pleura, the lower is covered by the peritoneum. It is impossible to separate these structures physiologically, so we must treat them together. The diaphragm is supplied by both vagus and sympathetic fibres belonging to the vegetative system, and the intercostals and phrenics of the spinal system. This brings the diaphragm into reflex connection with both the thoracic and abdominal viscera; and also with the superficial tissues of the shoulder girdle, thorax and abdomen. While one surface of the diaphragm is covered with pleura and the other with peritoneum, the main portion is made up of striated muscle. This organ consists of two distinct parts, the central tendon and the costal portion,

Sympathetics. The sympathetic nerve supply for the diaphragmatic pleura is probably the same as that of the costal pleura, and, therefore, we must assume that it comes from two sources; First, from the same source that supplies the pulmonary tissue (the upper five or six thoracic segments); second, from the sympathetic fibers which course with the intercostal nerves (6th to 12th thoracic segments).

The peritoneal surface of the diaphragm receives its nerve supply from the same source as that which supplies the peritoneum in general, the fibers which course with the intercostal nerves, 6th to 12th, and go to the celiac plexus.

Parasympathetics. The parasympathetic nerve supply which goes to the diaphragm, consists of fibres of the vagus belonging to the pulmonary plexuses and the fibers of the vagus which belong to the abdominal plexuses.

Spinal Nerves. The diaphragm consists of a central tendon and two strong muscular crura which connect with the spinal column, and a peripheral or costal portion which joins it to the lower postal margin. The central tendon of the diaphragm with its crura is innervated largely by the phrenics which take their origin from the 3rd and 4th, sometimes the 4th and 5th, cervical segments of the cord. The phrenics also send some fibers to the costal portion of the diaphragm. They pierce the diaphragm and are distributed to both surfaces. The costal portion of the diaphragm, on the other hand, is largely supplied by the lower six intercostal nerves, which also send some fibers to the central tendon. The diaphragm is shown in Pig. 30 in which the relative importance of the muscular portions, crura and costal portion, may be seen.

II. The Diaphragm: Clinical Consideration

The diaphragm has not received the careful clinical study that its physiologic importance warrants. The diaphragm is the most important muscle of respiration. It is connected reflexly thorough the sympathetics, with both thoracic and abdominal viscera, a fact which affords opportunity for many viscerogenic reflexes.

Sympathetic Reflexes

Diaphragmatic Visceromotor Reflex. The diaphragmatic visceromotor reflex is not easily recognized, because the same sympathetic nerves which supply the diaphragmatic crura come from the pulmonary plexuses, and the lower intercostals. Therefore, reflexes occur through the same spinal nerves and in the same tissues that show them when the pulmonary parenchyma on the one hand, or the lower costal pleura on the other hand, is inflamed. The same may be said of the reflexes which originate from inflammation of the peritoneal surface of the diaphragm. They occur through the same nerves and in the same tissues as reflexes due to inflammation of the abdominal viscera. Consequently, these diaphragmatic reflexes of sympathetic origin cannot lie differentiated by their location in the tissues from reflexes of sympathetic origin arising in the thoracic and abdominal viscera.

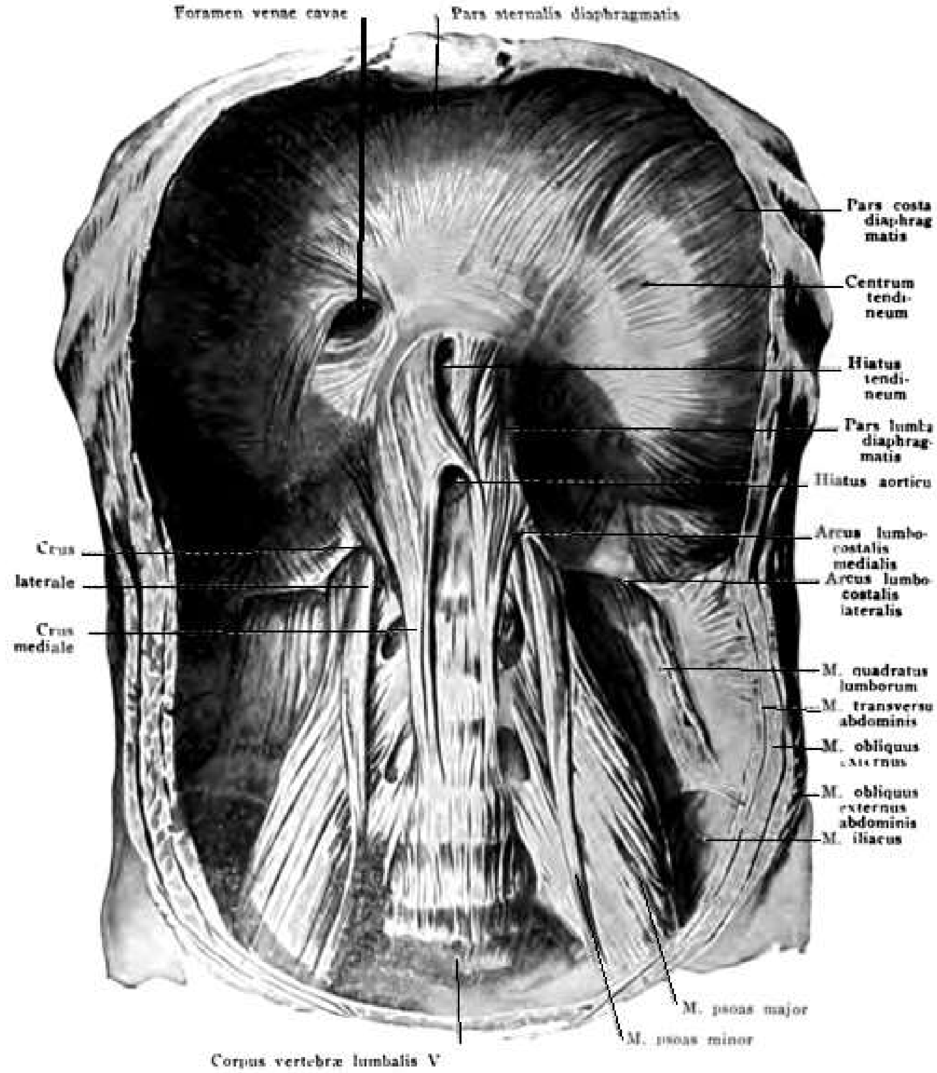

Figure 39. Diaphragm viewed from the front and below.
The diaphragm is made up of central fleshy tendons (pars lumbalis) and thinner fibres running to the ribs (pars costalis) and sternum (pars sternalis). The contraction of the diaphragm consists of shortening of both the crura (pars lumbalis), the pars costalis and the pars sternalis. With the abdominal viscera as a fulcrum, the contraction of the diaphragm widens the lower portion of the thorax as shown. In inflammations of the lungs its motion is restricted. It is probably in tonic contraction for the same reason that the neck and chest muscles are in contraction, having its nerve supply in part from the cervical portion of the cord. This restricted action seems to be confined to side involved. In some cases the limited motion does not seem to be present, but where it is present there is an actual shortening of the fibres, the same as the surface muscles of the body when they are contracted.

Diaphragmatic Viscerosensory Reflex. The same may be said of the diaphragmatic viscerosensory reflex as was said of the viscero- motor reflex. Inflammation of the pleural surface of the diaphragm reflects through its sympathetic nerves in two areas: First, the same area that shows the sensory reflex from the lung, which is particularly the 3rd and 4th cervical sensory zones; second, the areas which show the sensory reflex arising from inflammation of the lower portion of the costal pleura, the thoracic zones, 6th to 12th.

The viscerosensory reflex arising from the peritoneal surface of the diaphragm likewise cannot be differentiated from reflexes arising in the abdominal viscera, because reflexes from both sources express themselves through the lower six thoracic segments of the cord. It can be said, however, that as a rule when the peritoneal surface of the diaphragm is inflamed, both sensory and motor disturbances of reflex origin usually occur near that portion of the diaphragm which is involved instead of in the median line, in the peripheral distribution of the nerves.

Parasympathetic Reflexes

It is somewhat difficult to describe definite parasympathetic reflexes originating in the diaphragmatic pleura and diaphragmatic peritoneum, although any reflex that can arise from the pleura in general through irritation of vagus nerve endings, might arise when vagus endings in the diaphragmatic pleura are irritated. Thus, we find a cough very often as a symptom of diaphragmatic pleurisy. Arising from the peritoneal surface of the diaphragm, we have at times a slowing of the pulse, and parasympathetic reflexes arising in the organs of the enteral system. This is particularly true when there is a definite, inflamed area involving both neighbouring organs and the peritoneal surface of the diaphragm. This is not wholly due to the peritoneal involvement; but probably is due partly to it, and partly to the inflammation in adjoining structures. Inflammation of the diaphragm is a common cause of hiccough.

Reflexes through the Spinal Nerves

There are both motor and sensory reflexes which take place from stimuli arising in the diaphragm, the afferent impulses traveling centralward through both the phrenics and the lower intercostal spinal nerves. The phrenic motor reflex, if it could be differentiated from that from the lung, would show as an increased tonus of the muscles which arise from the 3rd and 4th, or 4th and 5th cervical segments of the cord; thus the scaleni, levator anguli scapulae and rhomboidei would be particularly affected. The phrenic sensory reflex also shows itself in the 3rd and 4th, or 4th and 5th cervical segments of the cord. This sensory reflex is the most constant symptom in diaphragmatic pleurisy. Fig 40 A and B shows the common site of diaphragmatic pain reflected through the phrenics.

When this phrenic diaphragmatic reflex is on the right side, it is located in the same areas as pain from the gall bladder. I have seen instances of cholecystitis in tuberculous patients where differentiation was all but impossible. Auscultatory findings sometimes aid in differentiation.

It can be seen readily, therefore, that from the tissues involved alone, it is difficult to differentiate these reflexes from those which occur through the sympathetic nerves when the pulmonary parenchyma is involved. In the latter, however, other segments are often stimulated, bringing other tissues under the reflex action. The diaphragm being innervated by spinal nerves in which the sensory neurons arc more sensitive than those of the sympathetics, shows reflex sensory disturbance more plainly than the pulmonary parenchyma.

Motor and sensory reflexes also take place through the lower six spinal (intercostal) nerves as well as through the phrenics. These show as a spasm of those muscles which receive their innervation from the 6th to 12th thoracic spinal nerves, the lower six intercostals, and the abdominal muscles. The sensory disturbance (pain) manifests itself somewhere in the path of the sensory spinal nerves which take their origin from these segments, usually near the lower costal margin ; sometimes, however, extending well down over the abdomen, and now and then even in the median line of the abdomen. Thus it can be seen that these motor and sensory reflexes originating through the lower intercostals cannot he differentiated, by the tissues involved, from the visceromotor and viscerosensory reflexes which originate from the lower portion of the costal pleura, as shown in Figs, 46 and 47, pages 130 and 131).

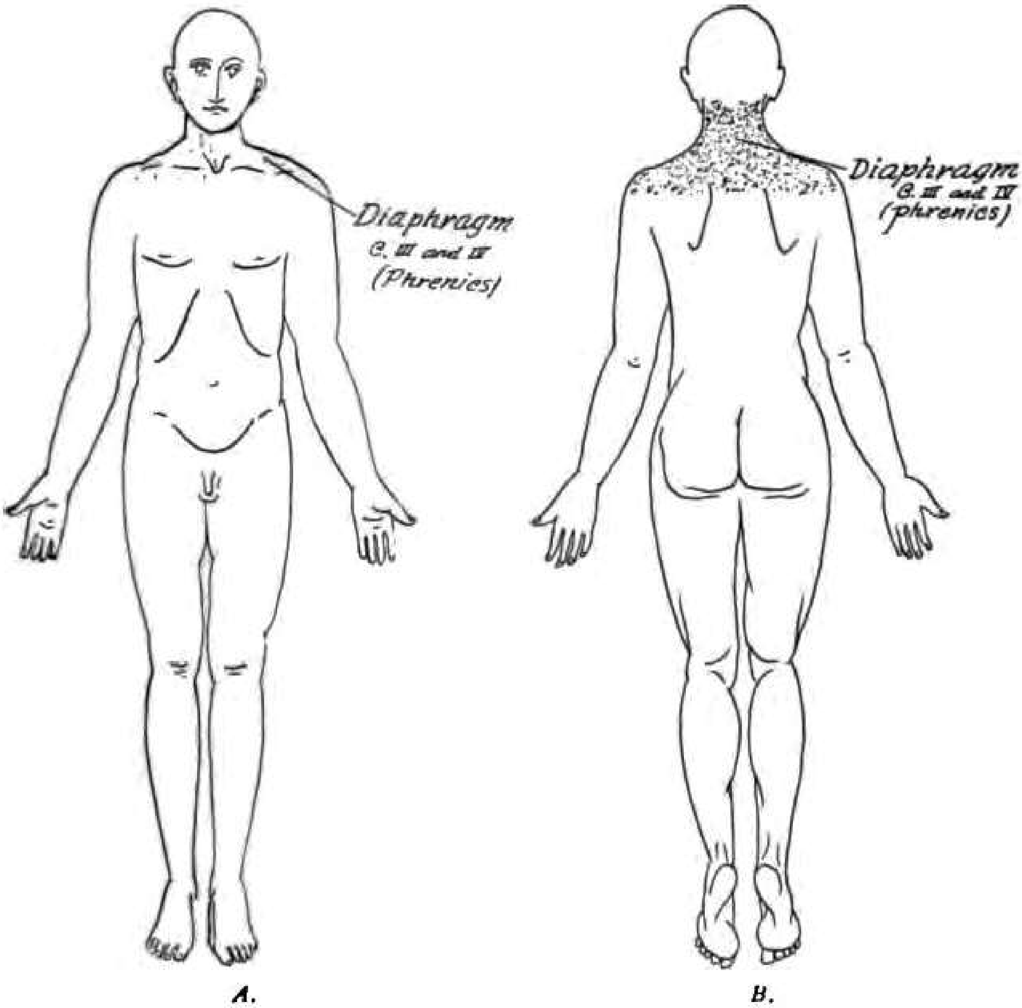

Figure 40. Site of diaphragmatic viscerosensory reflex.
A – anterior. B – posterior.
Afferent impulses travel centralward through the phrenics, producing reflex sensory disturbances, particularly in in the 3rd and 4th cervical zones. Note that these are the same areas involved in the pulmonary viscerosensory reflex, and on the right side the same as the hepatic viscerosensory reflex

Reflexes Shown in the Diaphragm, the Afferent Impulse Coming From Other Organs

The diaphragmatic muscle proper, receiving its innervation through the phrenics from the 3rd and 4th, or 4th and 5th, cervical segments of the cord, and from the lower six intercostal nerves, is bound reflexly to all organs which send afferent sensory impulses to the particular segments from which these spinal nerves arise.

The importance of the diaphragm and the relationship which it bears to the health of the individual, is not sufficiently appreciated by medical men. It is not only the most important muscle of respiration; but a normal action of the diaphragm affords a very necessary aid to the circulation of the blood. Disturbance in its function is followed by many functional disturbances, such as weakness, loss of endurance, dizziness, faintness, and other symptoms of the cardioneurotic group. These have been carefully studied by Wenckebach[1] and Eppinger[2], whose works are very valuable and suggestive.

When the diaphragm contracts it starts a whole train of action. It descends, enlarging the thorax from above downward, at the same time compressing the abdominal viscera, increasing the intraabdominal tension, and forcing the large abdominal muscles outward. The main factor in causing this major contraction is the crura which are supplied by the phrenic nerves. While they are contracting, however, the costal portion, which is supplied by the lower six intercostal nerves, also contracts, shortening this portion of the muscle. The effect of this is to raise the lower arch of the thorax which brings the anterior ribs upward so that the ribs as a whole come nearer to the horizontal plane. This increases the anteroposterior diameter of the thorax. In this the lower external intercostals and intercartilageni also have a hand, as well as in the next movement of the ribs, which is to turn and raise them like a bucket bail, enlarging the lateral diameter. As a result of these movements, the thorax is greatly enlarged. The action of the diaphragm in enlarging the thorax laterally is schematically shown in Fig. 41. The blood is aspirated by the enlarging thoracic cavity from the large veins, and literally squeezed from them by the compressing force exerted upon the abdominal viscera. The importance of this action to the health of the individual should be apparent. The influence of pathologic conditions in both the thoracic and abdominal cavities, which interfere with this normal diaphragmatic action, deserves careful study. Therefore, the reflexes which result in diminished diaphragmatic movement deserve most careful study not only from a diagnostic standpoint, but from the general stand- point of understanding the effect of disease upon the human organism.

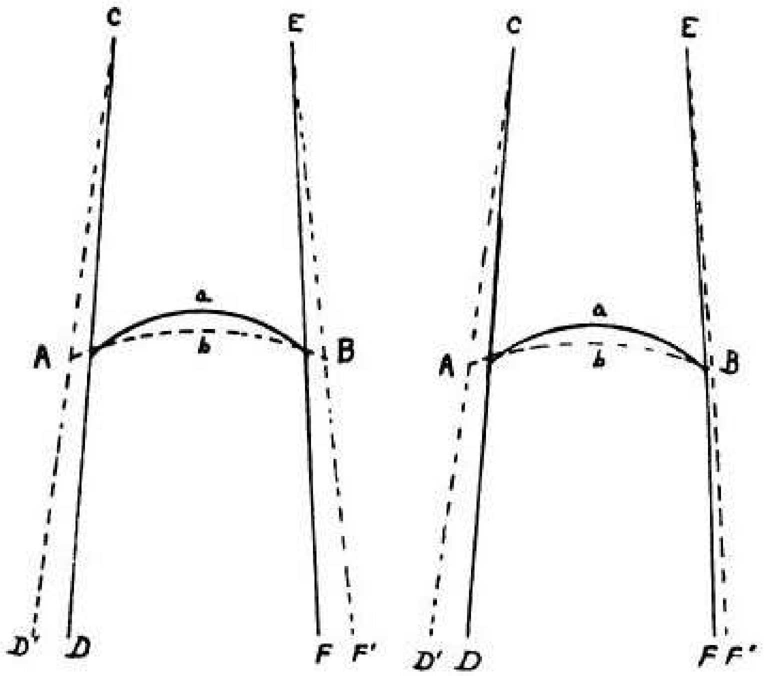

Figure 41. Schematic illustration of the influence of the diaphragm in enlarging the intrathoracic space. A – normal respiration. B – illustrating the effect when the movement of one side of the diaphragm is lessened. The intrathoracic space fails to be enlarged to the extent that the motion of the chest and abdominal wall EF(on the right picture) is restricted

Lungs. When the pulmonary parenchyma is inflamed, as in pulmonary tuberculosis, a very important motor reflex shows itself in the diaphragm. The afferent impulses go through the sensory sympathetic fibers which have their cell bodies in the ganglia of the posterior roots of the nerves arising from the upper five or six thoracic segments of the cord. The impulse is then carried upward by intercalated neurons to practically all of the cervical segments of the cord, but particularly to the 3rd and 4th, where it is transferred to the motor neurons which innervate the various muscles of respiration, as described in Chapter XVI, This is the portion of the cord which gives origin to the phrenic nerves, which are especially involved in the pulmonary reflex. This shows in the diaphragm as a limited motion; and is described clinically either as lagging or as diminished motion of the thorax. The muscle, being already in a state of partial contraction, responds with a limited motion to the normal respiratory impulse. This motor reflex is confined to the side I>f involvement, while the healthy side gives normal respiratory movement: consequently, it is of great value in the diagnosis of pulmonary inflammations. This reflex shows early in pulmonary tuberculosis, before the disease is widespread. Another factor on the part of the lung in producing diminished motion of the diaphragm is the lessened elasticity of the pulmonary tissue caused by disease processes.

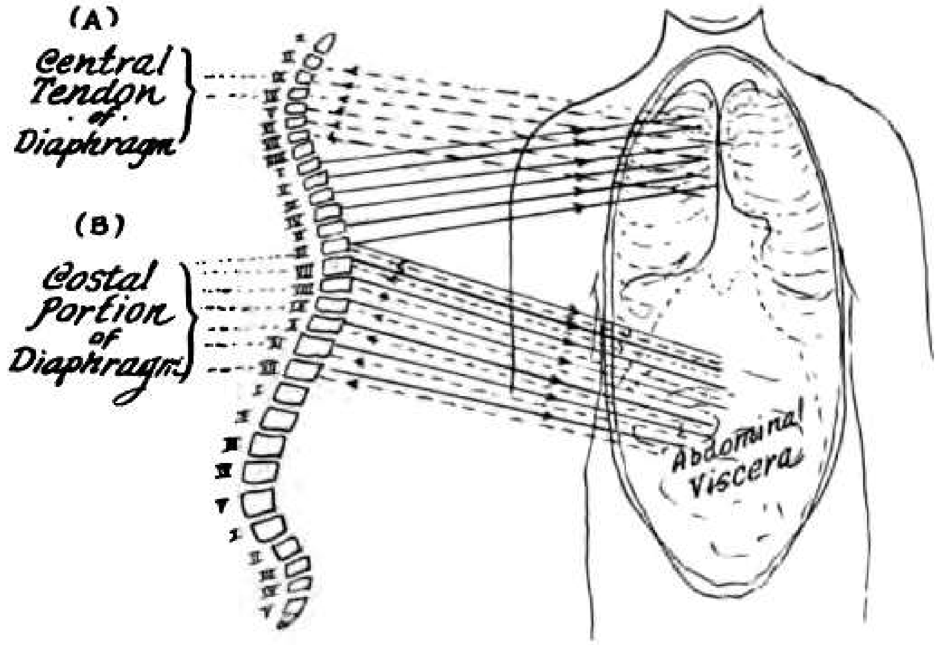

Figure 42. Showing the diaphragmatic from other organs.
A – lungs. B – abdominal viscera.
A - The motor reflex in the diaphragm which arises from the lungs is shown in the central tendon of the diaphragm. The afferent impulses travel through the sensory sympathetics to the cervical portion of the cord; the efferent impulses through the phrenics, arising from the 3rd and 4th cervical segments. The path shown in the figure is schematic. Instead of returning directly from the lung to the cervical segments as shown, the impulse travels back to the upper 6 thoracic segments, then upwards to the cervical segments through intercalated neurons in the cord as was shown in Fig. on page

B – The diaphragmatic visceromotor reflex which originates from the abdominal viscera is produced by impulses travelling centralward to the lower 7 thoracic segments, the efferent impulses being expressed through the lower 7 intercostal nerves, which supply the costal portion of the diaphragm.

Figure 42 A shows the paths through which stimuli arising in the lung effect a motor reflex in the diaphragm.

Pleura, When the pleura is inflamed, particularly the lower portion, afferent impulses are carried centralward either through the sensory sympathetics or through the sensory fibers of the intercostal nerves which supply it; and, on reaching the cord, are transmitted to motor neurons in the same segments, which, thus activated, produce a motor reflex spasm of the intercostal muscles, the costal portion of the diaphragm, and sometimes also of the superficial muscles.

Sometimes this tension involves a considerable portion of the muscles of the abdomen, but usually is confined largely to that portion near the costal margin. The costal portion of the diaphragm, which is innervated by these same lower intercostal nerves, being involved in the motor reflex and being aided by the superficial muscles, causes diminished inspiratory motion.

Figure 42 B shows the paths through which stimuli arising in the lower portion of the pleura or in the abdominal viscera effect a motor reflex in the diaphragm.

Abdominal Organs. Inflammation of the various abdominal viscera, stomach, intestine, appendix, liver, pancreas, or kidney, may produce a motor reflex which particularly affects the costal portion of the diaphragm, the afferent impulse traveling centralward to the thoracic segments, Vth to XIIth, through the sensory sympathetic fibers which supply these various viscera. When the impulse reaches the cord, it is transferred to the motor neurons in the same segments and is expressed in motor action through the intercostal nerves which go to supply the costal portion (particularly) of the diaphragm. While the increased tension (spasm) of the muscle cannot he detected, it shows as a disturbed motility, the same as the reflex through the phrenics from the lung and through the intercostals from the pleura. The result is that we may have a limited respiratory motion on the side of involvement, the same as we have from the thoracic viscera; the difference being that the lung shows particularly through the phrenics, while the pleura expresses itself in a marked reflex through the lower intercostals, and the abdominal viscera in a reflex less marked, through the intercostals.

Sole has described such a reflex as this in connection with acute abdominal conditions as described on page 128. It is probable that the diaphragm, intercostal and superficial muscles all take part in this reflex diminution of respiratory movement the same as mentioned in the preceding paragraph in reference to the reflex from the pleura.

The innervation of the liver, the small intestine, the appendix, the ascending colon and the right kidney is such that they would reflect largely on the right side of the diaphragm, while the stomach, pancreas, descending colon and left kidney reflect largely on the left side of the diaphragm.

Peritoneum. The peritoneum which inflamed produces a motor reflex in the diaphragm and the muscles of the abdominal wall, the afferent impulse going through the sympathetic nerves to the cord and the efferent component being found in the lower intercostal nerves which supply the costal portion of the diaphragm on the one hand and the abdominal muscles on the other.

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Chapter XVI

The Bronchi and The Lungs

I. Innervation of the Bronchi and the Lungs

The bronchi and lungs belong to the enteral system. They are developmentally formed from a diverticulum from the gastrointestinal canal, hence we should expect the same innervation as is found there. These structures are activated by the vagus and receive inhibitory fibres from the sympathetics as shown in Plate I, page 53.

Parasympathetics. Connector fibers to the smooth musculature surrounding the bronchi and to the glands of the mucous membrane, come from the visceral nucleus of the vagus and join the motor cells in the walls of the bronchi. Thus, as in the intestines and the heart, the motor cells of the parasympathetic system lie within the walls of the bronchi, while the vagus supplies the connector fibers which unite them with the central nervous system.

Stimulation of the afferent sensory fibers which course in the nervi laryngeus superior, tracheales and bronchiales of the vagus, and whose cells lie in the sensory nucleus solitarius, carry impulses to the higher centres in the brain which have an inhibiting influence on the respiratory center and cause the reflex act known as cough. They also carry sensory impulses which are responsible for many parasympathetic reflexes in other organs.

Sympathetics. The lungs are supplied by connector fibers which arise from the upper five or six thoracic segments of the cord. They pass to the stellate ganglion and there meet motor cells of the sympathetic system, which send out sympathetic fibres to the plexus pulmonalis for the lungs. These course with the blood vessels and bronchi throughout the pulmonary tissue.

Sympathetic fibers carry vasoconstrictor impulses to the tissues of the lungs. This was long disputed but now seems to have been definitely proved. They also carry impulses which are inhibiting to the vagus, whose function is to relax the bronchial musculature and depress bronchial secretion.

The pulmonary reflex of Abrams is most likely produced through the sympathetics.

The afferent impulses from the lungs course in the sympathetics to the same segments of the cord (1st to 6th thoracic) as those from which the connector fibres originate; but in producing reflex motor, sensory and trophic reflexes, they mediate with the cervical spinal nerves. Therefore, intercalated fibers must pass upward from the upper thoracic to the cervical segments through which the sensory afferent impulses from the lung are transmitted to the cervical spinal nerves. Fig. 43 from Villiger illustrates the intercalated neurons, their axons and collaterals. Inasmuch as the sensory, motor and trophic reflexes from the lung belong to the more complex variety, I desire to make plain the difference between these and the simple reflex, and cannot do better than quote from Villiger[1]:

"The simplest reflex path is established by the reflex collaterals. In this case only two neurons share the entire path, the transference from the centripetal to the centrifugal neurons being accomplished by means of the collaterals given off directly from the centripetal or afferent neuron.

"The release of the reflex may be induced, however, by intercalated neurons. Thus, between the centripetal and the centrifugal neuron a third neuron may intervene, thereby making possible the transference of the impulse conveyed by a single centripetal neuron to several centrifugal ones. Such intercalated neurons, for example, are the association-cells of the spinal cord, which distribute, by means of their axons and collaterals, impulses to many cells within the cord-segments of higher and lower levels. To this category belongs, further, the posterior longitudinal bundle. Impulses carried to Deiters' nucleus by the vestibular nerve may be distributed to the nuclei of the eye-muscles and to the motor cells of the cord by means of fibers, which proceed from Deiters' nucleus and run within the posterior longitudinal bundle. In consequence of the introduction of several neurons between the centripetal and the centrifugal conduction, the entire reflex mechanism may become very complex,"

In this quotation, Villiger terms afferent fibers, centripetal, and efferent, centrifugal.

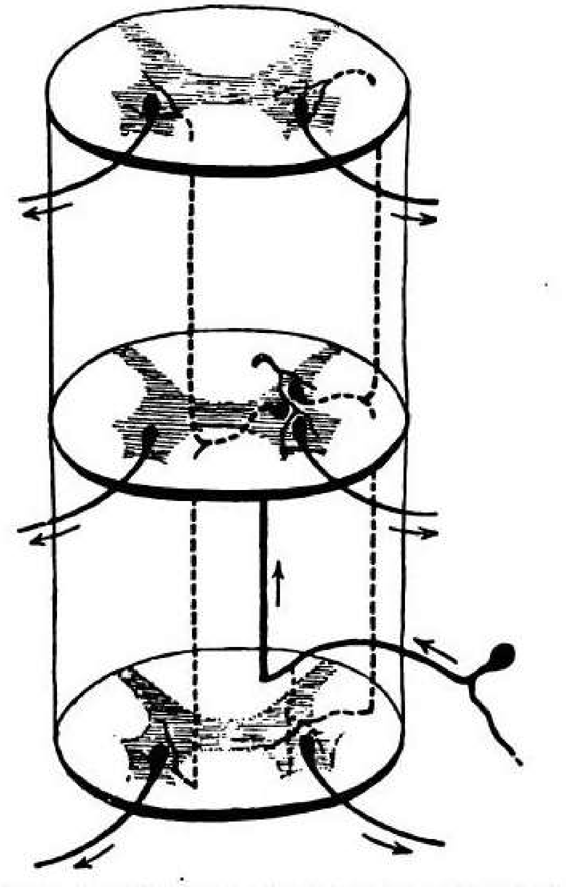

Figure 43. Reflex paths in the spinal cord.
Showing the manner in which nerve impulses are distributed to other levels by intercalated neurons. (Villiger)
Solid lines represent neurons going to and from the cord. Broken lines represent neurons taking impulses to other levels

II. The Lungs: Clinical Consideration

It has been my pleasure to describe a number of new reflexes from the lung, and also to offer an explanation for many of those which had previously been described by others. In the following table, I have arranged the reflexes which are commonly met in clinical practice in such a manner as to show at a balance the path through which the reflex is expressed. Column one shows that the afferent impulses from the lung must course over either the fibers of the vagus of the parasympathetic system or those of the sympathetic system. Column two shows the symptoms to be explained. Column three shows the efferent nerve or nerves through which the impulse courses to complete the reflex. These reflexes will be described fully later in this chapter.

Symptoms of Pulmonary Tuberculosis

Symptoms from the Lung			
Afferent Nerves	**Afferent Nerves through (Vagus) parasympathetics**	**Symptoms** Hoarseness Laryngeal Irritation Cough Inhibition of heart Increased muscle tonus and glandular secretions in gastro-intestinal canal Flushing of face Spasm of sternocleidomastoid and trapezius Deviation of tongue from midline Degeneration of facial muscles	**Efferent Nerves** Laryngeal Nerves Superior laryngeal nerve Laryngeal and nerves to all expiratory muscles with inhibition of nerves to inspiratory muscles Motor fibres of cardiac vagus Motor fibres of gastric and intestinal parasympathetic Sensory fibres of trigeminus Spinal accessorius Hypoglossus Trigeminus and facialis
Inflammation of lung	**Afferent Nerves through (Vagus) parasympathetics**	Flushing of ear Dilatation of pupil Spasm of muscles of shoulder girdle and diaphragm Lessened motion of chest wall, partly due to muscle spasm as above Pain above 2nd rib and spine of scapulae (superficial) Pain in muscles of shoulder girdle (deep) Degeneration of skin and subcutaneous tissue above 2nd rib anteriorly and spine of scapulae Degeneration of muscles of shoulder girdle	3rd sensory cervical Motor from Budge's centre (lower cervical and upper dorsal) Cervical motor nerves 2 - 8 Cervical motor nerves 2 - 8 Cervical sensory nerves, particularly 3rd, 4th and 5th Cervical sensory nerves 2 - 8 Cervical sensory nerves 3rd, 4th, 5th Cervical sensory and motor nerves 2nd to 8th

Figure 44. Symptoms of Pulmonary Tuberculosis

Sympathetic Reflexes

Pulmonary Visceromotor Reflexes. As previously stated, the lung are formed from a diverticulum from the intestines and they receive their innervation from the upper five or six thoracic segments of the cord. When the lung is inflamed, the afferent sensory impulses go back to the same segments of the cord over the same white rami. When the impulse reaches the sensory cells in the ganglion of the posterior root, however, instead of being directly transferred to the corresponding spinal nerves in the same segments, it is carried upward in the cord through intercalated neurons, as previously mentioned and transferred to motor and sensory spinal nerves in the cervical segments. Therefore, we have some difference in the distribution of visceral reflexes when the stimulation arises in the lungs from what we have when it arises in most other organs as illustrated by the reflexes which occur from stimuli in the intestines; because in the latter the efferent impulse seems to be carried strongest in the spinal nerves emerging from the same segment that receives the afferent impulse over the sensory sympathetic fibers.

The visceromotor, viscerosensory and viscerotrophic reflexes which arise from stimuli originating in the lungs seem to manifest themselves throughout most of the cervical segments, but to be more marked in the 3rd and 4th segments. They appear as motor and sensory changes in the tissues supplied by the cervical spinal nerves; and, if the disease becomes chronic, as trophic changes.

In the lung and pleura we have an opportunity to prove clinically that there is a differentiation in innervation between the anterior and posterior portions of the lung and pleura; for if there is an inflammation in the anterior portion of the lung or pleura, the motor, and later, the trophic changes in the tissues, manifest themselves in the anterior muscles and other soft tissues ; while if the posterior part of the lung is involved, the posterior superficial soft structures show the reflex changes. It is not at all uncommon to find spasm in the anterior muscles, and degeneration in the soft tissues anteriorly, and none posteriorly, and vice versa.

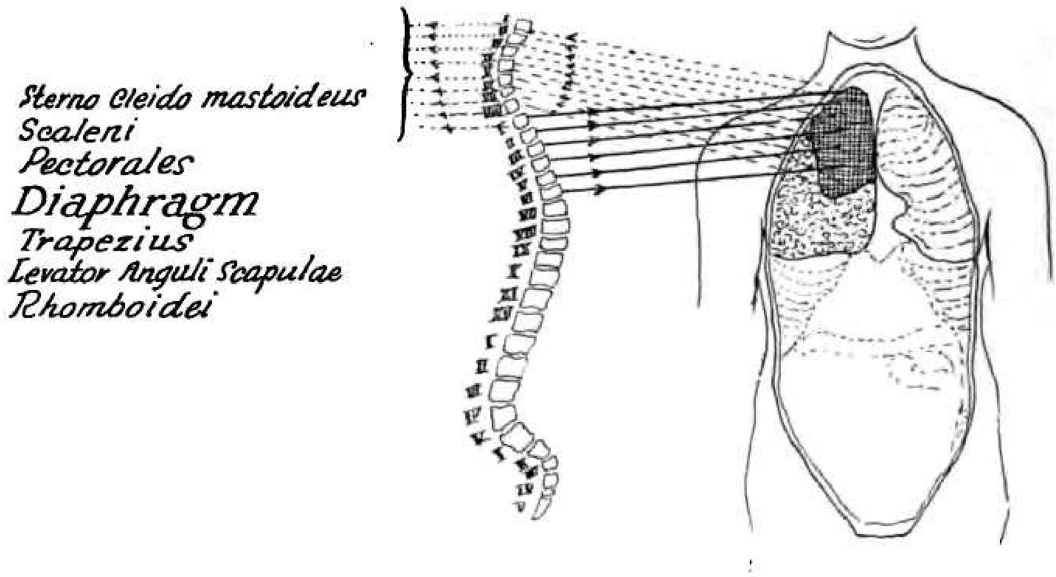

Figure 45. Schematic illustration of pulmonary visceromotor reflex.
Lines running between the lung and the spinal cord represent sympathetic nerves. Solid lines carry innervation to the lung. Broken lines carry innervation from the lung to the cord, where they are transmitted to the cervical portion of the spinal motor nerves, which complete the reflex. The muscles involved in this reflex are shown in the cut. The path of the reflex is not as shown directly from the lung to the cervical portion of the cord, but back to the upper 6 thoracic segments, from which it is carried upwards to the cervical portion of the cord by intercalated neurons, as shown in Fig 43

The visceromotor reflex which results from the lung shows itself in the contraction of the fibres of those muscles which receive their origin from the cervical portion of the cord and particularly from the 3rd and 4th segments. This is recognized clinically as an increased tone or spasm. The muscles which show this best {Fig. 44) are the sternocleidomastoideus, scaleni, pectoralis, trapezius, levator anguli scapulae, rhomboidei and diaphragm; receiving innervation from the cervical segments from the 2nd to the 8th. While the spasm cannot be seen or felt in the diaphragm, yet the limited action of this muscle is shown very plainly in the diminished motion of the side of the chest from which the visceromotor reflex arises.

It is characteristic of the visceromotor reflex, as well as the viscerosensory and viscerotrophic reflexes, that it is confined largely to the side of involvement. It will be readily understood that increased tonus or spasm in the muscles of respiration, would have a tendency to fix the side involved, resulting in a lessened respiratory movement.

The muscle having the greatest power in limiting the respiratory movement, unless the intercostals are also in spasm as a result of the underlying pleuritis, is the diaphragm as may be inferred from Fig 41, page 129. This is evident from the fact that this is the most important muscle of respiration.

The motor reflex (spasm) on the part of these various muscles, sometimes appears as an increase in size; at other times as an increased prominence and augmented tonus because of their shortening. It may sometimes be seen on inspection and may usually be determined more or less readily by palpation.

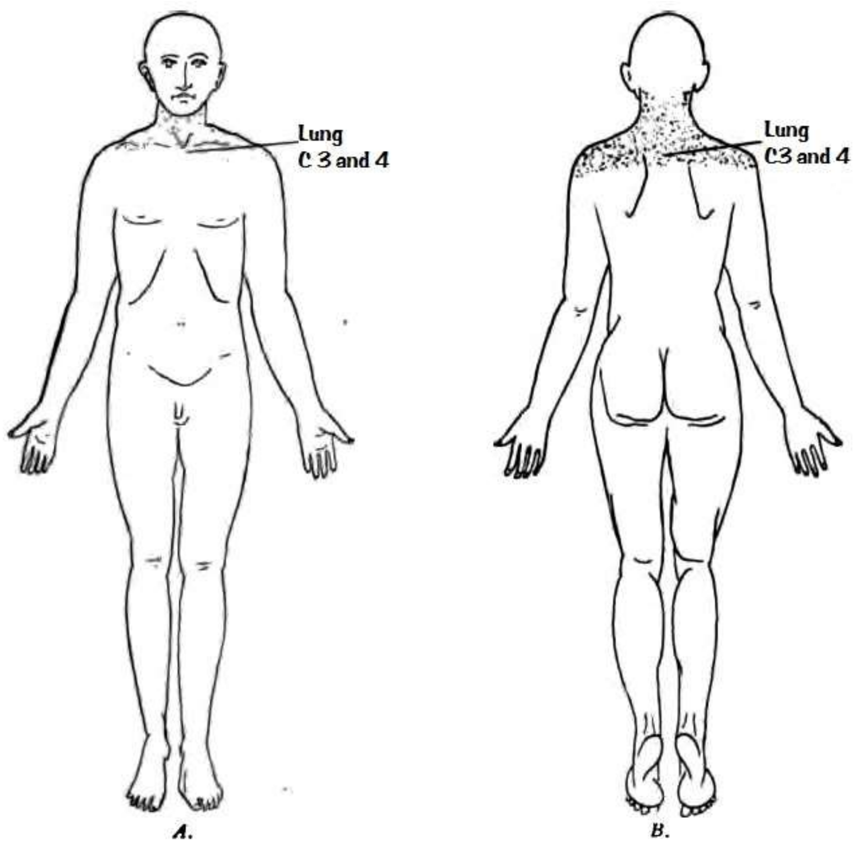

Figure 46. Pulmonary viscerosensory reflex.
Note the 3rd and 4th cervical sensory zones are involved, the same as are shown in the phrenic sensory nerve reflex from the diaphragm; and on the right side the same as is found in the hepatic viscerosensory reflex. Cutaneous pain form the lungs, for the most part, if not wholly, expressed above the 2nd rib (A) and the spine of the scapula (B)

The readiness with which the motor reflex is determined will depend upon the character of the muscles in a given patient prior to the pulmonary inflammation; that is, whether naturally well developed or not; whether hypertrophied as a result of the character of work pursued; or degenerated as a result of previous occupation or previous chronic inflammation. Individuals whose vocation does not call for an unusual use of the arms, generally have a degeneration of the shoulder girdle, which leads to a lengthening of the muscles and a dropping of the shoulder on the side of the hand which they use most. This affects particularly the sternocleidomastoideus, pectoralis and trapezius. The levator anguli scapulae and rhomboidei on the other hand are usually larger than on the other side. It is only those who do strenuous work who show enlargement of all these muscles. This must always be taken into consideration in the examination of patients. It is not only of great diagnostic value of itself, hut the conditions present must he considered if we would correctly interpret palpation and auscultatory findings.

It is difficult to determine the motor reflex in those with poorly developed muscles, also in those whose muscles are firm from use. If the palpable muscles in the latter type of cases are in spasm, the same reflex increased tonus will be present in the diaphragm and will show as a diminished motion.

Pulmonary Viscerosensory Reflex. The viscerosensory reflex resulting from inflammation in the lungs shows itself in the nerves arising from the same cervical segments that show the visceromotor reflex. It may be organized as an alteration to the sensations of heat, cold and pain, in the skin and a sensation of soreness in the deep tissues. The areas in the skin which show the greatest departure from normal in sensation, are those supplied by the 3rd and 4th cervical nerves as shown in Fig. 45 A and B, the same areas that show the viscerosensory reflex from the liver and the diaphragm through the phrenics. These nerves supply the skin and subcutaneous tissue over the neck and shoulder down as low as the second rib anteriorly and the spine of the scapula posteriorly, and out over the deltoid muscle. The deep soreness may involve all muscles of the shoulder girdle.

This viscerosensory reflex is extremely common in tuberculosis, both in its acute and chronic forms. Patients with tuberculosis often complain of pain in the interscapular legion, and also over the anterior surface of the chest. These particular sensory reflexes are deep pains and due to muscle hyperalgesia. The tissues about the hilus of the lung, which are practically extrapulmonary, produce their reflex effects in the interscapular region. The pleura may produce hyperesthesia or hyperalgesia or ordinary pain anywhere over the areas supplied by the thoracic spinal nerves. I have noticed a very interesting viscerosensory reflex complained of in the fingers in a few instances. This is important because it shows that while the greatest degree of reflex stimulation seems to be in the 3rd and 4th cervical segments, reflex action also takes place through the lower cervical segments. One case was a man who had a chronic tuberculosis which had left him with large cavities in the right lung. Every now and then an increase in the inflammatory process was experienced. At such times he felt a peculiar sensation in the ends of his fingers, which must have been brought about through the 7th and 8th cervical and 1st thoracic sensory segments.

It will he noticed that the skin areas and muscle areas which show pain from the lungs are not coextensive, yet they have in common an innervation from the same cervical nerves. The cervical cutaneous zones which arc particularly involved in the sensory reflexes, if the pulmonary parenchyma is inflamed, do not extend below the second rib anteriorly and the spine of the scapula posteriorly. Sensory nerves, however, from the same cervical segments supply the muscles belonging to the shoulder girdle including the pectoralis, trapezius and rhomboidei which extend far down over the chest wall.

This offers an explanation for the fact that the pulmonary sensory reflexes show in the skin of the neck, shoulders, and the chest above the second rib anteriorly and the spine of the scapula posteriorly; while the hyperalgesia which affects the muscles may extend down over the chest itself. This later expresses itself clinically as a "deep pain," The basis for this explanation lies in the difference in distribution of those cervical nerves going to the skin and those going to the muscles as shown in Figs. 4,5,6,7 pages 31 to 34, from Dejerine.

Pulmonary Viscerotrophic Reflex. The viscerotrophic reflex from the lung likewise expresses itself in the same areas as the viscero- motor and viscerosensory reflexes. The nutrition of tissues depends upon both sensory and motor nerves. The nutrition of the skin and subcutaneous tissue is influenced by the .sensory spinal nerves, while both sensory and motor nerves enter into the nutritional control of muscles and other skeletal structures. We find that the pulmonary viscerotrophic reflex shows itself best in the 3rd and 4th cervical sensory zones. It is most marked in the skin and subcutaneous tissue of the neck, extending downward over the chest to the second rib anteriorly and spine of the scapula posteriorly. It also affects all muscles which arc brought into action by the visceromotor reflex as detailed above; but particularly those receiving innervation from the anterior roots of the 3rd and 4lh segments, thus: sternocleidomastoideus, scalenus anticus and medius, trapezius and rhomboidei. The muscles affected are shown in Fig. 45, page 129. Thus the viscerotrophic is much wider in the extent of tissue involved than visceromotor, and coextensive with viscerosensory reflexes.

There is a condition present in most people which proves to be very confusing in determining the trophic reflex changes which arise from the lung in the soft tissues immediately below the clavicle on the side of the arm that is used more. As previously mentioned, the shoulder on the side which is used more, is lower than the other because of a lengthening of the muscles which support it. As the acromion drops, the insertion of the pectoralis in the upper arm is lowered. This lowers the entire pectoral muscle mass and accentuates the subclavicular groove. This must not be taken for the reflex degeneration of subcutaneous tissue and muscle which results from inflammation of pulmonary tissue. Careful examination will reveal the difference and show the lessening of the subcutaneous tissue as well as the changes in its texture which denote atrophy.

While innervation follows the body segmentation for the most part, yet it is not exact, and extension beyond the usual limits of a given nerve may now and then be found. Roughly speaking, however, it may be said that a viscerotrophic reflex affecting the skin and subcutaneous tissue above the second lib anteriorly and the spine of the scapula posteriorly and extending up into the neck, is of pulmonary origin ; while that extending from these areas downward to the lower intercostals, is of pleural origin. I realize, however, that the visceral pleura has the same nerve supply as the lung, and, consequently, reflects above the second rib and spine of the scapula; but a pleuritis of severe degree rarely, if ever, occurs without involvement of the underlying lung tissue. It is also possible that mediation to a limited extent might take place between the afferent sensory sympathetic neurons from the lung and the efferent spinal neurons in the upper five or six thoracic segments although I have never been able to determine this point to my complete satisfaction clinically.

This viscerotrophic reflex from the lung as it manifests itself in the skin and subcutaneous tissues on the anterior surface of the chest, often appears as what I have termed a "collar of degeneration." This degeneration affects both skin and subcutaneous tissue and shows in the same tissues that are the scat of superficial pain when the pulmonary parenchyma is inflamed. (Fig. 45.) At a glance it is often noticed that the skin gives a different appearance. There seems to be different pigmentation in the area which is degenerated from that which is not. Posteriorly, in the interscapular space, I have called attention to what I have termed the "hilus saucer of degeneration," as shown in Fig. 46, likewise affecting both skin and subcutaneous tissue. This in my experience indicates that there has been at some time a marked hilus inflammation. The hilus glands are extrapulmonary structures hence reflect in different cutaneous zones from the lung. On palpation the wasting of the subcutaneous tissue in these areas is readily determined. It is thinner than normal, has lost its elastic tone, and feels lifeless and doughy.

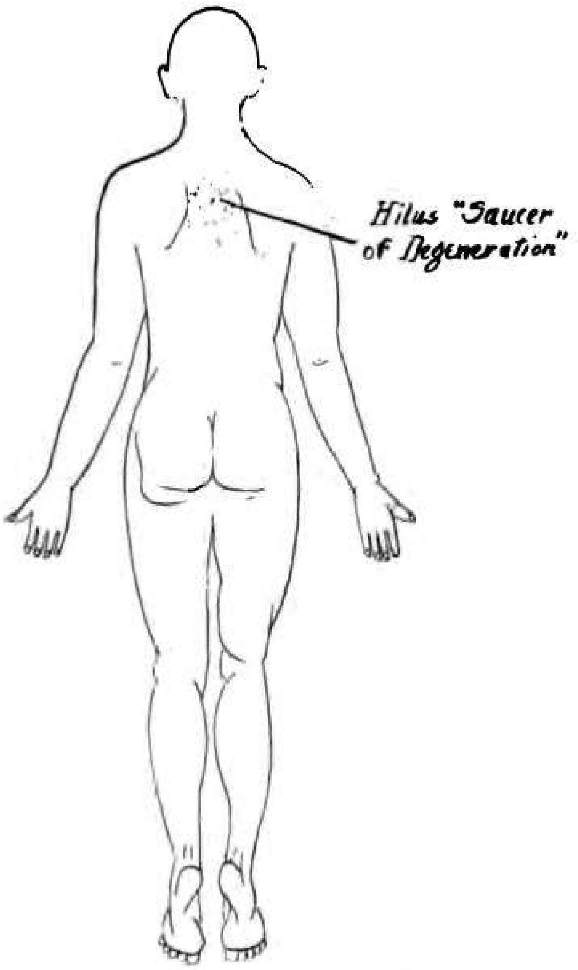

Figure 47. Hilus viscerotrophic reflex.
"Hilus saucer of degeneration". This reflex shows as a degeneration and wasting of the skin and subcutaneous tissue in the interscapular space. In some cases this degeneration is so marked that it appears hollowed out, like a saucer.

The viscerotrophic reflex furnishes particularly convincing proof that the innervation of the anterior and posterior portions of the lungs are supplied by distinct and separate groups of nerve fibers, which likewise mediate with distinct anterior and posterior spinal neurons which are confined in their distribution to anterior and posterior areas on the body surface. Inflammation in the anterior portion of the lung if it becomes chronic reflects on the anterior surface of the neck and upper chest; while that in the posterior part of the lung reflects in the posterior tissues. The 3rd and 4th cervical sensory zones which show the viscerotrophic reflex, are indicated in Fig. 47A and B.

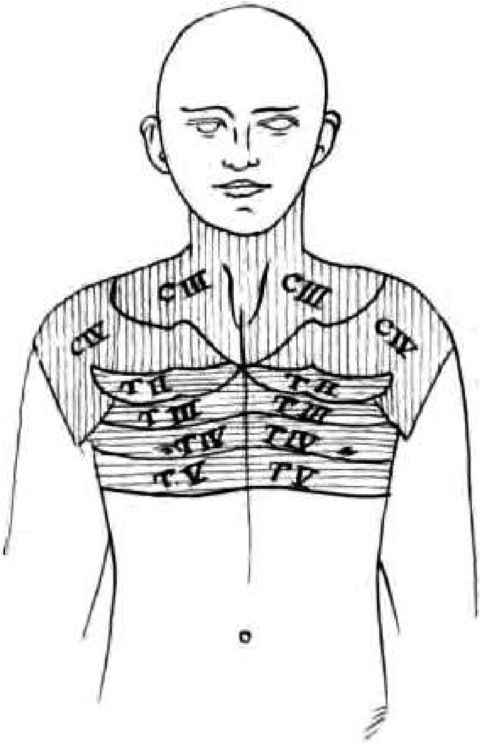

Fig. 38A.

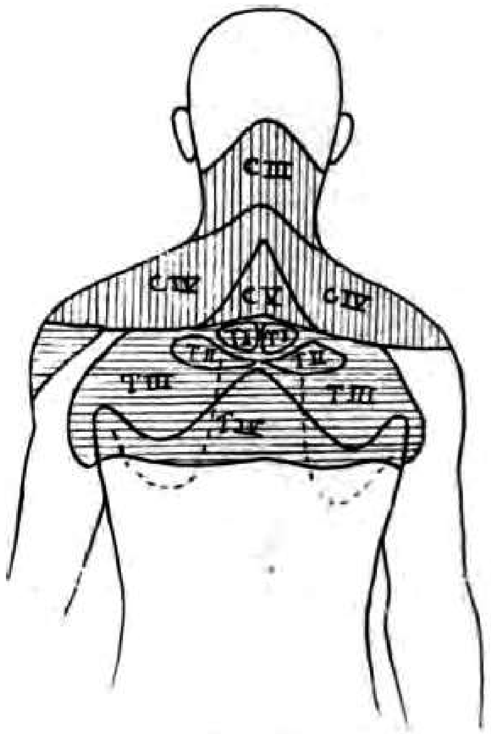

Fig. 38B.

Figure 48. Pulmonary viscerosensory and viscerotrophic reflexes.
This shows the areas affected by the cutaneous and subcutaneous reflexes.
A – Anterior view. The viscerotrophic reflex is shown particularly as a degeneration of the skin and subcutaneous tissue supplied by the 3rd, 4th and partly by the 5th cervical sensory roots. It will be seen that anteriorly this includes the tissues of the neck, shoulders and chest as far down as the 2nd rib.
B – posterior. Showing the cutaneous and subcutaneous areas supplied by the pulmonary viscero sensory and viscerotrophic reflexes. This includes the neck, shoulders and the portion of the chest above the spine of the scapula. The interscapular tissues of T1, T2, T3 and T4 show the "hilus saucer of degeneration".

It can be seen that the visceromotor, viscerosensory and viscerotrophic reflexes may be of great advantage in the diagnosis of diseases of the lung, because the changes are evident on examination by inspection and palpation. It can further be seen that the visceromotor and viscerotrophic reflexes may be utilized as a basis for differential diagnosis between inflammation of the lungs and pleura. These reflexes have a further very important bearing upon percussion and auscultation, because the results of percussion and auscultation are greatly modified by the amount and condition of these soft structures through which the blow and sound must pass. In some instances on the side of an old chronic pulmonary involvement, the soft tissues will be so degenerated that they are reduced from thirty to fifty per cent in volume as compared with those on the normal side. This is shown schematically in Fig. 47. It can be readily understood that such a condition must greatly modify the comparative percussion and auscultation findings. At other times, the visceromotor reflex causes such a tension of the musculature that it raises the pitch of the percussion note and greatly increases the resistance to the finger. This same condition also greatly modifies the respiratory sound as elicited by auscultation. The photograph shown in Fig, 48 illustrates the trophic changes in the muscles and subcutaneous tissues on the right side of the chest and spasm of the neck muscles on the left.

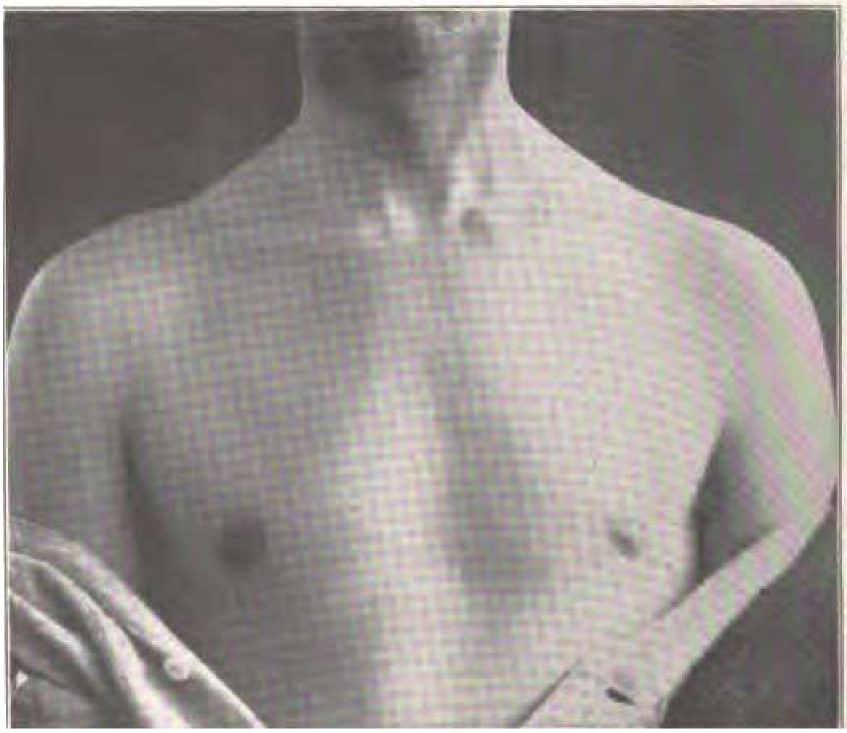

Figure 49. Spasm and degeneration as observed clinically.
This patient had suffered from a chronic tuberculous lesion occupying the upper part of the right lung which, at the present time, slightly active. The wasting of the subcutaneous tissue muscles shows by an increased flattening of the right chest, which amounts to almost a dishing out of the soft tissues from immediately above the nipple to the clavicle and a sinking of the supra- and infra- clavicular notches. It will, also be noticed that the shoulder muscle on the right ride are distinctly smaller than on the left This is due partly to the degeneration and lengthening of the muscle because of right –handedness, but also to the reflex trophic changes resulting from the chronic inflammation within the lung. Owing to the difficulty of photography. The right sternocleidomastoideus fails to show the amount of spasm present. This muscle stands out slightly prominent on the patient. On the left side there has been recent extension, of the disease as is indicated plainly by the increased prominence of the sternocleidomastoideus muscle on that side. Both the sternal and clavicular portions of sternocleidomastoideus stand out more prominently than normal, and to touch they are much firmer than they should be. The belly of the muscle is somewhat enlarged as evident in this picture.
On palpation, the soft parts on the right side are thin and the tissues appear doughy to the touch. On the left side, the muscles feel much firmer and offer a resistance that is much greater than is normal.
In order to make my meaning clear, I have slightly exaggerated the dishing out on the right side in this picture, although, unilateral wasting to the degree shown is found occasionally.

Parasympathetic Reflexes

As parasympathetic reflexes we describe all reflexes in other viscera, which result from afferent sensory impulses which originate in the lung and travel centralward over the pulmonary fibers of the vagus and express themselves peripherally in other organs of the vegetative system, We also include reflexes which express themselves in the bronchial musculature and secretory glands, through the pulmonary branches of the vagus, the impulse originating in the lung itself, or in other viscera, as may occur at times in asthma.

Parasympathetic Reflexes Shown on the Part of Other Viscera, The Impulses Originating in the Lung. Vagus. Inflammatory- conditions in the lung may influence reflexly the smooth musculature and secreting glands in all structures supplied by the vagus nerve and in some of these the effect is very evident.

In the *larynx* we have motor, sensory, and secretory reflexes shown through the superior laryngeal nerve. The parasympathetic sensory reflex shows in altered sensation in patients suffering from pulmonary disease, manifesting itself in irritation in the pharynx and larynx and the impulse which is followed by coughing. There is also a para- sympathetic motor reflex shown through this nerve, which manifests itself in a condition in which the cords are relaxed and baggy in the center instead of approaching each other as they should. This comes from an interference with the innervation of the cricothyroid muscle. The inferior laryngeal nerve supplies the remaining muscles of the larynx and many disturbances in muscular action which manifest themselves in an abnormal approach of the cords, are found as a result of the pulmonary reflex. These two reflexes produce various degrees of hoarseness and at times aphonia, which is so common in tuberculosis, beginning as soon as the pulmonary tissue is irritated and lasting through until the disease ends. They are shown in Figs. 64 and 64, page 179/171.

The glands of the pharynx and larynx also receive innervation from the laryngeal nerves and an *increased secretion* is frequently met as a reflex phenomenon.

On the part of the gastrointestinal tract, motor and secretory disturbances are extremely common as a result of the reflex which arises from the inflamed lung.

Hypersecretion on the part of the *stomach* and *intestines* is frequently present as a result of reflex irritation arising in pulmonary tissue. This on the part of the stomach may show as a hyperchlorhydria, a common symptom in all stages of tuberculosis. This manifests itself at times even during marked toxemia with high fever. When marked toxemia is present the sympathetics are stimulated, and in those structures which are normally activated by the parasympathetics and inhibited by the sympathetics, the inhibitory action of the sympathetics should predominate; so, throughout the entire gastrointestinal tract, with the exception of the sphincters, we should expect a general relaxation of the musculature and a decreased secretion. When the pulmonary tissue is involved, however, this does not always occur. In many instances, the prolonged irritation and inflammation in the lung stimulate reflexly the parasympathetics to such an extent that there is still a marked increase in motility and secretory activity in the gastrointestinal tract, in spite of the marked stimulation of the sympathetics produced by the toxemia. It is extremely common, therefore, to find in our patients suffering from chronic pulmonary tuberculosis, various degrees of hyperacidity and hypermotility. Reflex nausea and vomiting are frequently found during the stages of activity in this disease. This is not wholly due to the toxemia, as explained in the past, but may also be due to reflex stimulation of the vagus. These symptoms appear very commonly when cavities are being formed and marked irritation of pulmonary tissue is present. At the same time we have increased tonus in other branches of the vagus nerve. Spastic constipation, intestinal stasis, colicky pains and colitis are common. Motor and secretory disturbances on the part of the larynx are found; and a pulse, lower than would be expected by the amount of fever, is frequently present.

In the intestines the hypermotility affects both the circular and longitudinal fibers. If it affects the circular the more, constriction of the bowel takes place, interfering with the onward passage of the ingesta, resulting in colicky pains, spastic constipation, and more or less stasis. If the increased muscular tonus affects the longitudinal instead of the circular fibers, then the ingesta hastens on and a loosening of the bowels and diarrhoea results.

In the intestinal tract we also infer that there is an increased secretory activity, because the stools commonly show an increased water content.

The spastic constipation, which is commonly found in pulmonary tuberculosis, may be due to reflex stimulation of the circular muscles. This causes contracture, and the contracture as a rule is uneven, leaving points of constriction and areas between which are in a less degree of tonus. This explains the fact that is well known, that spastic constipation is usually attended by more or less gas and often by colicky pains. The spasticity varies so in degree that it may cause only a slight interference, or great difficulty, in emptying the bowel. Some degree of *intestinal stasis* as a result of reflex stimulation is commonly found accompanying pulmonary tuberculosis. It is closely related to spastic constipation in its aetiology. Owing to the fact that the ingesta is delayed in its passage through the bowel, an opportunity for increased bacterial action is offered, decomposition takes place with a liberation of toxins and gas. This results in a more or less marked toxemia, the symptoms of which appear as malaise, headache, and sometimes general aching. There are other symptoms which do not be- long to the toxic group which are also commonly present, such as nausea and vomiting. The condition may relieve itself if the stimulation of the sympathetics which results from the toxemia is sufficient to inhibit the action of the parasympathetics and permit the muscular tonus to lessen. Such conditions, however, are usually treated by cathartics. This moves the ingesta onward and removes the symptoms for the time being.

That form of *colitis* in which there is one or more soft stools a day, is also very common in pulmonary tuberculosis, and could be readily produced by an extra stimulation of the parasympathetics producing increased motility and increased secretory activity, as mentioned above.

The innervation of the *heart* is very markedly disturbed in pulmonary tuberculosis. There are numerous conditions present which, acting through the sympathetics have a tendency to increase the rapidity of the heartbeat, such as toxemia, insufficient oxygenation, and an interference with the normal circulation of the blood as well as the condition of the blood itself, and the various emotional and psychic states to which the patient is subject. On the other hand, there is a continuous stimulation of the pulmonary vagus which produces reflex action and has a tendency to slow the pulse. This makes for a very unstable condition of the pulse in pulmonary tuberculosis. While this may not manifest itself as long as the patient is at rest, when called upon for extra exertion the disturbance in innervation is evident. At one time sympathetic action may predominate and at another time vagus action; while in different individuals one will show a predominance of vagus action and the other a predominance of sympathetic action. The unstable innervation of the heartbeat is particularly shown when the patient is called upon to exert himself, for not only will the heart increase its rate of contraction more than it would under conditions of health, but also wilt it return to its average beat much more slowly than under normal conditions. The influence of the vagus upon the pulse in pulmonary tuberculosis is often evident even when marked toxemia with high fever is present. Under such circumstances, as a rule, a considerable area of lung tissue is involved and necrosis is usually occurring. The absorption of toxins should be sufficient under ordinary circumstances to stimulate the sympathetics sufficiently to cause a very rapid contraction of the heart, but under these circumstances the irritation to the pulmonary ends of the vagus is often sufficient to produce a reflex action in the cardiac branch of the vagus and cause the pulse rate to be much slower than would be expected from the degree of toxemia present. Sometimes when an acute cavity is forming, instead of the pulse increasing in rate in proportion to the rise of temperature, it remains markedly lower, as illustrated in Fig. 49.

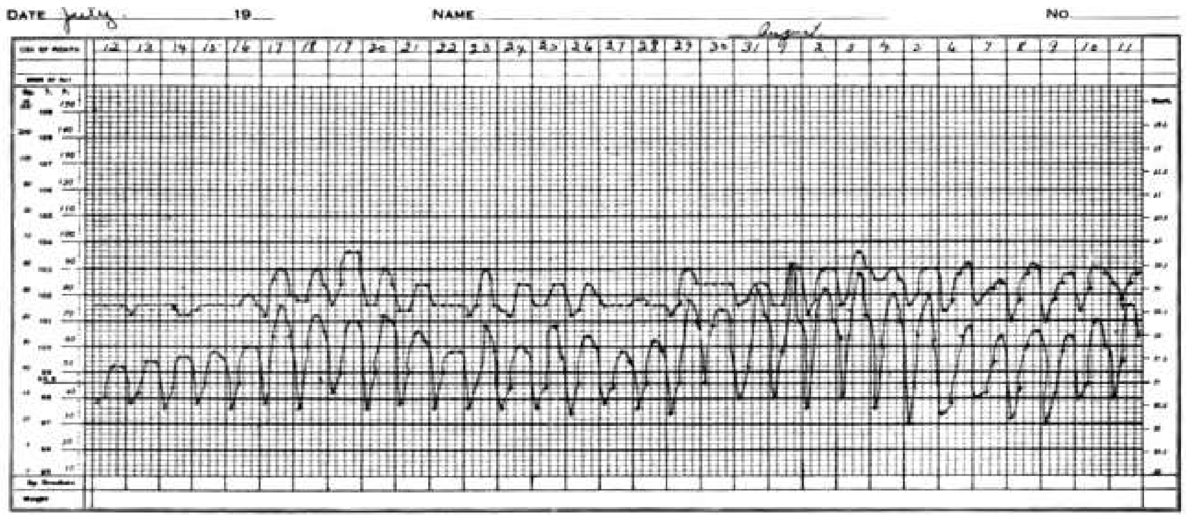

Figure 50. Bradycardia in the presence of cavity formation in the lung.
This chart represents one month temperature and pulse from a patient suffering from chronic active ulcerative tuberculosis. During the period between July 29th to August 5th, it will be noted that the temperature became very much higher than had been on the preceding days. This was accompanied by increased cough and expectoration and a definite cavity formation.
It will be noted that the pulse rate did not increase in proportion to the rise in temperature. The first few days of the chart show a temperature of between 99 and 100, with a pulse rate of between 70 and 80, which was about the same this patient had been previously running. During the period of cavity formation, the maximum temperature was between 101½ and 103, yet the pulse range was between 72 and 96, being most of the time below 90. This relatively slow pulse rate was due to the reflex stimulation of the heart through the vagus by afferent impulses coming from the inflamed lung.

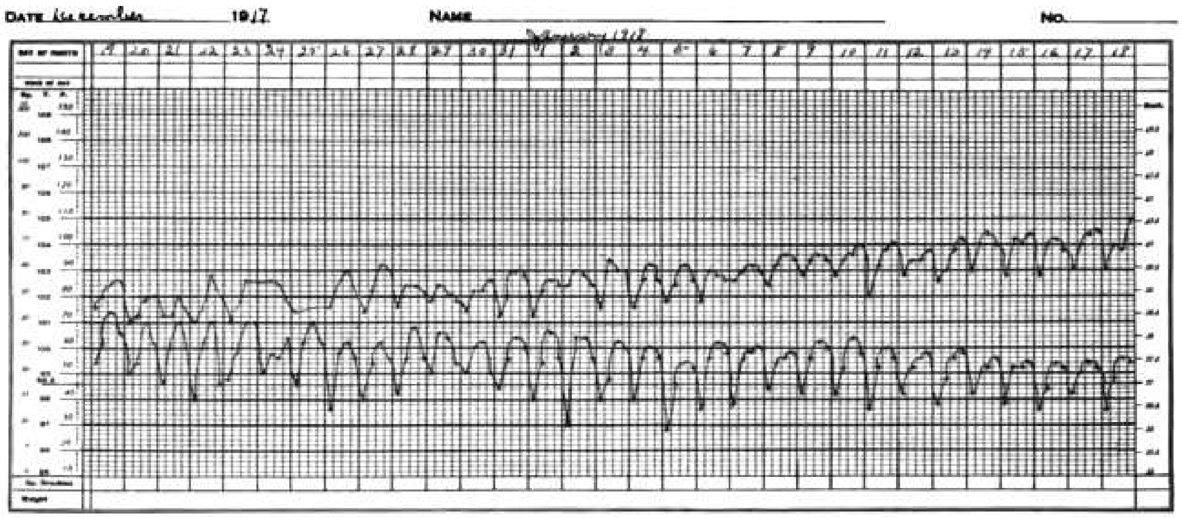

Figure 51. Chart showing how inflammation in the lung reflexly slows the heart.
The afferent impulse courses through the pulmonary and the efferent through the cardiac branches of the vagus nerve. At the beginning of the month with a temperature of 101, the maximum pulse for the day was between 80 and 90. The inflammation gradually subsided and at the end of the month the pulse was between 90 and 100 but the pulse had increased, the maximum for the day being between 100 and 110. This chart shows the pulse becoming progressively more rapid as the inflammation in the lung progressively decreases and the reflex stimulation in the vagus lessens.

This patient was suffering from a rapidly destructive process in the lung. The inflammation was quite severe as was indicated by the accompanying temperature chart.

Beginning about the twenty-eighth of July the temperature started to go higher and continued until a maximum of 103° was reached on the first and third of August. At this time the patient's enough increased and was accompanied by a very free expectoration, showing that a cavity in the lung had been formed.

It will be noticed that the pulse did not follow the temperature: neither in the lesser rise during the middle of July, nor the more marked one during the early days of August.

During the first days shown in the chart the temperature was only a little over 99", and the pulse was about 75. During the early days of August the temperature reached 103° but the pulse only went to 90, making an increase of 4° in temperature but only 15 beats in pulse.

This reflex bradycardia was due to the inflammation in the lung stimulating the afferent pulmonary branches of the vagus which mediate in the medulla with the efferent cardiac branches of the vagus producing an inhibitory effect on the heart.

Another evidence of reflex vagus stimulation upon the heart is shown in Fig. 50, this patient was suffering from an active tuberculosis with accompanying toxemia, and improved readily when put under treatment. The chart shows the pulse to be twenty beats higher at the end of the month with a maximum daily temperature of 99.5° than it was at the beginning with a temperature of 101°. The patient was at rest during the entire time. An explanation of this phenomenon is offered by visceral neurology as follows: At the beginning of the chart toxins were stimulating the sympathetics centrally and exerting an accelerating influence on the pulse; but the accelerating influence was overcome by the inflammation in the lung which was, at the same time, stimulating the pulmonary endings in the vagus, and producing a reflex inhibiting action upon the heart, through the cardiac branches of the vagus. At first the inhibiting action maintained a relatively slow pulse. But as the inflammation in the lung lessened, as indicated in the chart by the gradual fall in temperature, the reflex-inhibiting effect upon the heart decreased and the pulse became markedly accelerated.

Oculomotor Nerve. It is quite possible that there are distinct reflex effects which are carried to the IIIrd cranial nerve when the lung is inflamed. An unbalanced pupil is present in a great many of our tuberculous patients. Sometimes contraction is in evidence, and sometimes dilatation. Dilatation is a reflex in which both afferent and efferent impulses course in the sympathetics. The afferent impulse follows the usual course from the lung to the cord and mediates with nerve cells in Budge's center in the lower cervical and upper thoracic segments, from this center efferent stimuli pass out to the cells in the superior cervical ganglion from which arise the dilator fibers for the pupil. Dilatation is commonly recognized but the fact that this symptom is so irregular, being found at one time and not at another, although the observation is made in the same day; and the fact that it is found so irregularly in the disease, can be accounted for by the fact that the dilator fibres of the sympathetics are opposed by the IIIrd cranial nerve which may lie reflexly influenced as a result of afferent impulses traveling centralward through the sensory fibers of the vagus.

Patients with pulmonary tuberculosis also suffer a great deal from disturbance in accommodation. Oculists often complain that they have difficulty in fitting glasses to patients with tuberculosis, and the patients themselves complain a great deal of the glasses not fitting them. The condition here, I take it, is much the same as we find it in cases of neurasthenia and psychasthenia, where there is disturbance in accommodation.

Trigeminus. One of the reflexes which it has been difficult to ex- plain satisfactorily is that of hectic flush. It has generally been considered as being due to toxemia; but that does not explain it. It is a one sided phenomenon and found on the side of the pulmonary involvement where one lung only is affected ; or, on both sides, but varying in degree according to the degree of activity, where both lungs are affected. It seems therefore that reflex action alone can explain this phenomenon.

It has been shown that stimulation of sensory spinal roots either before or after they have passed through the posterior root ganglia causes dilatation of the vessels in the area supplied by the roots, no matter what the character of the stimulus. To explain this Starling' says: "We must assume that the axons of the peripheral sensory nerves branch, some branches going to the surface, others to the muscle cells of the cutaneous arterioles."

The sensory fibers of the fifth cranial nerve are analogous in their function to the sensory fibers of the spinal nerves; and they stand in the same relationship to the afferent fibers of the vagus in the production of reflexes as the spinal sensory nerves do to the afferent fibers of the sympathetic system.

Dastre and Morat[1] traced the dilator fibers from the spinal nerves contained in the cervical sympathetics and showed that most of them unite in their course with the trigeminus. They showed further, that, by cutting the trigeminus before it is joined by the sympathetics and stimulating the latter, very slight vasodilatation effects are produced; but that, after cutting the cervical sympathetics and permitting the fibers to degenerate, stimulation of the trigeminus was still able to produce vasodilatation of the vessels of the face. "This proves that there are some dilator fibers in the trigeminus which are of cerebral origin."

This fact, together with the further fact that the vagus afferent fibers mediate with the sensory efferent neurons of the trigeminus in the medulla, affords a satisfactory explanation for the production of hectic flush as it manifests itself in the areas supplied by the trigeminus nerve.

The most common seat of hectic flush is in the upper portion of the cheek although in certain cases I have observed it to extend over the side of the nose and over the forehead near the median line.

The flushing of the ear, which is also frequently seen in tuberculosis, has an entirely different path for its production. Here the afferent impulse courses in the sympathetics and is transferred in the cord to the third cervical nerve.

Herpes is a common pulmonary parasympathetic reflex expressed through the trigeminus nerve. It is particularly common in pneumonia but it is sometimes found in other affections of the lung. It also occurs in common colds and some gastrointestinal conditions. The afferent impulse, in the case of the lung, travels centralward over the sensory fibers of the vagus, the efferent passes outward over the sensory fibers of the trigeminus.

Atrophy of the face muscles occurs occasionally as a result of stimuli arising in the lung. It in best seen in chronic one-sided lesions ac- companied by marked destruction. The facialis joins in the reflex.

Tooth decay which is so common in pulmonary tuberculosis could be partly accounted for as a pulmonary reflex through the trigeminus.

Facialis. The vegetative fibers of the VIIth nerve supply the mucous membranes of the *nasal cavities*, mouth and soft palate. Patients with pulmonary tuberculosis often suffer from an increased secretion of the nasal mucous membrane, which might be due to a para-sympathetic reflex. The catarrhal condition of these mucous membranes has long been known in pulmonary tuberculosis. It was taught that the catarrh "ran into" tuberculosis; but now we see it is more probably a parasympathetic reflex, expressing itself through the secretory fibers of the VIIth cranial nerve. The facialis has an important part in the production of atrophy of the facial muscles,

Facialis and Glossopharyngeal. The salivary glands are supplied by the chorda tympani from the VIIth and Jacobson's nerve from the IXth cranial nerves. An increased salivary secretion is noticed in patients suffering from pulmonary tuberculosis every now and then, and particularly is this noticed if the larynx is involved. This also occurs at times in angina pectoris and in stomach disturbances.

Accessorius. A parasympathetic motor reflex through the accessorius is also evident when the pulmonary tissue is inflamed.

This is shown in the muscular branches which go to the sternocleidomastoideus and trapezius. These two muscles have a double innervation which is capable of giving motor reflex, one from the sympathetics, the other from the parasympathetics. The oesophagus and larynx are also affected reflexly through the accessorius.

Hypoglossus. I noted a few years ago that the tongue of patients suffering from chronic tuberculosis, largely limited to one side, sometimes shows a deviation from the median line when protruding, the tongue pushing over to the side on which the greater amount of inflammation had occurred. This is probably a trophic reflex in which the sensory impulse travels through the vagus and the efferent impulse is carried over the hypoglossus. It results in an atrophy of the side of the tongue on which the pulmonary lesion exists, so that the muscle is smaller and weaker than on the other side. When the tongue is protruded, it is forced to the side on which the disease is found.

Pelvic Nerve. As far as the pelvic nerve is concerned, reflexes from the pulmonary parenchyma arc not so readily determined, al- though it is entirely possible that there is a definite influence upon those portions of the generative organs, the bladder and rectum, which are activated by the parasympathetics. One cannot understand the reactions which take place in the body unless he bears in mind that organs which are widely separated in the body have their activity closely integrated through the nervous system. Patients with tuberculosis, particularly women, suffer a great deal from a relaxation of the vesical sphincter. This might readily be produced by a reflex action, the afferent impulse being carried centralward through the vagus or sympathetics and then through intercalated fibers, being transmitted to the neurons which arise from the sacral portion of the cord, which carry efferent impulses to the bladder sphincter.

Parasympathetic Reflexes Shown on the Part of the Lung, The Impulses Originating in the Lung, or in the viscera

The only two parasympathetic reflexes which can arise in the lung as a result of impulses coming from stimuli originating either in the lung or in other viscera, are increased bronchial tonus or spasm (asthma) and increased bronchial secretion (bronchitis).

We may thus have an *asthma* or a *bronchitis* arising from stimuli in the lung or in other organs. It has Ions been thought that asthma is frequently of reflex origin; and the seat of the stimulus has been variously placed: Pulmonary tuberculosis, eye strain, nasal irritation, polyps, septal spurs and deflections, hay fever, sinus infection, stomach and intestinal irritation, heart affections, and affections of the genitourinary tract, have all been suggested as causes; and all have the physiologic reflex connection through the parasympathetics to produce it. No doubt some of the cases of bronchitis are also of reflex origin, the afferent impulse arising either in the lung or in other viscera. What the difference in stimulation is that will produce a bronchial spasm at one time and au increased bronchial secretion at another, we cannot answer satisfactorily at this time, although it seems that the stimulus which produces increased secretion (bronchial) usually arises from the respiratory mucous membrane, -while the cause of spasm of the musculature (asthma) is commonly of extrapulmonary origin. I have seen many cases of asthma, however, which developed coincidentally with healing of pulmonary tuberculosis with the formation of dense scar. In the bronchitis which accompanies such an asthma the secretory stimulus for the glands may act directly upon the motor cells in the plexuses in the bronchial walls.

It has long been known that patients suffering from pulmonary tuberculosis can take care of an unusual amount of food prior to the time that degenerative changes begin to appear in the intestinal tract. Oftentimes, when suffering from a marked degree of toxemia which has a tendency to lower the appetite and digestive capacity, the patients are still able to cat large quantities of food and digest it. This is probably due to the influence of the parasympathetic reflexes which heighten the muscular contractility and secretory activity of the digestive tube. Even though the sympathetics are markedly stimulated, they are not able to inhibit the vagus activity because of the fact that it is reinforced by the reflex stimulation from the inflammation in the lung.

In closing this chapter I quote from a recent paper on pulmonary reflexes:*

"It will thus be seen from this study of the lung, which is only an example, that no organ is an entity; but that it is bound in close relationship with other internal organs. This relationship is particularly strong throughout the enteral system, and the so-called "functional disturbances" on the part of organs of this system become a real genuine part of disease processes.

"The symptoms on the part of all of the important organs which result from parasympathetic reflex action, are those of instability rather than of any one continuous condition.

"While this study is confined to the lung, it will be plain to any student of visceral neurology that the same principles apply to all organs of the body ; and that these reflexes are particularly strong in other important internal viscera, — the stomach, the intestines, the liver, the pancreas, the kidney, the generative organs, the heart, the blood vessels, — and that all are bound reflexly to each other and that one cannot be seriously inflamed without sending afferent impulses centralward, which result in disturbance of function in other organs bound to them by the vegetative nerves."

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Chapter XVII

The Pleura

I. Innervation of the Pleura

The pleura receives its nerve supply from the sympathetics, parasympathetics, and the spinal nerves.

Parasympathetics. The parasympathetics arise from the same source as those to the lung. The connector motor fibers come from the visceral nucleus of the vagus; and the sensory from the nucleus solitarius of the same nerve. These sensory fibers are particularly in close communication reflexly with the sensory fibers to the larynx which course in the superior laryngeal nerve, as is shown by the sensation of irritation with the desire for cough when the pleura is involved. Both visceral and parietal pleura are supplied with parasympathetic fibers from the same source.

Sympathetics. The sympathetics which supply the pleura are from two different sources. Those which innervate the visceral pleura belong to the pulmonary supply. Their connector neurons arise from the upper five or six thoracic segments and their motor cells lie in the stellate ganglion. The parietal pleura on the other hand, receives its sympathetic supply partly from the same source as the visceral pleura and partly from filaments which course in the intercostal nerves. The motor fibers which course in the intercostal nerves are given off from cells which lie in the vertebral ganglia and are connected with each thoracic segment from the 1st to the XIIth by its respective connector fibers. The sensory fibers course centralward to the ganglia on the posterior roots of their respective thoracic segments and carry impulses to those segments. The diaphragmatic pleura also probably receives sympathetic innervation from both sources.

Spinal Nerves. The spinal nerves which supply the pleura are the phrenics, which furnish motor and sensory fibers to the diaphragm, particularly the central tendon, and two small branches to the apical pleura as the phrenics cross it; and the intercostals (1st to XIIth inclusive) which supply every portion of the costal pleura.

II. The Pleura: Clinical Consideration

It will be noted that the pleura differs from most other viscera in that it has a plenteous supply of fibers from the spinal nerves as well as from the sympathetics and parasympathetics. This affords an opportunity for three sets of motor and sensory reflexes; one in which the afferent sensory impulse travels centralward through the sympathetics, another through the parasympathetics, and a third through the spinal nerves.

Sympathetic Reflexes

Pleural Visceromotor Reflex. The pleural visceromotor reflex. Fig. 51, has been known for a long time but it has not received the clinical recognition that it deserves, as witnessed by the frequency with which the diagnosis of intercostal neuralgia is made when acute pleural inflammation is present, and should be made certain by the motor reflex (spasm) present in the underlying intercostal muscles.

It is impossible, and only of theoretical value, if possible, to separate the motor reflex caused by afferent stimuli coursing in the sympathetics and those coursing in the spinal intercostal nerves; 80 no attempt will be made.

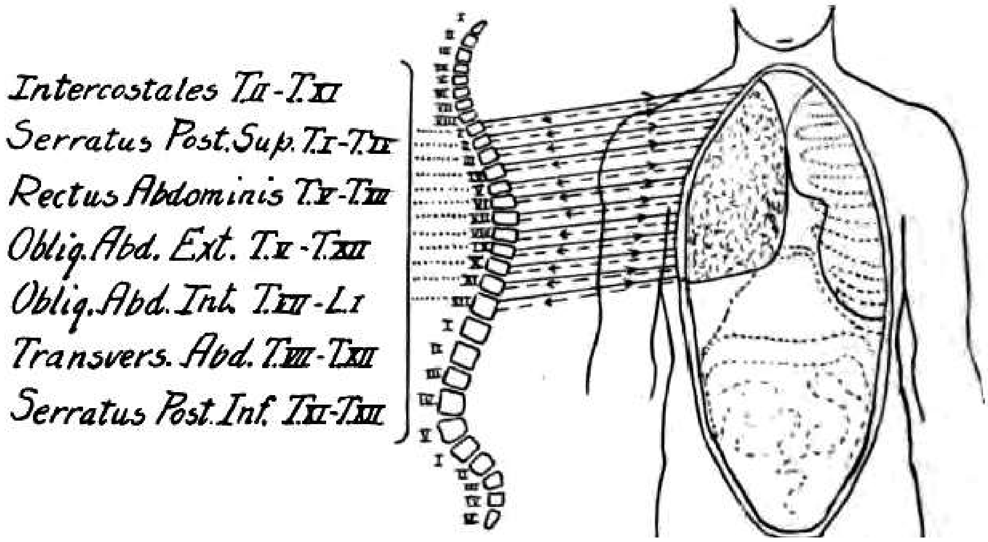

Figure 52. Pleural visceromotor reflex.
Lines connecting the pleura with the segments of the cord 1st to the 12th, represent sympathetic nerves. Solid line represent the sympathetic nerves supplying the pleura. Broken lines represent sensory sympathetic nerves which carry the afferent impulses from the cord to the pleura. Dotted lines on the other side of the cord represent spinal nerves which receive impulses from sensory sympathetic nerves and transmit them to the muscles shown, producing the pleural visceromotor reflex.
It will be seen that the abdominal muscles may also be involved in the pleural visceromotor reflex; that at times, particularly when the lower portion of the pleura is involved. This shoes as a marked spasm which is sometimes considered as indicating acute disease of the abdominal viscera.

The best known motor reflex arising from the pleura is that which expresses itself in the lower intercostal muscles when the underlying pleural surface is the seat of inflammation. That which is found at times in the upper abdominal muscles near and immediately below the costal margin, is usually due to an inflammation of the lowest portion of the parietal or the costal portion of the diaphragmatic pleura, or both. The possibility of its existence should always be borne in mind, when rigid muscles and pain are found in this region. Such signs are usually taken as being due to subdiaphragmatic pathology, but the possibility of their being of lower parietal and diaphragmatic pleural origin should not be forgotten.

The involvement of the upper abdominal structures in the pleural visceromotor and viscerosensory reflexes is an indication that the afferent stimuli have spread to neurons other than those which are usually involved in the reflex. In the same manner we sometimes find pain in angina pectoris in the neck (3rd and 4th cervical zones) or over the right side of the chest.

Motor reflexes of pleural origin exist in the upper intercostal muscles more commonly than in the lower, but are rarely recognized. Much of the feeling of resistance that is felt on palpation and percussion over the apices and the first and second interspaces in early active pulmonary infection, is due to an underlying motor reflex (spasm) in the apical and intercostal muscles; or a thickening of the pleura and an advanced pathologic change in the muscles resulting from it as described by Coplin[1]. The importance of this increased tension of muscles should be impressed on all who have witnessed the frequency of thickening of the pleura over the apices on post-mortem examination of bodies with limited apical involvement; and from this, the importance of its recognition as a clinical diagnostic factor should be emphasized.

The path of all motor reflexes involving the intercostal and upper abdominal muscles as a result of pleural involvement, is clear. The afferent sensory impulses travel centralward through either the sympathetic sensory or intercostal sensory fibers, or the efferent motor impulse leaves the cord in the spinal nerves arising from the thoracic segments corresponding nearest to the seat of inflammation. The result is a spasm of the muscles, or that portion of the muscles, which receives fibers from the motor nerve nerves which lie in reflex relation with the sensory neurons which receive their stimulation from the inflamed pleura.

There is another group of muscles which, from the standpoint of their physiologic reflex relationship, could be the seat of a pleural motor reflex, the afferent impulse traveling through the sympathetic nerves. This is the same group that shows the visceromotor reflex when the pulmonary tissue is involved, and takes its innervation from the cervical portion of the cord. (See Chapter XVI.) This is evident from the fact that the visceral pleura is supplied by sympathetic fibers from the pulmonary plexuses. Such a reflex, however, cannot be differentiated from that arising in the pulmonary parenchyma when the latter is inflamed, and is of no value as a differential sign between inflammations of the lung and pleura; showing as it does, in the anterior muscles of the shoulder girdle if the inflammation is situated anteriorly, and in the posterior muscles if situated posteriorly.

Pleural Viscerosensory Reflex. The sensory reflexes arising from the pleura are important. Inasmuch as I am now discussing only those which arise from afferent impulses which course centralward through the sympathetics, I shall not discuss those pains of pleural origin which are found in the cervical zones of the neck and shoulder, but leave them until I discuss the afferent impulses which course through spinal (phrenic) nerves. We must not forget, however, that it is possible to have pleural viscerosensory reflexes in the cervical zones, the afferent impulse coursing in the fibers of the visceral pleura which are derived from the pulmonary plexuses.

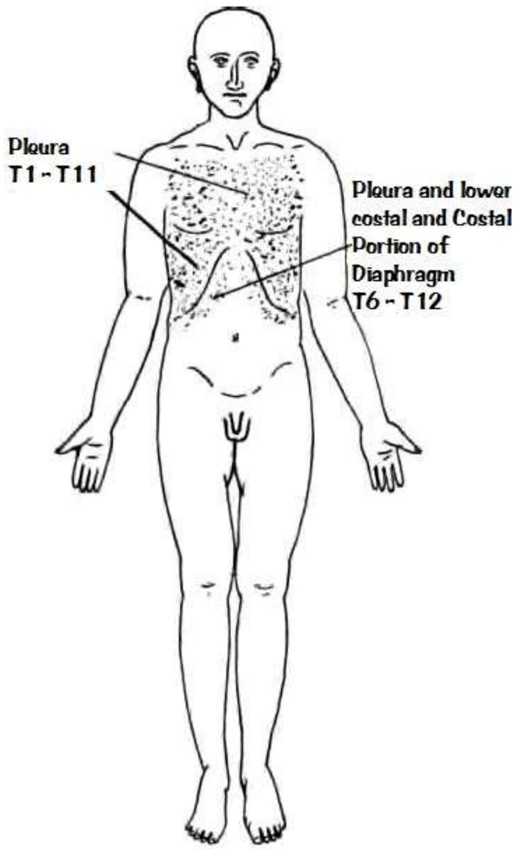

Figure 53. Pleural viscerosensory reflex.
As shown in the figure, pleural pain may occur over any portion of the chest wall and, if the lower costal pleura are involved, the [pain may extend down to the upper surface of the abdomen.

The viscerosensory reflex which expresses itself in the skin of the thoracic and upper abdominal zones, may be caused, like the motor reflex from the costal pleura, by irritating stimuli which course centralward over either the sympathetics or the filaments of the intercostal nerves which supply the pleura. The reflex may express itself in any zone supplied by sensory fibers which arise from the spinal segments from the 1st to the 12th thoracic inclusive (Fig. 51). Pleural pain then may be expressed over the surface of the chest, in the skin of the entire abdomen, or in the chest and abdominal muscles. "While pain over the lower abdomen is improbable, it might occur, if the inflammatory process was unusually severe. I have seen it low down at times. Pleural pain which arises from the parietal or costal pleura, as a rule is expressed over the sensory zones of the chest, and if it extends over the abdominal areas it rarely goes far below the margin of the ribs. In this connection it must be remembered that the extent of tissue involved in the pleural viscerosensory reflex depends greatly upon the strength of afferent stimuli, which means upon the severity of the inflammation.

Pleural Viscerotrophic Reflex. The tissues which show motor and sensory changes when the inflammation is acute, show degenerative changes when it becomes chronic. This fact should always be borne in mind when considering diseases of the lungs and pleura. Any reflex trophic change in muscles or other soft tissues whose innervation depends upon nerves arising from the cervical portion of the cord, is due most often to inflammation of pulmonary tissue or of the visceral pleura. Since the latter rarely occurs without lung tissue being inflamed, it is safe to say that degeneration of these structures means chronic inflammation of the underlying lung. On the other hand, degenerative changes o£ reflex origin which are found in the muscles or other soft tissues which receive their innervation from the thoracic portion of the cord are most apt to be due to impulses which have come from the parietal or costal pleura; and means that that portion of the pleura which is situated so as to send afferent impulses to the cord and reflect in the atrophied tissues, has been the seat of chronic inflammation.

The viscerotrophic reflex from the lung is expressed for the most part in the neck and upper chest muscles and the skin and subcutaneous tissue above the second rib anteriorly and the spine of the scapula posteriorly; while that from the parietal or costal pleura is expressed almost entirely in the intercostals and in the skin and subcutaneous tissue between the second rib anteriorly and the spine of the scapula posteriorly, on the one hand, and the lower margin of the ribs on the other.

Spinal Nerve Reflexes

As spinal nerve reflexes I would designate those which arise from afferent sensory impulses which are carried from the pleura to the cord through the sensory fibres of either the intercostales or the phrenics. The former cannot be distinguished from the visceromotor. Viscerosensory and viscerotrophic reflexes which are caused by impulses carried centralward from the parietal or costal pleura through the sympathetics; the latter, however, while not producing a motor reflex that is recognizable, produces a very important viscerosensory reflex which expresses itself in the neck and shoulders in the 3rd and 4th cervical sensory zones.

This sensory reflex is present when the apical pleura or the pleura covering the central tendon of the diaphragm is inflamed. The latter expresses itself in the same zones as the pain from the lung, but as a rule is more severe; and usually comes on acutely. Fig. 36, page 185, shows the position of the reflex pain which results from afferent impulses traveling through the phrenics and is usually found in the presence of diaphragmatic pleurisy. The same areas are involved as in the pulmonary viscerosensory reflex.

In accounting for the pain in the neck and shoulder which patients suffering: from chronic pulmonary tuberculosis experience. We must not forgot the small branches of the phrenic nerve which are given off to the pleura when the phrenics cross it in the neck.

There are three sources of origin for the sensory reflex (pain) felt in the neck by patients suffering from pulmonary tuberculosis: 1, the pulmonary tissue; 2, the diaphragmatic pleura; and 3, the portion of the apical pleura which is supplied by the twigs given off from the phrenics.

A pain in the shoulder is experienced every now and then when the pleura is suddenly filled with air as occurs in spontaneous or induced pneumothorax. This is probably a result of stretching or breaking up of adhesions which irritate the sensory fibers of the phrenics; or it might possibly be due to irritation of the sensory sympathetics in the visceral pleura, for these would express the pain in the same place as the fibres from the lung, — the neck and shoulder.

The efferent components of the sensory reflex for inflammation in the lung, inflammation in the visceral pleura, and inflammation of those portions of the apical pleura or diaphragmatic pleura which are supplied by the phrenics, is practically the same. They are the cervical spinal nerves arising from the 3rd and 4th segments of the cord. While impulse from the lungs and visceral pleura may be mediated in other cervical segments, yet the 3rd and 4th are the segments usually affected. Hiccough sometimes occurs as a result of intrathoracic disease through irritation of the sensory fibers of the phrenics. I have seen several cases of intractable hiccough follow spontaneous pneumothorax.

Parasympathetic Reflexes

The pleura gives origin to one very important parasympathetic sensory reflex. I refer to the irritation experienced in the larynx when the pleura is inflamed. This is expressed through the superior laryngeal nerve. Cough, which is a complex act, is caused reflexly by stimuli which course centralward over the sensory parasympathetics from the pleura.

That there may be reflexes in the gastric and intestinal vagus and in other structures innervated by the parasympathetic nerves is also possible and probable. The difficulty in detecting them arises from the fact that the pleura is rarely inflamed without the pulmonary tissue, which causes the same group of symptoms, being inflamed too.

Chapter XVIII

The Heart

I. Innervation of the Heart

Although the heart of higher vertebrates consists of striated muscle, it is beyond the control of the will and belongs to the so-called vegetative structures. It is activated by the sympathetics, which, cause increased rapidity of contraction when stimulated. They are sometimes spoken of as the nerves which cause systole in contra- distinction to the vagus fibers which oppose the sympathetics, slow the heart and are spoken of as being the fibers which preside over diastole. The innervation of the heart is shown in Fig. 53.

Sympathetics. The sympathetics which supply the heart arise from the 1st to the Vth or 6th thoracic segments of the cord. They pass upwards through the lateral ganglia to the stellate ganglion, the ganglion of the annulus of Vieussens, the inferior cervical ganglion, and some pass on to the medium and superior cervical. The principal accelerator fibers come from the upper thoracic segments and pass to the heart from the stellate ganglion and the annulus of Vieussens. These fibers course as nonmedullated fibers from these ganglia, and after passing though the ganglion of Wrisberg, lying between the pulmonary artery and the aorta go directly to the heart muscle.

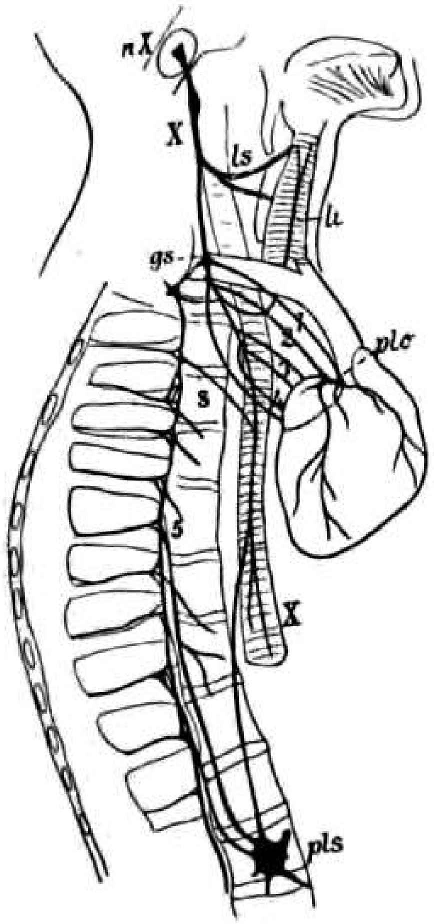

Figure 54. Innervation of the heart.
nX – vagus centre; X – nervus vagus; gs – ganglion stellatum; ls – N. laryngeus superior; li – N. laryngeus inferior; s – nervus sympatheticus; pls – plexus solaris; plc – plexus cardiacus; 1 – the superior central branch to the heart; 2 – the ascending nerve; 3 – the inferior central branch to the heart; 4 – the superior and inferior external branch to the heart; 5 – ansa vieussenii. (Bechterew)

When stimulated they increase the rate of contraction of the heart muscle without increasing blood pressure; in fact, at times the pressure may fall. There are also Abel's in the sympathetics which increase the force of the heartbeat, shorten the time of systole, increase the ventricle output and raise blood pressure without a general change in vasomotor tonus.

Parasympathetics. The vagus supplies the heart with three separate bundles of nerves; first, from the superior laryngeal; second and most important, from the recurrent laryngeal; and, third, a branch from the thoracic portion of the vagus.

The right vagus cares particularly for the deep layers of the heart muscle, while the left vagus goes to the plexus cardiacus superficialis.

'When the vagus is stimulated, it inhibits the action of the heart and slows the pulse; when inhibited, heart action is accelerated.

Vagus fibers enter the heart as medullated fibers and connect with motor nerve cells which lie in the heart itself. It has been shown that all of those cells lying in the organ itself belong to the vagus and none to the sympathetics.

The inhibitory influence upon the heart may be produced reflexly by stimulating the vagus in many different organs. Brodie and Russel[1] found that the pulmonary vagus produces the strongest reflex inhibitory influence upon the heart. Irritation of the pulmonary branches produces a reflex slowing of the heart almost equal to that caused by stimulation of the vagus in the neck. Irritation of the larynx will also slow the heart.

The effect of irritation through the gastrointestinal branches has long been recognized, that from the appendix, the gall bladder, the gastric and intestinal walls.

Not only is the reflex inhibitory influence of the parasympathetics upon the heart shown when the branches of the Xth nerve are stimulated, but when fibers of other sensory nerves in reflex communication with the parasympathetics are concerned. Pressure on the eyeball and irritation in the nose will both slow the pulse, the afferent sensory stimuli being carried centralward through the sensory branches of the Vth cranial nerve.

When both vagus and sympathetic fibers to the heart are similarly stimulated, inhibition prevails (Bechterew[2]),

Peculiarities of Heart Innervation. In some of the lower forms of animal life, such as the tortoise, both striated and unstriated muscle are found. There is a strong layer of unstriated muscle next to the endothelium of the auricle which extends out into the sinus venosus and the beginning of the large veins.

The innervation of this unstriped layer is different from that of the rest of the heart. It is activated by the vagus and receives inhibitory fibers from the sympathetic, while the striated muscle is activated by the sympathetics and receives inhibitory fibers from the vagus. This unstriped muscle acts toward atropine and muscarine in the same manner as the bronchial and enteral unstriped musculature. Gaskell calls attention to this fact and says further that the striated heart muscle behaves like the enteral .sphincter muscles, is activated by the sympathetics and receives inhibitory fibers from the vagus. As the unstriped muscle has disappeared from the higher vertebrates, it has withdrawn its innervation and left the heart with the same innervation as the sphincters of the gut.

The nerve cells which lie in the heart muscle are associated only with the vagus fibers. They are associated in three ganglia: Remak's along the superior vena cava, Ludwig's along the inter auricular septum, and Bidder's at the auriculoventricular junction. The vagus fibres therefore, enter the heart as medullated fibers having their motor cells within the heart muscle. The sympathetics on the other hand enter the heart as nonmedullated fibers, having their motor nerve cells in extracardiac ganglia. After the vagus fibers enter the heart they send off collaterals to many ganglion cells lying within the muscle substance, which arc inhibitory cells to the heart musculature.

The sympathetic fibers on the other hand, arise in the upper thoracic segments of the cord, pass as medullated connector fibers to the stellate ganglion and the ganglion of the annulus of Vieusses, and then go as nonmedullated fibers through the ganglion of Wrisberg, to the heart. These fibers, instead of connecting with motor cells in the heart, go direct to the muscle cells.

Rhythm. Rhythm is a property of involuntary muscles which should be understood in order to appreciate the condition which we meet in the heart and other structures supplied by the vegetative system. I cannot do better than quote the view of Gaskell[4] upon this subject:

"Involuntary muscle is covered over with a network of fibres, which arise from peripheral nerve cells. This network degenerates when separated from its parent nerve cells. The nerve cells belong to two nervous systems, the sympathetic and enteral systems, and are called intrinsic or extrinsic according to their situation upon the muscular organ or at a distance from it. The intrinsic cells have been considered to be of a different character to the extrinsic, and the initiation of rhythm in the involuntary muscle has been ascribed to the intrinsic only. It was manifestly impossible to ascribe it also to the extrinsic cells, for, being situated outside the rhythmical organ, they could be removed, and yet the rhythm continued. The intrinsic cells to which the rhythm is attributed, sometimes belong to the sympathetic system, as in the ureter, sometimes to the enteral system, as in the intestine and heart, sometimes they are inhibitory cells, sometimes motor.

"The evidence is strong, that isolated pieces of muscular tissue will contract rhythmically in the absence of all nerve cells. Such pieces of isolated muscles always possess a nervous network round their muscle fibers, so that if the rhythm of the involuntary muscle is always to be regarded as of nervous origin, the initiation of rhythmic discharges must in this case be attributed to this network. This is a proposition which is to my mind highly unlikely. All muscular tissue possesses the power of rhythmic contraction to a greater or less degree. Ordinary striated muscle, with its more rapid contraction, has lost this power to a much larger extent than unstriped or cardiac muscles. The more embryonic the muscle the greater is its rhythmic power.

"The power of manifesting rhythm depends upon the condition of the muscle, upon what is often called a condition of tone; this condition does not necessarily imply contraction but rather a readiness to contract, owing to the muscle having attained a condition of unstable equilibrium. This condition of tone is dependent upon both nervous and chemical factors. As long as the muscle is in continuity with the nerve cell, which nourishes its nerve, the action of that nerve cell keeps the muscle in a condition of tone, so that it can manifest rhythmic contractions. When it is separated from its nerve cell it loses its tone, but that condition can be restored by the action on the muscle, of certain chemical substances, especially salts of sodium, BO that the rhythmic activity again becomes evident. This seems to me yet another instance of the condition of a tissue not being dependent solely on its connection with the nervous system, but also upon chemical substances brought to it in its nutrient fluid. The nervous action upon which the tone of the muscle depends is ultimately conveyed to the muscle by the network of fibers on it. It is said to be a true network, not an interlacing of fibers, and in many cases it is formed from the axons of both sympathetic and enteral nerve cells.

According to Fletcher's observations on the retractor penis muscle, it will not degenerate until separated from both systems of nerve cells.

"It is, however, universally accepted that the separation of either nerve cell profoundly modifies any rhythmic activity present at the moment of separation, though later a readjustment may take place with the return to a condition very near or identical with the original ; the permanent removal of the cells of one of the two systems, which are in connection with the network, need not necessarily prevent an effectual control of tone by the peripheral network ; that is to say, the integrity on the nervous side of one system only is sufficient to maintain a nervous control of tone. Thus the tone of the heart can be maintained by the intrinsic nerve .cells alone, although they belong entirely to the vagus system only. It does not follow that the maintenance of rhythm in an isolated heart implies that this rhythm is dependent entirely on its intrinsic nerve cells ; but rather that the normal double tone control of the two systems can under altered circumstances be carried on with greater or less efficiency by one system only,"

The term "enteral" as applied to the nervous system in the above quotation applies to the parasympathetic system.

II. Clinical consideration

Cardiac Visceromotor Reflex. The heart, being supplied by the sympathetics which are connected with the 1st to 5th thoracic segments, has no important superficial neck or chest muscles in which to show a motor reflex. {See Fig. 54.) The upper intercostals are sometimes in spasm and give a sense of constriction during attacks of angina; and under certain circumstances the muscles of the arm become somewhat affected through the 1st thoracic nerve. As a rule, however, the motor reflex is not as well-known as the sensory reflex in affections of the heart.

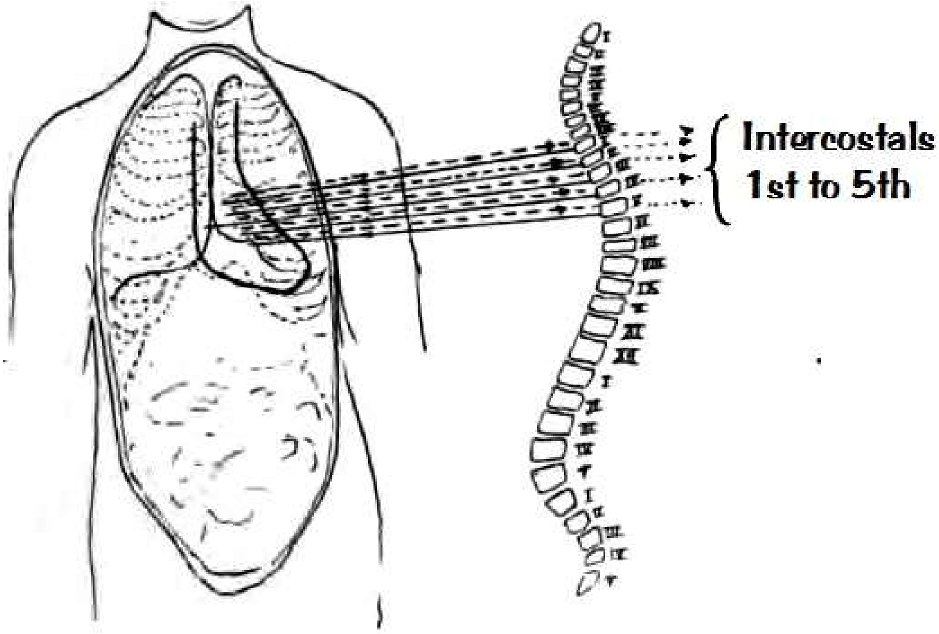

Figure 55. Cardiac visceromotor reflex.
Lines connecting heart with the segments of the cord from the 1st to the 5th segments, represent sympathetic nerves. Solid lines represent the sympathetic nerves supplying the heart. Broken lines represent the sensory sympathetic nerves which carry afferent impulses from the heart to the cord. Broken lines on the other side of the cord represent spinal nerves which received impulses from the sensory sympathetic and transmit them to the muscles shown, producing the cardiac visceromotor reflex.

Cardiac Viscerosensory Reflex. The viscerosensory reflex from the heart is one of the best known reflexes that is met with in clinical medicine. It is usually found in the upper half of the left chest, running out and down the inner surface of the arm and hand to the ends of the little and ring finger (Fig 54). This pain in the arm under certain conditions becomes very severe; and, at times, a hyperalgesia of the skin and deep soreness occurs which, as in the ease of John Hunter as quoted by Mackenzie," became "so severe that he could not bear to be touched."

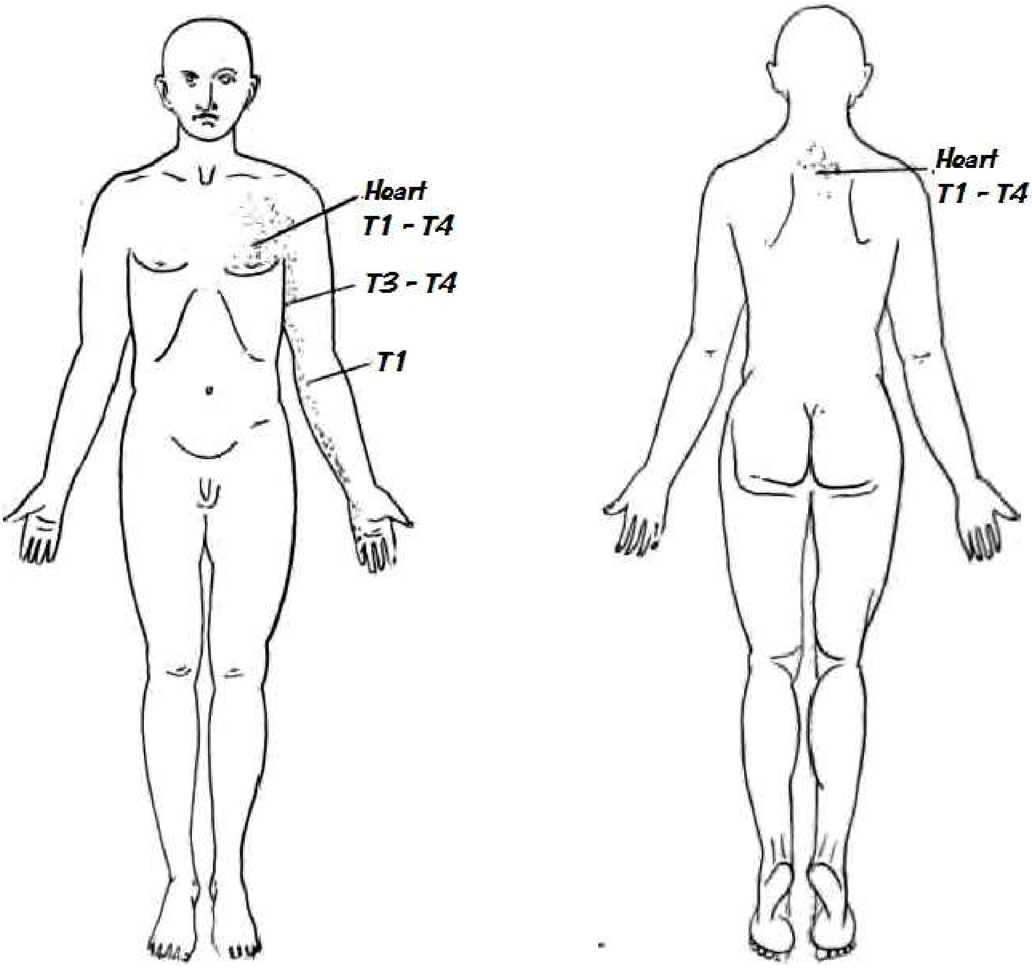

Figure 56. Cardiac viscerosensory reflex.
A – anterior view. The anterior portion takes in the upper area of the chest, particularly the 1st, 2nd and 3rd thoracic zones and the inner side of the arm, this being supplied by the 1st, 2nd and 3rd thoracic segment.
B – posterior view. The area of pain on the posterior surface is over the vertebrae in the 1st to the 4th thoracic segments.

At times the pain in diseases of the heart is not confined to the usual seat, — upper left chest and inner side of the arm, — but extends over on the right side of the chest and up into the neck. After the acute pain has subsided, the skin sometimes remains in a state of hyperalgesia for a period of time as previously mentioned and the left sternocleidomastoideus and trapezius muscles may also become tender, as mentioned by Mackenzie." The explanation of this extension of the painful skin areas, is probably furnished by the observations on reflexes due to impulses of varying strength, as discussed by Mackenzie[6]. It requires a certain stimulus to produce pain, or a motor reflex, through a given nerve fibre. If the stimulus is greater than that required to bring about this result, it does not increase the contraction of the given muscle fibers or increase the pain produced by the given sensory fibers, but the greater stimulus manifests itself by the efferent impulse being conveyed to a greater number of neurons, which causes the reflex to show in wider areas.

The explanation of the tenderness noted in the sternocleidomastoideus and trapezius muscles, is not so clear to me. While there is reflex connection between the various nerves and the accessorius which furnishes partial innervation for these muscles, yet the accessorius, so far as we know, contains only motor fibers; and according to our idea of hyperalgesia, the reflex could not be through this nerve. In order to explain this tenderness as being produced by the spinal nerves, the afferent impulses would have to be transmitted to the upper thoracic portions of the cord, through the sympathetics which supply the heart; they would then have to be carried upward in the cord through intercalated neurons to mediate with the spinal nerves emerging from the second, third, and fourth cervical segments from which the sternocleidomastoideus and trapezius receive their final nerve supply. This latter would seem to be the more rational explanation, and, if correct, shows that the reflexes from the heart have, in part, the same indirect mediation with the spinal nerves as those from the lungs. This path for the heart is not recognized, but I see no argument against its existence.

Cardiac Parasympathetic Reflexes. Of parasympathetic reflexes from the heart, I would mention the nausea which at times occurs in patients suffering from heart disease. Heart patients also very often complain a great deal of their digestive systems. The type of disturbance which should be expected is that of an increased tonus throughout the digestive tube. The impulses which produce these reflexes are carried centralward through the cardiac vagus and express themselves through the motor fibers of the gastric and intestinal vagus. We now and then hear of cardiac asthma. Such a condition may exist, being brought about through reflex stimulation of the pulmonary vagus. In this manner, bronchitis could also be produced aside from that which is due to the weakness of the heart.

The Manner in Which the Heart Is Influenced by Stimuli from Other Organs. More interesting .than the manner in which the other organs are reflexly affected by the heart, is the way the heart is influenced by diseases of other structures. The heart is an organ which responds quickly to all kinds of stimuli, either physical or psychic. Its beat can he slowed by pressure upon the eyeball, the afferent impulses going through the Vth cranial nerve, the efferent through the cardiac vagus. It can also be slowed by irritation in the nasal mucous membrane, the afferent impulses going through the Vth cranial nerve, the efferent through the cardiac branches of the vagus. Bradycardia can also be produced by stimulation of the larynx, by inflammation in the lung, in the gall bladder, the stomach, the intestinal wall, or the appendix. In all of these organs supplied by the vagus, the afferent sensory impulses course through the respective branches of the vagus from the organ in which the stimuli originate; and the efferent impulses travel peripherally through the cardiac branch of the vagus.

A slowing of the pulse is a very common symptom in many cases of intestinal tuberculosis (Fig. 34, page 110). I have called attention to this repeatedly in my writings, and have shown many charts illustrating this in "Clinical Tuberculosis.'" The slowing of the pulse rate as found in pulmonary and intestinal tuberculosis is often marked in spite of the fact that the patient is suffering from marked toxemia with high temperature, conditions which, under ordinary circumstances, stimulate the sympathetic and increase the pulse rate. The effect of toxemia upon the heart is to increase the pulse rate. The same condition is brought about through fear, anxiety, worry, pain, and malnutrition; also by many of the internal secretions, such as adrenin, by the increased metabolic activity caused by the secretion of the thyroid, and the secretion from the pituitary. All of these measures which increase the heart rate do so by, directly or indirectly, stimulating the sympathetic nerves or acting in conjunction with them, or depressing the action of the vagus.

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Chapter XIX

The Aorta

I. Innervation of the Aorta

Embryologically the aorta is formed high in the pharynx; and as it descends it leaves the anterior (upper) part of the arterial system, which remains in adult life, to care for the portion of the body anterior to (above) and including the upper extremities, while that portion which becomes the aorta travels backward (downward) with the heart until it reaches the position found in adult mammals and man.

Sympathetics. The upper aorta is supplied by sympathetic nerves from the aortic plexus. The motor cells from which these fibers originate lie in the upper four or five vertebral ganglia. The connector fibers for these ganglia arise from their respective thoracic segments.

The blood vessels of the body are innervated by fibers coming from all segments of the cord from which sympathetic connector fibers originate. Those anterior (superior) to the aorta are supplied by connector neurons which meet sympathetic motor cells in the superior cervical and stellate ganglia. The former send fibres to the arteries of the head and the latter to the subclavian. The aorta is innervated by connector fibres from the upper four or five thoracic segments. The heart is innervated from the same segments but apparently from neurons which arise only from the left half of the cord, for heart pain expresses its maximum effect in the 1^{st}, 2^{nd} and 3^{rd} segments on the left side of the body.

Parasympathetics. Depressor fibers from the vagus supply the aorta and reflexly slow the heart and cause general vasodilatation.

II. The Aorta: Clinical Consideration

The arch of the aorta, the portion which is best known for furnishing pathologic conditions, is supplied with sympathetic fibers from the upper vertebral ganglia, and bound reflexly with the upper spinal thoracic nerves. Pain from the aorta is confined to the upper thoracic segments, and seems to show its maximum effect either near the vertebral column in the 1^{st}, 2^{nd}, 3^{rd} and 4^{th} thoracic sensory zones or in the peripheral distribution of the nerves, arising from those segments in the arm and on the anterior surface of the chest.

This peripheral pain, like that from the heart, I have found most commonly on the left side. In dilatation or aneurism of the arch, it may extend over the 1^{st} and 2^{nd} sensory thoracics out and down the inner aspect of the arm, and over the upper five or six thoracics to the surface of the chest wall. We may find also, at times, that the impulse is transferred by intracentral neurons in the cord to both higher and lower levels, the pain showing in the cervical sensory zones and in the intercostals below those mentioned. In this the aorta is like the heart. The pain, being due to distention of a hollow viscus, is precipitated and increased by conditions such as strain and exertion which call for greater distention of the arterial wall. Unlike pain produced by acute inflammatory processes, the condition stimulating the nerves is here often present for a long time, consequently the pain may be present over long periods of time.

It is impossible to differentiate pain caused by inflammation of the arch and that from the heart. (See Pig. 46, page 218.)

Since the depressor fibers from the vagus which supply the heart also extend into the aorta we would expect the same parasympathetic reflexes from those portions of the aorta which receive these fibers as occur in cases of the heart. These fibers also have a very important function in regulating blood pressure. When the blood pressure rises in the aorta it stimulates the endings of the vagus and reflexly slows the heart and also acts upon the centres in the central nervous system and sends out stimuli over the sympathetics which produce general vasodilatation.

Chapter XX
The Blood Vessels
Arteries
The arteries of the body possess the all-important quality of contractility which is indispensable to maintaining blood pressure and normal circulation. Contractility depends upon the smooth circular muscles found in the arterial walls. The smaller the vessel, the greater the relative muscular development of its walls and the greater the arterial force upon the circulation.

Small ganglion cells like those found in the heart and the intestines have been found in the vessel walls, which probably have to do with maintaining a certain degree of action more or less independent of the higher centres.

The nerves which supply the arterial walls contain both motor and sensory fibers. These sensory fibers exert an influence upon the heart and also upon the vessels themselves, which reflexly influence Wood pressure.

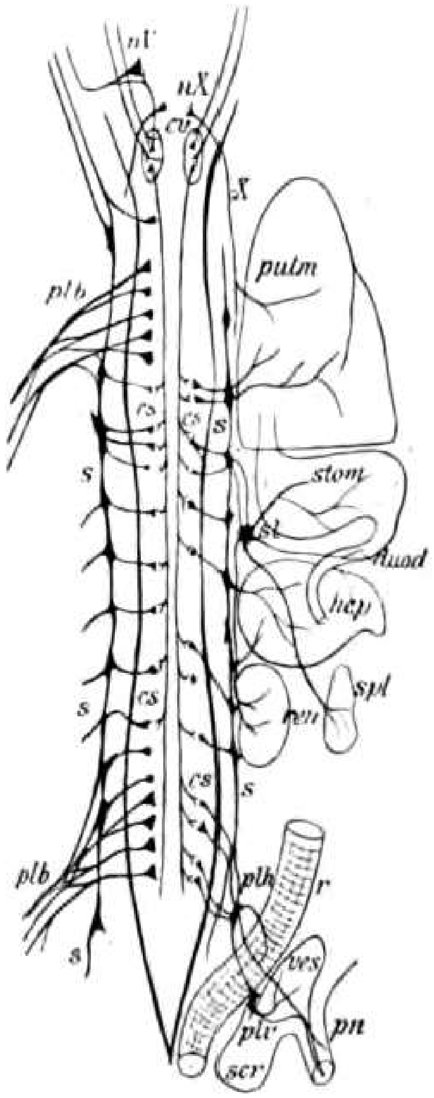


Figure 57. Distribution of vasomotor centres and nerves. cv – chief vasomotor centre in medulla; cs – spinal vasomotor centres; s – nervus sympatheticus; nX – vagus centre; X – nervus vagus; nV – trigeminus centre; plb – plexus brachialis; plh – plexus hypogasricus; plv – plexus vesicalis; pulm – lungs; stom – stomach; duod – duodenum; hep – liver; spl – spleen; ren – kidneys; r – lower portion of colon; ves – urinary bladder; scr – scrotum; pn – penis. (Bechterew)

The Vasomotor Nerves

The musculature of the blood vessels belongs to the group of tissues which is supplied by the sympathetic nerves (Fig. 56). For the most part as far as known today, the sympathetics are unopposed in nearly every portion of the body in their vascular control; the exceptions to this will be mentioned later. The nerves which supply the blood vessels are called vasomotor nerves.

Not only are the sympathetics the vasoconstrictor nerves which reduce the lumen of the vessels and raise the blood pressure when stimulated, but they also produce dilator effects as well and have the function of maintaining the normal tonus of the vascular musculature. There has been considerable discussion in literature in recent times as to whether adrenin under normal conditions aids the sympathetic system in maintaining the tonus of blood vessels.

That this is not true is evident from the valuable contributions of Hoskins[1,] Vincent[2] and Stewart [3]. The experiments of these physiologists show that under normal conditions there is considerable doubt whether adrenin is found in the blood stream at all; and further indicate that under normal physiologic conditions it has no effect upon the body economy. In an emergency, however, when the sympathetics arc markedly stimulated, the chromophil cells of the medulla of the adrenals are stimulated and adrenin is poured into the blood stream.

Its effect except upon the sweat glands is the same as that of stimulation of the sympathetic nerves, and under these conditions it seems to fortify and prolong the sympathetic action. It must not be thought however, that adrenin acts upon the blood vessels alone. It acts upon practically all structures innervated by the sympathetics, the sweat glands being a known exception. Adrenin does not, as is generally believed, always produce vasoconstriction. The effect depends upon the dosage and produces a vasoconstriction in one set of vessels and a compensatory vasodilatation in others.

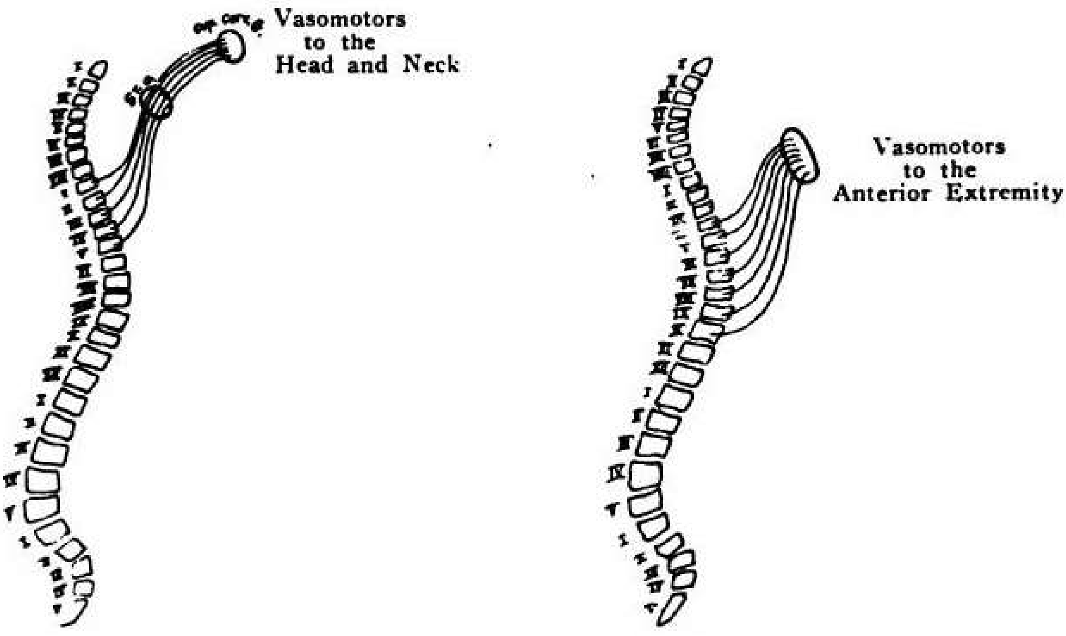
The vasomotor nerves leave the cord by the anterior roots throughout the length of the thoracicolumbar segments which give origin to sympathetic fibers (1st thoracic to the 4th lumbar). Therefore, their connector fibers arc found in all white rami.

The motor cells which give origin to the nonmedullated fibres which supply the vessels, are found in both lateral and collateral ganglia. The *lateral ganglia* send nonmedullated fibres to care for all the blood vessels which go to structures supplied by spinal and cranial -segmental nerves; and to the thoracic viscera. Thus the vessels going to all the skeletal tissues, those of the head, neck and thorax, arc supplied by motor cells which lie in the lateral ganglia.

The *collateral ganglia* supply motor cells which give origin to the fibers which control the vessels of the abdominal and pelvic viscera. These vessels are called the splanchnic vessels, and are of the greatest importance in the maintenance of blood pressure and the circulation of the blood. The splanchnics are the storehouse for surplus blood when not required by body activity. When special activity on the part of any organ is required, more blood is needed and the splanchnics are called upon to deliver it. This action is brought about through the splanchnic nerves working in harmony with the part undergoing activity.

The vessels of different areas of the body are supplied by nerves from particular sections of the cord, as follows;

Head and Neck. Vasomotor connector fibers for the head and neck leave the cord by the first four or five thoracic segments. They pass through their corresponding lateral ganglia, the stellate, inferior and medium cervical to the superior cervical ganglion, where they end in motor cells which send out nonmedullated fibers along the carotid artery to the entire region of the head and neck. The 2nd , 3rd and 4th segments give maximal effect when stimulated, as shown in Fig. 57.



A B

Figure 58. Schematic illustration of the vasomotor supply of the vessels of the head, neck and arm.
A - Schematic illustration of vasomotor supply for head and neck. The connector neurons that supply the vasomotor control for the head and the neck arise from the 1st to the 5th thoracic segments of the cord. They pass upwards through the stellate ganglion to the superior cervical ganglion and then on to the vessels that supply the head and the neck.
B – Schematic illustration of vasomotor supply for the upper extremity. The connector neurons that supply the vasomotor control for the upper extremity arise from the 4th to the 10th segments of the thoracic cord. They pass upwards to the stellate ganglion in which originate the true sympathetic fibres which supply the vasomotor control of the vessels of the arm.

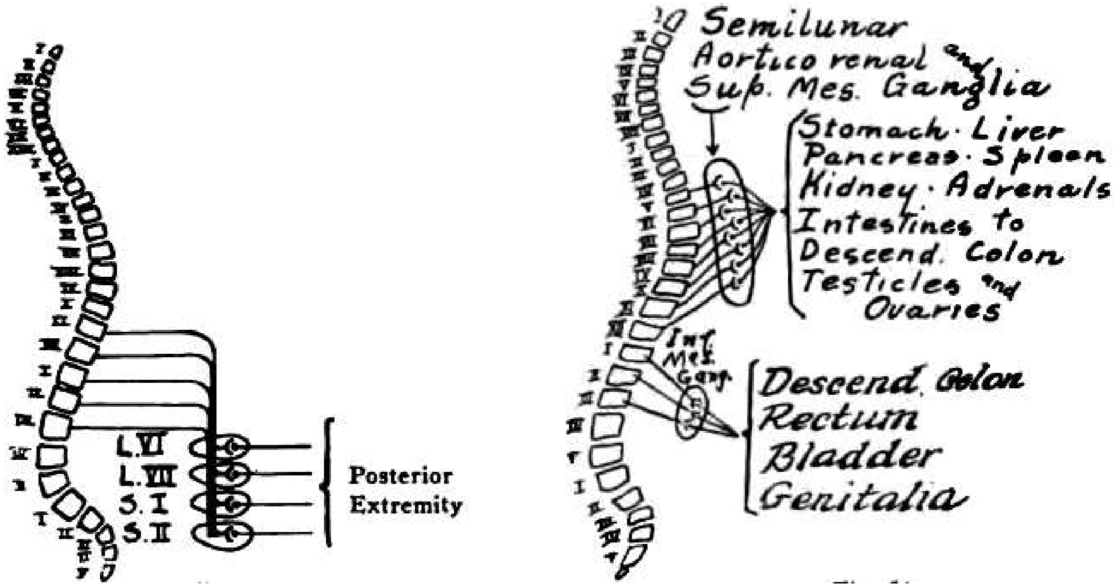
Anterior Extremity. The connector fibers for the anterior extremity arise from the 4th to the 10th thoracic segments. These pass through the various lateral ganglia on the way to the stellate ganglion, where they find the motor cells which give origin to the nonmedullated fibers which pass in the grey rami to the various cervical nerves of the brachial plexus, and go to all the vessels of the anterior extremity, as shown in Fig. 57B.

Posterior Extremity. The connector fibers for the posterior extremity arise from the 11th, 12th and 13th (cat) thoracic, and 1st, 2nd and 3rd lumbar segments of the cord. These fibers pass downward to the 6th and 7th lumbar (cat), and first sacral ganglia, where they meet the motor cells which give origin to the nonmedullated fibers which are connected with the nerves of the sacral plexus through grey rami, and are thence distributed throughout the vessels of the lower extremity, as shown in Fig. 58.

The Blood Vessels

Abdominal and Pelvic Viscera. Most of the connector fibres from the lower seven thoracic and upper three lumbar segments, join to form the splanchnic nerves which are the most important of all nerves carrying fibers to vessels. The splanchnic nerves find their motor cells for the vessels of the abdominal and pelvic viscera in the semilunar, superior mesenteric, renal, ovarian or spermatic and inferior mesenteric ganglia, as shown in Fig. 58.

Reciprocal Stimulation of Viscera and Somatic Structures Through Vasomotors. — The distribution of vasomotor nerves offers a path through which stimuli from the peripheral nervous system may influence the viscera and through which visceral stimuli may influence peripheral structures.



A B

Figure 59. Schematic illustration of vasomotor supply to lower (posterior) extremity, abdominal and pelvic viscera. A – the connector neurons for vasomotor control of the lower extremity arise from the 11^{th}, 12^{th} thoracic and 1^{st}, 2^{nd}, and 3^{rd} lumbar segments of the cord. They pass downwards to the lower lumbar and upper sacral ganglia, and then on to supply the lower extremity.
B – schematic illustration of vasomotor supply pf abdominal and pelvic viscera. The vasomotor supply to the upper abdominal viscera comes from the 5^{th} to the 12^{th} thoracic and passes through the superior mesenteric ganglion. The vasomotor supply for the descending colon and pelvic viscera comes from the 1^{st} to the 3^{rd} lumbar segments and passes down to the inferior mesenteric ganglion.

Vasomotor Control. The blood vessels are controlled by one chief center in the medulla, and by subsidiary centres in the spinal cord. Vasomotor control from the medullary center proceeds in part through such cranial nerves as the vagus (Xth) hypoglossus (IXth) and trigeminus (Vth), but for the most part the connection is through the cord and the spinal centres.

The Splanchnic Nerves

The splanchnic nerves are the most important vasomotor r the body. They arise from the Vth to XIIth dorsal, and 1^{st} to 3^{rd} lumbar roots. These connecting fibers proceed to the semilunar, superior and inferior mesenteric, renal, ovarian and spermatic ganglia; and there end in the motor cells which give origin to the nonmedullated fibers which supply all of the vessels of the important abdominal and pelvic viscera.

Every ganglion which supplies an organ with sympathetic fibers also supplies the vessels of that organ with vasomotor nerves. The following table from Gaskell[4] based largely upon the work of Bradford and Langley, is useful for ready reference for the vasomotor supply of various parts of the body:

Situation of Blood Vessels	Situation of Motor Ganglion Cells	Roots containing Connecting Nerves
Head and Neck	Superior Cervical Ganglion	1,2,3,4,5 Thoracic; 2,3,4 give maximum effect
Heart	Ganglion Stellatum and Inferior Cervical Ganglion	4,5,6,7,8,9 thoracic; 2,3 give maximum
Anterior (upper) Extremity	Ganglion Stellatum	4,5,6,7,8,9 thoracic and 10 slightly
Posterior (lower) Extremity	6th lumbar, 7th lumbar and first sacral ganglion	11,12,13 thoracic, 1,2 lumbar and 3 lumbar slightly
Kidney	Renal Ganglion	4,5,6,7,8,9,10,11,12,13 thoracic, 1,2,3,4, lumbar
Spleen	Semilunar Ganglion	3,4,5,6,7,8,9,10,11,12,13 Thoracic, 1,2,3, Lumbar
Abdominal Viscera	Superior Mesenteric Ganglion and Semilunar Ganglion	6,7,8,9,10,11,12,13 Thoracic and 1,2, Lumbar
Pelvic Viscera	Inferior mesenteric Ganglion	1,2,3,4, Lumbar

Figure 60 Table showing vasomotor supply for parts of the body

There has been some question whether the vessels to the brain, lungs, and coronary vessels, ha\e vasoconstrictor nerves, but this has been finally decided affirmatively lively, Gaskell commenting on this says:

"I for one cannot believe that muscles exist without motor nerves."

Vasodilator Nerves

The question of vasodilatation is one that has received much attention at the hands of physiologists. As a rule it may be said that vasodilatation, as far as nerve control is concerned, is governed by the sympathetics through vasomotor centres in the medulla and cord. The requirements of different parts of the body are met by different degrees of stimulation of the sympathetics; but whether there are genuine dilator fibers in the sympathetics, is questionable There are, however, some genuine, vasodilator nerves, such as the chorda tympani (7th cranial) which, when stimulated, causes dilatation of the vessels in the submaxillary glands; the *small petrosal* (IXth cranial), which carries dilator fibers to the parotid gland; the *lingual* which dilates the vessels of the tongue, and the *nervus erigens* which dilates the vessels of the penis.

Vasodilatation is produced in all muscles and glands during the stage of their activity. Tissues produce chemical products during the stage of activity which are acid in nature and are spoken of as *acid metabolites*. These have the property of acting locally upon the musculature of the vessels in the part affected and producing vasodilatation. All organic extracts influence the tonus of the vessel walls and produce lowered blood pressure (Swale Vincent[5]).

Fibers which produce vasodilator effects, pass to ganglia in or near the tissues Innervated before they end in the true dilator fibers, the same as the parasympathetic fibers as described in connection with the heart.

Stimulation of the posterior spinal sensory roots either before or after passage through the root ganglia causes dilatation in the area supplied by the sensory root affected. This occurs no matter what the stimulation used. This is exceedingly interesting because the impulses pass outward contrary to the direction of the usual impulse in sensory nerves. Bayliss[6] who made this discovery, called these impulses "*antidromic*" or reversed impulses. Starling' in commenting on this action says:

"So far this phenomenon of a nerve fibre functioning {not merely conducting) in both directions is almost without analogy in our knowledge of the other nerve-functions of the body. There is no doubt, however, that similar antidromic impulses are involved in the production of the so-called trophic changes, such as localized erythema or the formation of vesicles (as in *herpes zoster*) which may occur in the course of distribution of a sensory nerve, and is always found to be associated with changes, inflammatory or otherwise, in the corresponding posterior root ganglia. Moreover, evidence has been brought forward that these fibers may take part in ordinary vascular reflexes of the body, that in fact they are normally traversed by impulses in either direction."

Vessel Tone

The vessels of the body maintain a certain tonicity through the action of the sympathetic nerves upon the musculature of their walls. This differs from the tonus of the heart, respiratory system and gastrointestinal systems, where tonus depends on opposing nerve supply; one activating, the other inhibiting. In the vessels, this tonus is maintained by variation in the strength of the stimulation of the one (sympathetic) system. The degree of stimulation is determined by the vasomotor centres in the medulla and cord. The vasomotor control is such that the tonus in one vascular area may differ greatly from that in another. Compensation takes place between various organs so that a vasoconstriction in one is met by a vasodilatation in another, and the normal blood pressure maintained. The vasomotor balance is very delicate and is subject to changes, according to physical stimuli acting upon the body and psychic effects, but always modified by the requirements of the various tissues. It is necessary to maintain a fairly stable blood pressure; so when one large area of vessels contracts another must dilate, and vice versa.

Action of Adrenin upon the Vasomotors. In a discussion of vasomotor control, it is important to cite the results of the action of adrenin upon blood pressure as determined by the newer experimental work of our American physiologists. This has been recently summarized by Hartman[8] in a paper in which he cites his own and other important experiments which show that the prevailing idea as to the universal constrictor action of adrenin upon blood vessels, regardless of dosage, is no longer tenable.

Adrenin acts differently in different structures; and differently according to the size of the dose administered. In the blood vessels in some structures it produces a dilatation. The steps in this discovery are stated by Hartman thus:

"Cannon and Lyman[9] demonstrated that cats respond to small doses of adrenalin (intravenous) by a fall in blood pressure in a majority of cases. To be sure, other more or less isolated observations of this sort had been made previously, but the credit belongs to them for establishing the fact. Because this was opposed to the generally accepted idea of adrenalin action it appeared attractive for further re- search. An attempt was made by me to account for the fall in blood pressure. By tying off the arteries of the splanchnic area or of the head and limb area and then determining the blood pressure response to adrenalin, I was led to the discovery that there was a shifting of the blood from the splanchnic area to the outlying skeletal muscles," This was accomplished by active dilatation of skeletal muscle areas attended simultaneously by active constriction of the splanchnic area. At the same time it was observed by use of the nasal plethysmograph that the nasal mucosa constricted.

"Later, Hoskins, Gunning and Berry,[10] using the plethysmographic method, confirmed my observation that there was active dilatation in the 'peripheral' regions, but they went further and demonstrated that the skin constricts while the muscle dilates. Hoskins and Gunning" and ourselves" working independently, made a study of the spleen, kidney and intestine by the use of oncometers. On the whole, the observations of both of us agreed with the first observations on the differential action of adrenalin[10], i.e. depressor doses of adrenalin cause constriction of the splanchnic area. However we did differ from each other to a certain extent in our findings on the intestine. While Hoskins and Gunning frequently obtained dilatation of the intestine with small doses, we found constriction to be the more common and that dilatation usually resulted from larger doses and was preceded by constriction."

While it is broadly stated that adrenin acts peripherally at the myoneural juncture on the same tissue that is supplied by sympathetic fibers, Hartman's experiments indicate that this is not a universal fact, and show it to be untrue as far as the vasomotor mechanism is concerned. The fact that peripheral vessels may contract while splanchnic vessels dilate, indicates that the factors which control the vasomotor mechanism for different parts of the body must differ. On this point Hartman' says:

"We believe that we have proved that the mechanism causing vasodilatation in the intestine, when adrenalin is injected into the general circulation, is located in the collateral sympathetic ganglia, probably in the superior mesenteric ganglion."

Further:

"Thus far our work indicates that the limb mechanism is located in both the dorsal root ganglia and the sympathetic ganglia."

Recapitulating, he says:

"In the adult, adrenalin poured into the blood in small quantities, causes by its peripheral effects, constriction of the vessels in the skin, mucous membranes, and abdominal organs, driving the blood into the vessels supplying the skeletal muscles which are actively dilated for its reception through the effect on the sympathetic and dorsal root ganglia mechanisms. But as the quantity of adrenalin liberated increases, the peripheral effect begins to overcome the ganglia effect in skeletal muscle, the intestinal vessels by action on the sympathetic ganglia begin to dilate and the blood is reversed in its path.

"Although the effect of adrenalin on blood pressure, a fall with small doses and a rise with larger doses — is the more evident, the differential effect is after all the more important."

The clinical importance of these newer experiments upon the vasomotor nerves is evident. Karly in the writer's attempt to explain the effects of toxemia upon the nervous system as manifested in clinical medicine, he was impressed by the fact that the syndrome of toxemia is a double one." Tart of the effect of toxins is expressed upon nerve cells in general. The entire nervous system is rendered unstable, producing such symptoms as malaise, lack of endurance and nerve irritability. It was further noticed, however, that the peripheral expression of toxins is a sympathetic syndrome, thus, lack of appetite, coated tongue, hypochlorhydria, hypomotility throughout the intestinal tract (constipation), increase in pulse rate and rise in temperature. The latter symptoms were all so clearly those of increased activity of the sympathetic nerves, except rise in temperature, that I was forced to classify it as such although I was not able to explain it until later.'"

My opinion that pathologic hyperpyrexia, or fever, belongs partly to the syndrome of sympathetic stimulation and is due to an interference with the elimination of heat as well as an increased amount of heat production, was based both upon physiologic facts and clinical observation, as follows: (1) the effect of toxins acting directly through the sympathetic nerves and probably indirectly through an increase in adrenin production, is to produce vasoconstriction in the blood vessels of the skin, which interferes with heat elimination; (2) the greatest amount of body heat, 85 per cent, is eliminated through the skin; (3) that preceding and at the beginning of a rise of temperature as a result of toxemia, the superficial blood vessels are constricted ; (4) that pathologic hyperpyrexia, known as fever, occurs when the extra heat produced in the body fails to be eliminated ; and (5) that physiologic hyperpyrexia, such as occurs during active physical exercise, a game of tennis for example, is not followed in the normal individual by fever; because dilatation of the superficial blood vessels and sweating ta.ke place, which favour the rapid elimination of the surplus amount of heat which has resulted from the exercise, and a rapid return to normal.

Now that we understand that adrenin can affect the superficial and splanchnic vessels differently, and that small amounts of it produce cutaneous vasoconstriction, we are further strengthened in our explanation that fever, pathologic hyperpyrexia, is due to or maintained by the toxins acting' upon the cutaneous vasomotor nerves in such a way as to cause constriction and the interference with heat dissipation, as well as to an appreciate increased heat production. This vasoconstrictor effect is probably produced both by direct stimulation of the sympathetics and also by the action of small amounts of adrenin, the production of the latter being stimulated by the action of the toxins upon the sympathetics.

The better understanding of the action of adrenin upon the vasomotor mechanism may help solve some of the problems connected with the better understanding of shock.

Nearly all of the sensory nerves of the skin when stimulated cause stimulation of the splanchnics, the result varying with the stimulus. Pain unless severe causes splanchnic vasoconstriction. The close connection between the nerves of the surface of the body and the connector fibers for the sympathetics in the thoracicolumbar segments of the cord, suggests the effect that surface sensory stimuli may have upon the vasomotor nerves of the body.

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Chapter XXI
The Salivary Glands
I. Innervation of Salivary Glands

The secretion of saliva is a double process. The secretion of the watery elements and the salts is increased by stimulation of the parasympathetics; while secretion of the organic substances depends upon stimulation of the sympathetics. The secretion of saliva may be reflexly stimulated through mechanical contact with the endings of the trigeminus (Vth cranial) and chorda tympani of the facial (VIIth cranial) nerves; and through the taste nerves of the glossopharyngeal (IXth cranial nerve). It is also stimulated by the thought of, the sight of, and odour of food. Thus afferent sensory stimuli which cause the reflex secretion of saliva may course in any one of the sensory cranial nerves.

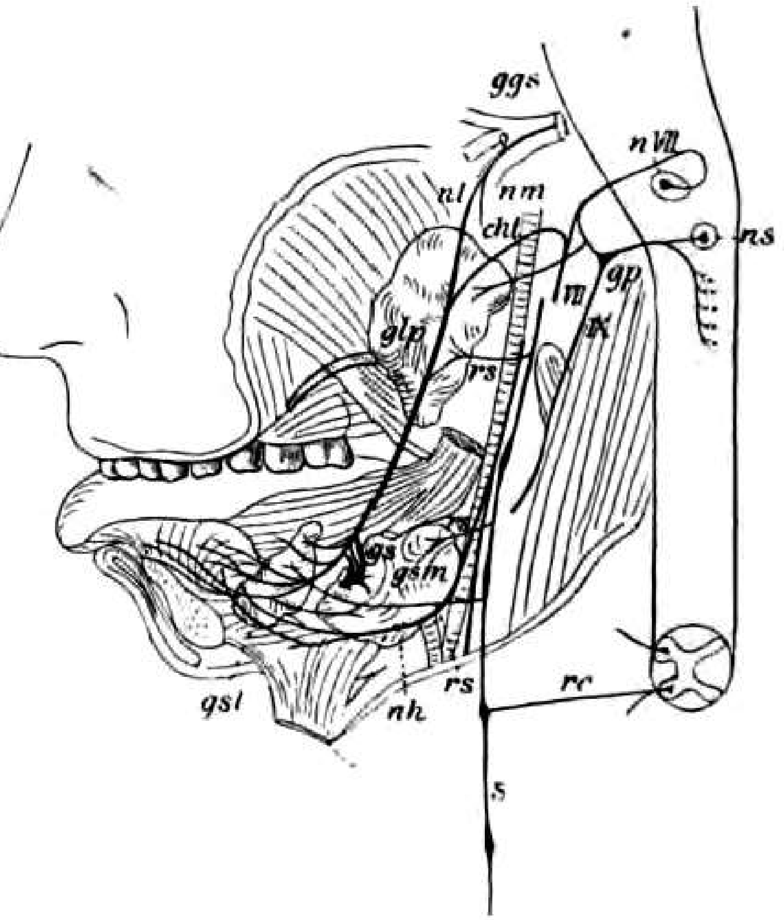


Figure 61. Innervation of the salivary glands.
glp – parotid gland; gsm – submaxillary gland; gsl – sublingual gland; ggs – Gasserian ganglion; nl – nervus lingualis; nm – nervus mandibularis; nVII – nervus facialis; cht – chorda tympani; IX – nervus glossopharyngeus; ns – centre for salivary secretion in medulla; gp = ganglion petrosum; s – sympathetic nerves; rs – sympathetic branch to salivary glands; gs – submaxillary ganglion; nh – nervus hypoglossus; rc – ramus communicans. (Bechterew)

"Whether the sympathetics have a direct inhibitory influence on the secretory activity of the glands which is produced by the parasympathetics (nervi tympanicus and chorda tympani); or, whether they decrease the watery elements of the secretion, simply through producing a vasoconstriction, thus limiting the blood supply to the glands, is not definite; but, clinically, we find that all such things as stimulate the sympathetics, such as fear, anger, and toxemia, depress salivary secretion and may be accompanied by a dryness of the mouth, while patients who are strongly vagotonic at times even have an abnormal amount of saliva.

The secretion of saliva depends upon three separate glands. The innervation of each is shown in Fig. 59, also in Fig 93 (Plate IX) page 221.

Parotid Gland. The parotid gland is supplied with *sympathetic* fibers from the superior cervical ganglion through the plexus meningeus medius. These, when stimulated, produce vasoconstriction in the vessels of the gland; and a thick, tenacious secretion of saliva with the watery elements wanting. The sympathetics activate the blood vessels and by causing constriction of them, when stimulated, reduce the amount of watery elements of the saliva and make the mouth dry.

This gland is also supplied by the *parasympathetics* from the nervus tympanicus (Jacobson's nerve) of the glossopharyngeal (IXth cranial}, the fibres of which are supplied to the gland through the nervus auriculo temporalis of the trigeminus (Vth cranial). Stimuli applied to these fibers cause a dilatation of the blood vessels of the gland and a free flow of thin watery saliva.

Submaxillary and Sublingual Glands. These two glands like the parotid, receive both sympathetic and parasympathetic fibers.

The sympathetic fibers arise from the superior cervical ganglion and reach this gland by way of the external maxillary plexus. They produce, when stimulated, a constriction of the vessels of the gland and a thick, tenacious secretion the same as they do in the parotid gland. The parasympathetic fibers come through the chorda tympani of the facial (VIlth cranial) and join the lingual of the trigeminus (Vth cranial) and pass with it to the glands. When stimulated the chorda tympani produces dilatation of the vessels of the glands and an abundant watery secretion.

II. Salivary Glands: Clinical Consideration

Such psychic conditions as fear and anger, and conditions of marked toxemia such as accompany the acute infectious diseases or exacerbations in chronic infections, are usually accompanied by a salivary secretion far below normal. There are also conditions present at times in which the amount of saliva is so great as to greatly annoy the patient.

There is at times a marked increase in salivary secretion in tuberculosis of the lungs and larynx. This must lie a reflex action through the sensory neurons of the vagus and the motor neurons of the VIlth and IXth cranial nerves. Increased flow of saliva is often seen in eases of gastric disturbances, and at times in severe attacks of angina pectoris.

Chapter XXII

The Nasal and Pharyngeal Mucous Membranes and Accessory Sinuses

I. Innervation of Nasal and Pharyngeal Mucous Membranes and Accessory Sinuses

The mucous membranes of the nasal and pharyngeal chambers and accessory sinuses are supplied with both sympathetic and parasympathetic fibers; also with sensory fibers from the Vth cranial nerve as shown in Fig. 53.

Sympathetics. The sympathetic fibers come from the superior cervical ganglion and pass through the nervus petrosus profundus to the sphenopalatine ganglion, whence fibers go to the tissues. They have a vasoconstrictor effect on the vessels which supply these structures.

Parasympathetics. The parasympathetic motor fibers which supply the nasal, palatine and pharyngeal mucous membranes, and the accessory sinuses come from the sphenopalatine ganglion. They arise in the vegetative nucleus of the facial (VIIth cranial) nerve; and, after entering the sphenopalatine ganglion, they emerge and course with branches of the *trigeminus* (Vth cranial) nerve; the nervi nasalis posteriores to the mucous membrane of the nose, and the nervi palatini to the hard and soft palate, and nasopharynx. They activate the secreting glands and furnish dilator fibers to the vessels. The pharynx also receives innervation from the glossopharyngeal and vagus.

II. Nasal and Pharyngeal Mucous Membranes and Accessory Sinuses: Clinical Consideration

Disturbance in Secretion

Dryness of the Mucous Membrane of the Nose and Throat. Dryness of the mucous membrane of the nose and throat occurs in several acute conditions in which the sympathetics are stimulated. A dryness of these mucous membranes is noticed at times during toxemia with high fever. It is not the fever, a9 usually suggested, which produces the drying; but the same condition that stimulates the vasomotor nerves and produces cutaneous vasoconstriction and interferes with the elimination of heat, stimulates the sympathetics to these mucous membranes and inhibits secretion.

Excessive Secretion. Excessive secretion of the glands of the nose occurs in bay fever and acute or chronic rhinitis. It is temporarily increased reflexly from irritations in the eye, and I have often thought that patients suffering from pulmonary tuberculosis complain at times of an unusual amount of secretion from all the mucous membranes of the upper air passages. This same excessive secretion is seen at times in asthma. The afferent sensory stimulus in such cases travels in the vagus, and the efferent through the vegetative fibers of the VIIth cranial nerve.

Motor and Sensory Disturbances

Many motor and sensory reflexes originate in the nasal mucous membrane. *Sneezing,* which is a powerful expiratory effort, is produced by afferent impulses through the sensory fibers of the Vth cranial nerve. These may come from irritation of the cutaneous branches, or from the nasal mucous membrane itself. Hay fever may be due to a direct irritation of the nasal mucous membrane, the afferent impulses coursing in the Vth cranial, the efferent in the vegetative fibers of the VIIth cranial.

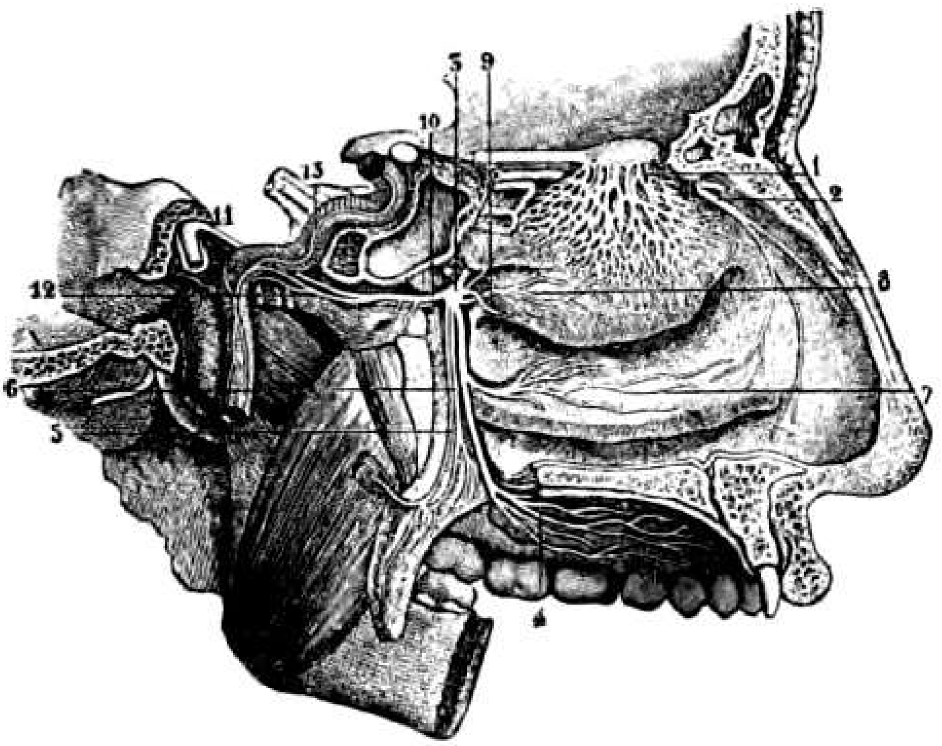


Figure 62. Nerve supply of nasal mucous membrane.
Nerves of outer wall of nasal cavity 3/5 (Sappey from Hirschfeld and Leveille). 1 – network of branches of olfactory nerve descending into the region of the upper and middle turbinals; 2 – external branch of nasal nerve; 3 – sphenopalatine ganglion; 4 – ramifications off greater palatine nerve; 5 – small palatine nerve; 7 – branch to region of lower turbinals; 8 – branch to region of upper and middle turbinals; 9 – nasopalatine branch to septum (divided) (Luciani)

Pressure in the nose at times will produce reflex asthma, the afferent sensory impulse traveling through the fibers of the Vth cranial nerve, the efferent motor effect being discharged through the Xth (vagus) cranial nerve. Such a reflex may be inhibited by anesthetizing the nasal mucous membrane by cocaine. The mucous membranes of the nasal sinuses have the same innervation as the nasal chambers themselves. Clinicians have reported asthmatic attacks to arise from sinus inflammation. This is readily explained through the reflex connection of the sensory fibers of the Vth and the motor fibers of the Xth cranial nerves. Irritation of the nasal mucous membranes, at times, will also slow the heart. The reflex in this instance travels over the same path as the one just described, except it manifests itself in the cardiac instead of the pulmonary branches of the vagus. Reflex action from this same source could easily affect the gastrointestinal branches of the vagus. "We have noted a tendency to *hyperacidity* and *spastic constipation* in some patients during attacks of hay fever. While this might be caused by a general unbalancing of nerve equilibrium, resulting in parasympathetic hyperirritability, yet the connection between the various groups of vegetative neurons in the cranial nerves is sufficiently close to suggest a reflex cause as not at all improbable. Herpes of the lips, or "cold sores," probably result from reflexes in which both afferent and efferent impulses course over the trigeminus. This may be inferred from the nerve connection shown in Fig 93 Plate IX, page 221.

Chapter XXIII

The Larynx

I. Innervation of the Larynx

The larynx is supplied by two nerves, the superior and recurrent laryngeal branches of the vagus. The former supplies the entire larynx with sensation, and the cricothyroid muscles with motor power, while the recurrent laryngeal is wholly motor and supplies all of the other muscles of the larynx. Sympathetic fibres supply the vessels and the mucous membrane. Fig. 61 shows the nerve supply to the larynx.

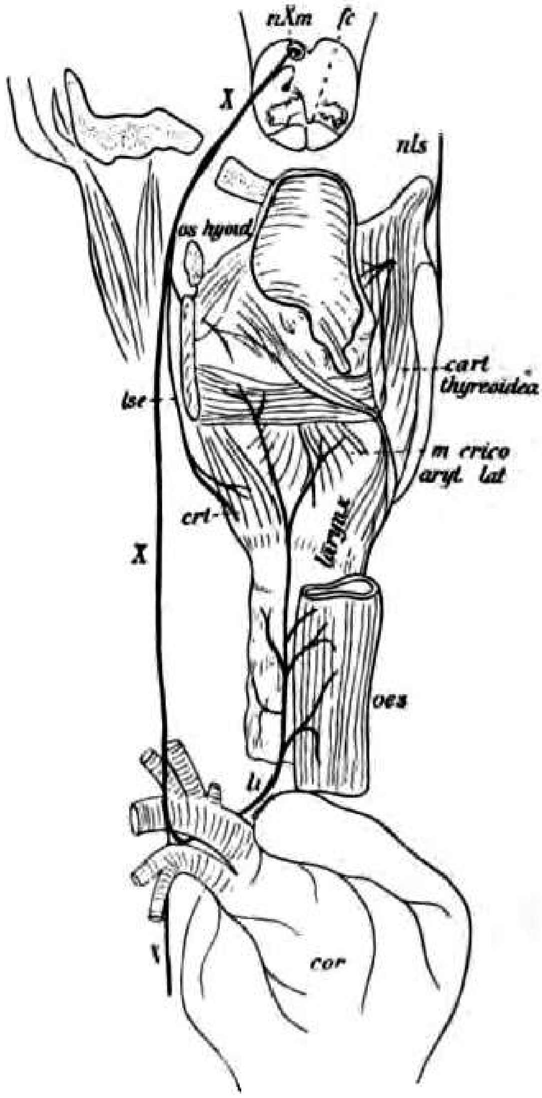
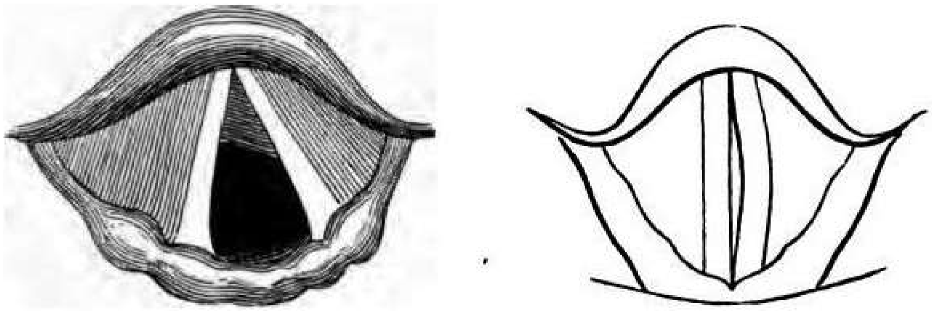


Figure 63. Nerve supply of the larynx.
nXm – motor centre of the vagus; X – Nervus vagus; nls.N – laryngeus superior; lse – external branch of the laryngeus superior; li.N – laryngeus inferior; fc – cerebral laryngeal tract of the vagus; oes – oesophagus; crt – musculus cricothyroideus. (Bechterew)

II. The Larynx: Clinical Consideration

Injury or paralysis of the superior laryngeal causes hoarseness, interferes with the sensation of the larynx, and produces trophic change; while injury or paralysis of the recurrent laryngeal causes aphonia. Stimulation of the recurrent laryngeal causes laryngospasm, stimulation of the superior laryngeal causes sensory phenomena, such as the common irritations which lead to cough.

The clinical aspects of laryngeal reflexes emphasize a fact which is apparent in other divisions of the parasympathetics: viz., that reflexes in the internal viscera occur easiest in those structures which arc most closely united by their innervation, — thus reflexes expressed in the larynx arc most apt to originate in impulses coming from the pulmonary and pleural branches of the vagus, and those expressed in the gastrointestinal tract are most apt to be due to impulses originating in other portions of the gastrointestinal tract. While I see nothing to prevent an impulse, arising in the gastrointestinal tract or in the cardiac muscle from expressing itself in a sensory reflex in the larynx leading to cough, at the same time anyone must recognize that most impulses which lead to the act of coughing arising in the respiratory tract and pleura. There is a possible physiologic basis for the traditional stomach cough.



A B

Figure 64. Schematic illustration of motor disturbance in cords through recurrent laryngeal nerves.
A - This form of reflex shows in some form of disturbance in the approximation of the inferior ends of the cords.
B – schematic illustration of motor influences in cords through superior laryngeal nerves. This shows as an inability of the cords to approach in the centre, giving a baggy appearance.

A sensory reflex leading to irritation and cough often arises from the parasympathetics in the lungs, pleura, larynx, tonsils and pharynx. It sometimes arises from that branch of the vagus supplying the external auditory canal.

Aside from the sensory reflexes which lead to cough, there are motor reflexes which express themselves in the larynx, which at times assume considerable importance. Among these should be mentioned laryngospasm as often observed in whooping cough and so-called croup; the forms of disturbance in innervation which result from pressure of mediastinal glands, aneurisms or other mediastinal tumours upon the recurrent laryngeal nerve ; and the motor reflex which results in both recurrent and superior laryngeal nerves from afferent impulses which arise in inflamed pulmonary tissue. This is some- times seen as an early sign of pulmonary tuberculosis. It is also seen when the tissue is breaking down (cavity formation) and when the mediastinum is shifting as a result of contraction.

The reflex motor disturbance in the larynx when expressed through the recurrent laryngeal nerve appears as a disturbance in adduction, as shown in Fig. 62A. The cord on the affected side fails to come up to the center to meet the opposing cord. The motor reflex expressed through the superior laryngeal shows as a bagging of the cords, as shown in Fig, 62B. They are not drawn taut and they do not approximate each other at the center.

These reflexes become very important as signs of early tuberculosis, and at times accompany marked inflammation daring the course of the disease. Early hoarseness, which, if carefully observed, will be found in a very large percentage of eases, may be due to this motor reflex. At times when cavity is forming and the inflammation of pulmonary tissue is at its highest point, marked or complete aphonia will be present. This is often considered to be a tuberculous involvement of the larynx, and the diagnosis is rendered somewhat difficult by the fact that coughing is usually severe during these times, and as a result the cords may be injected.

The path of this reflex is plain, the afferent impulses course centralward over the sensory fibers of the pulmonary vagus, and the motor effect is carried out through the inferior and superior laryngeal branches of the vagus.

Parasympathetic Trophic Reflex. I would like to call attention to a trophic reflex which occurs in the larynx as a result of pulmonary tuberculosis. In this, the afferent impulse courses in the pulmonary branches of the vagus and the efferent in the laryngeal branches of the vagus. The tissue degenerates, loses its resistance, and offers a favourable soil for the implantation of tubercle bacilli. These trophic changes offer a reasonable explanation of the fact that lesions in the larynx are usually secondary to chronic infection in the lung; and that if they are unilateral, they usually occur on the side of the pulmonary involvement.

Chapter XXIV
The Eye
I. Innervation of the Eye

Many portions of the eye are innervated by vegetative fibers, — musculus cilairiis, musculus sphincter papillae, musculus dilator papillae, musculus Müller, musculus levator palpebral, and the lachrymal glands. Some of these are activated by the sympathetic and others by the parasympathetic system. It also receives sensory fibres from the ramus ophthalmicus of the Vth cranial nerve which is accountable for its parasympathetic reflexes. The innervation of the eye is shown in Fig. 64.

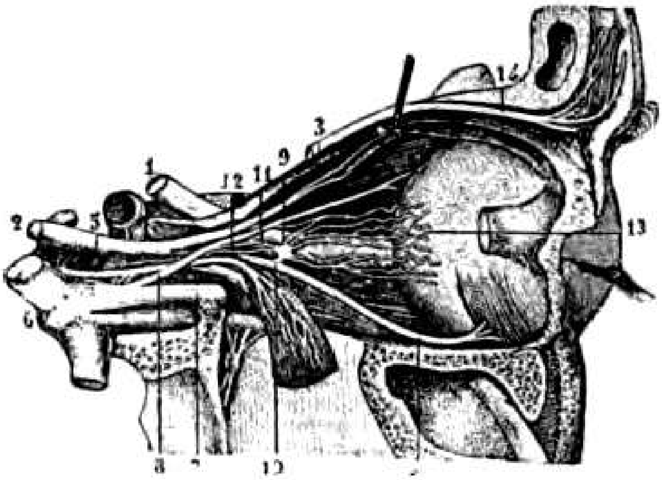


Figure 65. Innervation of the eye. Nerves of orbit. Lateral view.
The ramus externus is divided and turned back. 1 – optic nerve; 2 – trunk of IIIrd nerve; 3 – it's superior division to levator palpebrae and rectus superior; 4 – its longer and lower branch to the inferior oblique; 5 - 6th nerve joined by branches of the sympathetic; 6 – Gasserian ganglion; 7 – ophthalmic nerve; 8 - its nasal branch; 9 – ciliary ganglion; 10 – its short, 11 – long; and 12 sympathetic roots; 13 – short ciliary nerves; 14 – supraorbital nerve. (Luciani)

Sympathetics. The sympathetic filters to the eye, as far as we definitely know, supply the muscle of Müller and the pupil. The orbital muscle of Müller, when contracted, pushes the eyeball forward. This muscle is important in the production of exophthalmos. Sympathetic fibers also supply dilator fibers to the pupil which antagonize the constrictor fibers of the IIIrd nerve, and if able to over- come them, produce dilatation of the pupil.

The sympathetic fibers going to the eye arise from Budge's center in the spinal cord in the region of the 7th and 8th cervical and 1st, 2nd and 3rd thoracic segments (Fig. 65). The connector fibers pass through the rami communicantes on through the upper thoracic and inferior and medium cervical ganglia, and do not end in the sympathetic motor cells of the eye until they reach the superior cervical ganglion. Here they end in motor cells and continue as nonmedullated grey fibers given off from these cells, until they reach the Gasserian ganglion. Here they unite with the ophthalmic branch of the Vth nerve (trigeminus) and course in the nervi ciliaires longi to the vessels of the eye, the dilator muscle of the pupil and the Mullerian muscle.

Parasympathetics. The vegetative fibres which course in the IIIrd cranial nerve, Fig 93, Plate IX, page 221 are in the parasympathetic division. The oculomotor nerve arises from several nuclei; one of those nuclei is made up of smaller ceils than the others. Prom this nucleus, fibers arise which terminate in the ciliary ganglion, and which belong entirely to the vegetative system. Prom the ciliary ganglion fibers pass to the pupil, the ciliary body and the musculus levator palpebrae.

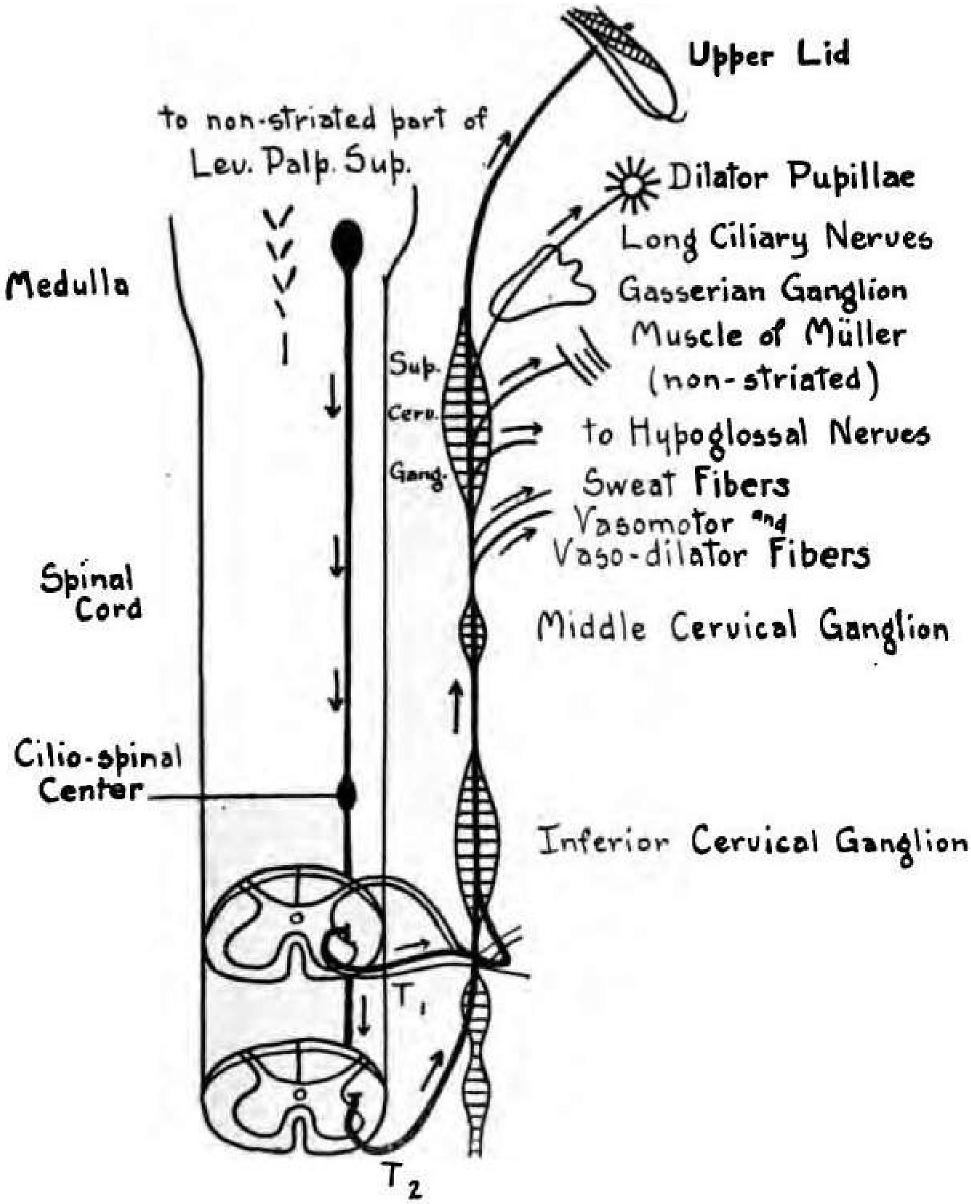


Figure 66. Diagrammatic illustration of the ocular fibres of the cervical sympathetics (After Purves Stewart)

The fibers going to the pupil contract it; and, in this oppose the dilating fibers of the sympathetics.

The ciliary body is innervated by parasympathetic fibers which course in the IIIrd nerve. Stimulation of these fibers produces a contraction of this muscle which has the effect of shortening the focal point. There is some question whether or not the parasympathetic fibers in this muscle are opposed by sympathetic fibers which tend to relax the muscle and lengthen the focal point. The consensus of opinion at this time is that the eye accommodates itself to distance by a gradual relaxation of the ciliary body without the active assistance of a sympathetic inhibitory nerve. When the excitability of the motor cells in this division of the oculomotor nerve is very high, it may result in accommodation spasm.

The musculus levator palpebrae when activated has a tendency to widen the lid slits of the eye and give the appearance of fright. This is the condition found in exophthalmic goitre which results in two common parasympathetic symptoms, — von Graefe's sign, in which the contraction of this muscle prevents the upper lid from following the cornea closely as the eye is lowered; and Dalrymple’s sign, in which the contraction causes the lid slits to be wider than normal, so that the sclera shows between the pupil and the lid

II. The Eye: Clinical Considerations

There are many clinical conditions which manifest themselves through stimulation of cither one or the other division of the vegetative nerves ill and about the eye.

Pupil. Dilatation of the pupil may occur either as a reflex through the sympathetics; from stimulation over Budge's center in the cord, 7th and 8th cervical and 1st to 3rd thoracic segments; from peripheral stimulation, as from adrenin; from general sympathetic stimulation, such as occurs in toxemia; from psychic stimulation from such factors as fear, pain and even joy: Psychic dilatation may be due to cortical action in lessening the excitability of the oculomotorius; or subcortical, in raising the dilator excitability of the sympathetics by stimulating a center which lies in the median portion of the corpus subthalamicus. An explanation for the dilatation of the pupil which takes place on the side of involvement in pulmonary tuberculosis is suggested by its one sidedness. This indicates that it is of reflex origin. It probably is due to stimulation of Budge's center in the cord by afferent stimuli from the lung, both afferent and efferent stimuli coursing over the sympathetics.

Contraction of the pupil follows the impingement of light upon the retina, the impulse being carried through the optic tract. It is carried to the geniculate body and corpora quadragemina, or, according to some authors, into the grey matter in the floor of the IIIrd ventricle, where collaterals arc given off which connect with the parasympathetic motor cells in the nucleus of the IIIrd (oculomotorius) nerve. The brighter the light, the stronger the impulse and the greater the contraction of the pupil.

Argyll Robertson Pupil. This condition is an early sign of tabes dorsalis and of progressive paralysis. It consists in a preservation of the pupillary reaction to convergence and to accommodation with a loss of reaction to light, but no impairment of sight. The cause of the phenomena has caused differences of opinion. Higier[1] says it could be due to a basilar meningitis involving the fibers from the optic tract which pass between the geniculate bodies through the arms of the anterior corpora quadragemina.

Rigidity of the pupil to light. When the pupil is completely rigid the parasympathetics in the oculomotor nerve have no influence upon it; and the sympathetics, whose dilator action normally is not very great, are not able to cause dilatation.

The oculomotor fibers which proceed from the ciliary ganglion normally maintain tonus in the ciliary muscle. While the sympathetics have an inhibiting action, it is not the only influence that dilates the pupil. A lessened stimulation of the oculomotor fibres will permit the pupil to dilate. Damage to the ciliary ganglion, therefore, produces a maximum dilatation of the pupil. In eases of fainting, central lues, epileptic and hysterical attacks, and great fear, a widely dilated and rigid pupil is a result of action in cortical areas; while rigidity with contraction of the pupil is due to increase in the sphincter tonne.

The study of pharmacologic remedies with reference to their action upon the vegetative nerves has shown that they may he used at times with differential diagnostic value as discussed in Chapter XXXIII. According to Higier, the action of cocaine and adrenalin upon the dilator fibers of the pupil may be taken to suggest the character of a lesion. If a dilute solution (1-3 per cent) of cocaine be dropped into the conjunctival sac and dilatation of the pupil fails to appear, itis evidence of a weakening of the sympathetic pupillary control. If evidence of disturbance of the sympathetics is obtained, the next question is to decide where the location is located, whether operable or inoperable. This may be determined by adrenalin. Two drops of a 1 per cent solution of adrenalin is dropped into the eye at three different times within five minutes. Normally no effect is evident. If the dilator fibers ate rendered sensitive as they usually are in affections which involve the sympathetic fibers distal to the superior cervical ganglion, then after a period of fifteen minutes has elapsed a marked dilatation of the pupil will ensue. This adrenalin mydriasis is common in affections involving the anterior and middle cranial fosse, such as diseases of the orbit and fractures at the base of the skull. Such affections are as a rule limited to one side. If the adrenalin mydriasis is double, then one must think of disturbances in the endocrine glands, which produce a general sympathetic irritability, such as Basedow's disease.

Exophthalmic goitre shows a very interesting eye picture. While the chief eye symptom, that for which the condition is named, is a protrusion of the eyeball, due to contraction of the Müllerian orbital muscle, which is activated by the sympathetics, there are other eye phenomena which are of parasympathetic origin. Of these von Graefe's and Dalrymple's signs deserve mention.

Von Graefe's Sign. This is a condition in which the upper lids do not follow the cornea readily when the eyes are lowered. This phenomenon is due to a heightened tonus of the fibers of the IIIrd nerve which supply the musculus levator palpebrarum.

Dalrymple's Sign. This sign consists of a widening of the lid slits giving the expression of fright. This is due to the same cause as von Graefe's sign, an increased tonus in the fibers supplying the musculus levator palpebrarum.

If both divisions of the vegetative system show symptoms in the same individual in the presence of exophthalmic goitre, it must be due to either some process acting locally on neurons supplying certain structures or to an underlying difference in excitability of the neurons supplying different structures in the same individual, which causes them to become activated when the cell bodies are sensitized by the increased thyroid secretion, as I have discussed in a recent paper.'

Reflexes in Other Organs from the Eye. I have called attention in many of the Clinical Chapters to the reflexes which result from eye strain, particularly those in the gastrointestinal tract. Eye strain will very commonly produce nausea and even vomiting at times, hyperchlorhydria, spastic constipation and intestinal stasis. The course of these reflexes is most probably through the afferent sensory fibers of the Vth nerve which mediate with the motor fibers of the vagus. In headache, another common symptom of eye strain, both afferent and efferent fibers course through the Vth nerve.

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Chapter XXV
The Lachrymal Glands
I. Innervation of the Lachrymal Glands

The lachrymal glands are supplied by both sympathetic and parasympathetic fibers, the former from the superior cervical ganglion, the latter from the VIIth cranial (facial) nerve. They receive sensory fibers from the nervus lachrymalis of the Vth cranial nerve, which carry the afferent impulses in parasympathetic reflexes.

Sympathetic. While it is known that the sympathetic system sends fibers to the lachrymal gland, yet little is known of their function. Prom the fact that patients who are suffering from severe toxemia with high fever often suffer from dryness of the eyeballs, and further from the fact that toxins which are responsible for the fever stimulate the sympathetics, it would seem that the sympathetic fibers are endowed with the function of opposing the parasympathetics which are the activating fibers.

Parasympathetic. The parasympathetic fibers which activate the lachrymal glands, have their origin in the VIIth cranial (facial) nerve. The fibers leave the facial nerve in the geniculate ganglion and pass with the nervus petrosus superficialis major, and reach the nervus subcutaneous malae, a branch of the trigeminus at the sphenopalatine ganglion. This nerve then freely anastomoses with the nervus lachrymalis, a branch of the Vth cranial (trigeminus), and passes to the lachrymal gland. This is shown in Fig. 59; also in Plate IX, page 312.

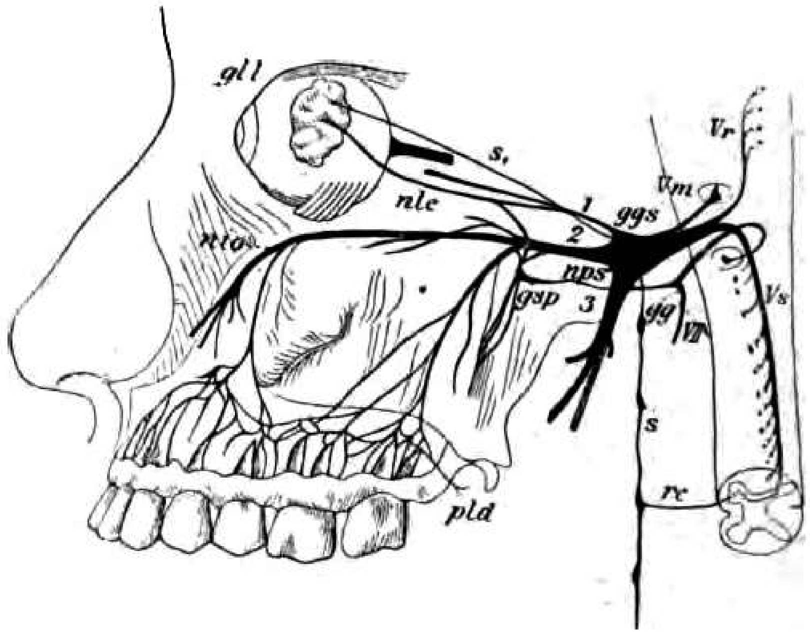

Figure 67. Innervation of the lachrymal glands. gll – lachrymal gland; rc – ramus communicantes; s – nervus sympatheticus; s_1 – sympathetic fibres to the eye (coursing with the fibres of the trigeminus); VII – root of facial nerve; gg – ganglion geniculi; nps – nervus petrosus superficialis, major; gsp – ganglion sphenopalatinum; nlc – nervus lachrymalis; Vs – descending; Vm – motor; Vr – reflex roots of the trigeminus; 1, 2, 3, - 1st, 2nd, 3rd branches of trigeminus; ggs – Gasserian ganglion; nio – nervus infraorbitalis; pld – plexus dentalis. (Bechterew)

While the parasympathetic fibers pass to the gland with fibers belonging to the trigeminus (Vth cranial), they do not belong to it in the sense that they originate from a nucleus of the trigeminus; but belong to the facialis (VIIth cranial).

II. The Lachrymal Glands: Clinical Consideration

Dryness of the Eyes. There are many conditions in which a dry- ness of the eyes occurs. This is found particularly in infectious diseases with high fever. During fever, secretion from many of the glandular structures of the body is lessened. This should be expected as a result of the action of the toxins upon the sympathetics.

Epiphora. Epiphora or an excess of tears, is found in certain diseases oi the eye itself and often as a reflex from diseases of the nasal mucous membrane. Acute rhinitis is commonly accompanied by weeping eyes. Hay fever also has excessive lachrymation as a common symptom. The connection is evident since the parasympathetic fibers of the VIIth cranial nerve supply the lachrymal glands and these are in reflex connection with the sensory fibers in the Vth cranial nerve. Other reflex effects upon the lachrymal secretion will be noted in other diseases producing nasal stimulation; and it is probable that afferent reflexes may also even come from organs supplied by others of the parasympathetic nerves. It is not an uncommon symptom in individuals who are strongly vagotonic.

Chapter XXVI
The Urogenital Tract
I. Innervation of the Urogenital Tract

The Müllerian and Wolffian ducts are derived from the segmental duct which is of epiblastic origin. Therefore the muscles surrounding these ducts belong to the dermal system, and, as such, are activated by motor cells whose connector fibres belong to the thoracicolumbar or sympathetic outflow.

The Müllerian ducts become the Fallopian tubes, and, after fusing, form the uterus and vagina; while the Wolffian duct gives origin to the vas deferens and ejaculatory duct. When that stage of evolutionary development was reached which demanded a separate excretory organ, the kidney was formed. It arises as a bud from the dorsal side of the Wolffian duet near its termination in the cloaca. This bud pushes upward, gradually elongating the stalk on which it grows. This becomes the ureter. Its course is posterior to the peritoneum, and it does not stop until the upper pole of the kidney has reached the eleventh rib. The lower end of the stalk of the bud, which is the lower end of the ureter, migrates along the Wolffian duct until it leaves it and becomes established in that part of the cloaca from which the bladder is made. Thus, when fully developed, the ureter and kidney are wholly separated from the Wolffian body, although they are derived from it.

All of the structures derived from the Mullerian and Wolffian ducts have the same innervation. They are activated by the sympathetics, Gaskell says there is no evidence that the ureter, uterus and vas deferens have any connection with the pelvic nerve (parasympathetics).

The bladder and rectum originally formed a single cavity, but as the excretory function of the urinary apparatus became of greater importance to the animal, these two structures separated and each became a distinct cavity with an external opening of its own. The bladder, rectum and large intestine correspond to the cloaca of lower life. They are developmentally related and possess similar innervation. In then we have, aside from the usual circular and longitudinal muscles, which arc found throughout the gut, a second system of muscles, the sphincters. Their origin is as follows: The cloaca was originally divided into three parts and each of them protected above and below by a circular band of muscle (sphincter). Thug the contents of the small gut would be prevented from entering the cloaca; relaxation of the outer sphincter could permit of the evacuation of urine without faeces; or, if both outer and inner rectal sphincters were relaxed, both urine and faeces could pass out. It fan readily be understood how, when the posterior chamber differentiated into the urinary bladder, it carried with it the outer sphincter musculature which further differentiated into the sphincter of the bladder and the urethral musculature.

The *bladder* and *urethra* then carry with them the same innervation us the systems from which they are embryologically derived. The sphincter, that part of the bladder between the sphincter and the ureteral orifices known as the trigone, and the urethral musculature are activated by the sympathetics and inhibited by the parasympathetics. The body of the bladder is innervated in the same manner as the cloacal walls, activated by the parasympathetics (pelvic nerve) and inhibited by the sympathetics. Thus it is evident that the urogenital structures are more or less complex embryologically and also show this same complexity from the standpoint of innervation.

With the foregoing embryologic discussion, I hope to have made this quite clear and will now take up the innervation of the more important structures of this system.

We shall first discuss the innervation of those structures which are derived wholly fi-om the Müllerian and Wolffian ducts, viz.:

1. The Fallopian Tubes, Uterus, Vagina, Vas Deferens, Seminal Vesicles, and Ureter. These, except the cervix uteri are activated by the sympathetics, the connector fillers arising, according to different observers from the 10th thoracic to the 5th lumbar. The 10th thoracic to 4th lumbar are Die chief sources of supply. *The sympathetics carry the. Inhibitory fibers as well as the activating*. In this way they resemble the dermal musculature. This is to be expected because of the fact that the Müllerian and Wolffian ducts are of epiblastic origin. Like other smooth muscles of epiblastic origin, the muscles in these organs do not seem to be supplied by any parasympathetic fibers.

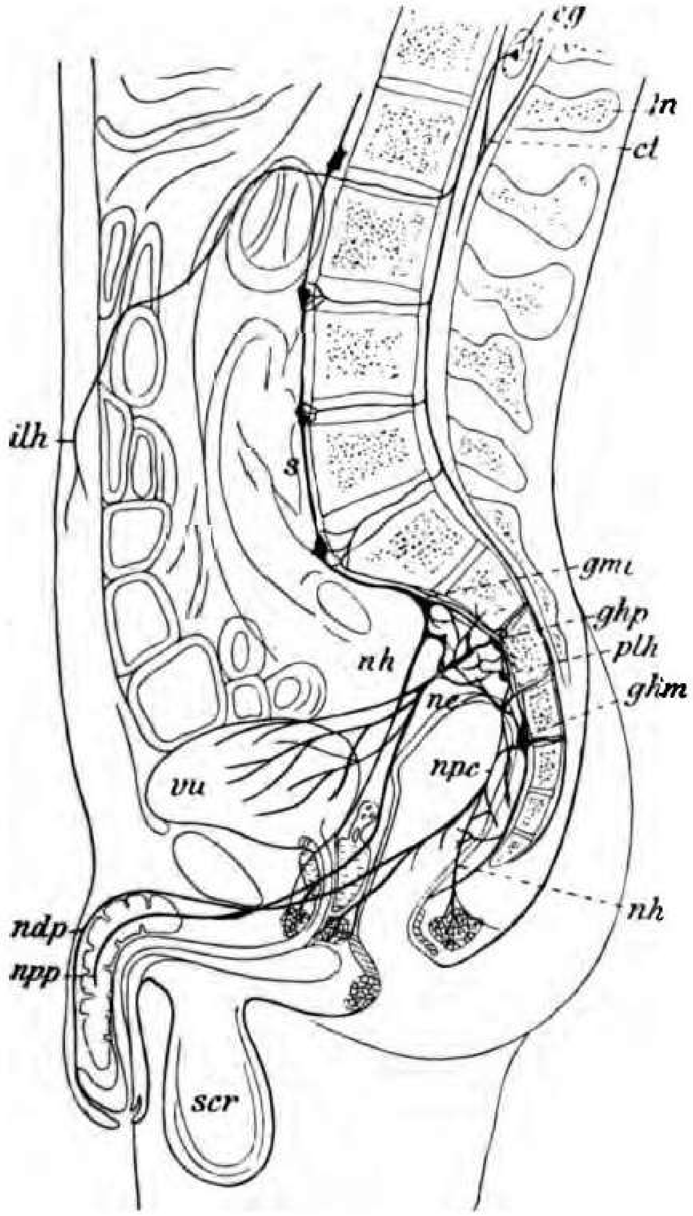

Figure 68. Innervation of the generative organs (male)
cg – spinal centre for the organs of generation, on level of 1st lumbar vertebra; s – nervus sympatheticus; ct – conus terminalis; ilh – nervus iliohypogastricus; gmi – ganglion mesentericum inferius; ghp - ganglion hypogastricum; ghm – ganglion haemmarhoidale; nh – nervus erigens, or pelvicus; npc – nervus pudendus communis; nh – nervus haemmarhoidalis inferior; ndp – nervus dorsalis penis; npp – nervus perinei profundus; vu – urinary bladder; scr – scrotum. (Bechterew

The cervix has a separate nerve supply which comes from the *sacral nerves*; according to some authors this activates the cervix and produces inhibitor influences on the body of the organ (Bechterew), Gaskell, however, finds no parasympathetic fibers in the body of the uterus.

There is another peculiarity in the innervation of these structures in that the connector fibres which arise from the lumbar segments 2nd to 5th, pass as medullated fibers through the inferior mesenteric (ganglion and meet the motor cells on the muscles which they innervate, in much the same manner as the parasympathetics do throughout the enteral system.

2. The Prostate and the Glands of Cowper and Bartholin. These are supplied by secretory nerves from the sympathetics. The prostate, however, seems to partake of characteristics of both the Wolffian duet and the cloaca as far as innervation is concerned, as might be inferred from its derivation. The musculature around the prostate is derived from the cloacal structures and innervated by the pelvic nerve. Stimulation of the pelvic nerve probably causes a forcing out of secretions by contracting the musculature, and not by stimulating secreting glands. Stimulation of the hypogastric produces true secretion. Figs. 67 and 68 from Bechterew show the innervation of the organs of generation of the male and female.

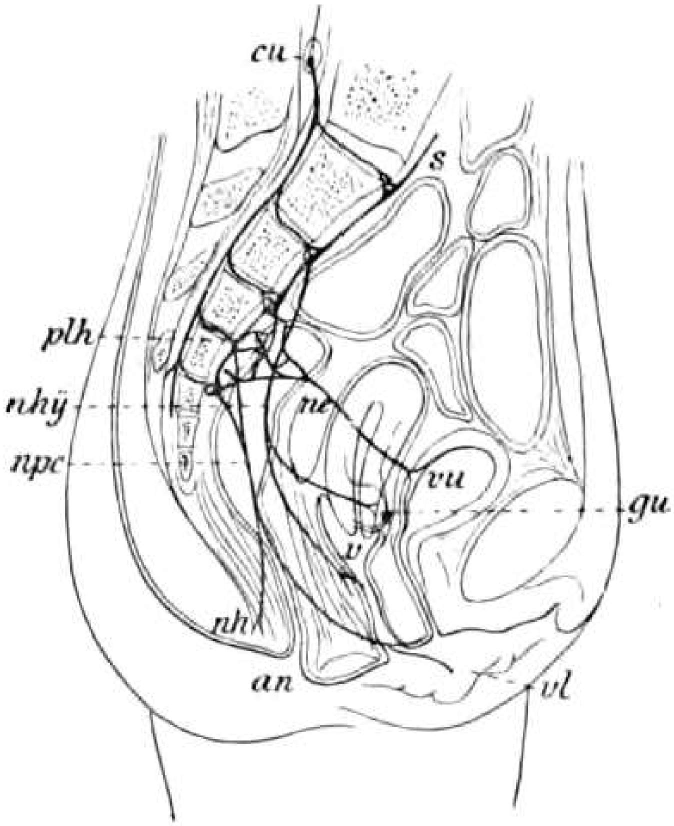

Figure 69. Innervation of generative organs (female).
Innervation of uterus and vagina. cu – spinal uterus centre; s – nervus sympatheticus and sympathetic ganglion; plh – plexus hypogastricus; npc – nervus pudendus communis; nh – nervus haemmarhoidalis; gu peripheral ganglion in vaginal wall; v – vagina; vu – bladder; vl – vulva; an anus. (Bechterew)

3. The Penis. The penis is supplied by *sympathetic* fibers from the hypogastric plexus which go to all the smooth muscles, such as the retractor penis muscle belonging to the dermal system; and by *parasympathetics* from the pelvic nerve (nervus erigens). This nerve was originally named *nervus erigens* from the fact that it was the nerve which is active in producing erection. Later physiologists have given it the name of pelvic in order to indicate thereby its greater distribution. When stimulated, this nerve produces a relaxation of the smooth muscle of the corpora cavernosa. At the same time a dilatation of the vessels ensues and they become filled with blood. Simultaneously the muscles, transversus perinei profundus, ischiocavernosus and bulbocavernosus, contract and increase the hyperaemia. This results in an increase in the size of the organ to the extent of four or five times that of its relaxed condition.

4. The Urinary Bladder. The bladder, as previously mentioned, is formed from the cloaca and carries with it with the musculature of the walls of the gut and that of the sphincters. Therefore, the bladder has two distinctly antagonistic systems of innervation.

The parasympathetics, which go to the bladder run as connector fibers in the pelvic nerve until they reach motor cells which lie on the bladder musculature. They activate the musculature of the bladder walls, except the trigonum; and inhibit the musculature in the trigonum, the sphincter and urethra. Therefore, stimulation of the pelvic fibers going to the bladder compresses the walls and relaxes the sphincter and thus causes emptying of the viscus.

The sympathetic fibers to the bladder antagonize the parasympathetics. When stimulated they constrict the sphincter and urethral muscle and relax the musculature of the bladder wall with the exception of the trigonum, which they contract. The trigonum is closely related to the sphincter muscles. The motor cells which give origin to the sympathetic fibers lie in the inferior mesenteric ganglion and the connector fibres originate in lumbar segments of the cord, (2^{nd} to 5^{th}).

5. Ovary and Testicle. The ovary, aside from the function of ovulation produces internal secretions which have a very marked influence on the individual. It not only influences the growth but exerts an unusual nervous influence throughout life. The ovary is supplied for the most part by sympathetic fibers which arise from the same segments of the cord as those supplying the testis. They arise from the 9^{th} and 10^{th}, or 10^{th} and 11^{th} thoracic segments, pass through the small splanchnic nerves to the aorticorenal ganglion and follow the ovarian artery in the plexus arteriae ovaricae to be distributed to the ovarian vessels and tissue. When stimulated these nerves increase ovarian activity. The internal secretion from the corpus luteum is sympathicotropic, like that of the adrenal, and thyroid. The parasympathetic fibers come from the pelvic nerve, according to some authors but do not activate the gland.

The *testes*, aside from the production of spermatozoa, produce an internal secretion which has an influence on metabolism and growth, and is well illustrated in the case of castrated animals and eunuchs.

The testis is supplied by nerves for the most part which course in the blood vessels. They are almost wholly of sympathetic origin. They arise from the 9^{th} and 10^{th}, or 10^{th} and 11^{th} thoracic segments, pass through the small splanchnic to the aorticorenal ganglion and spermatic plexus to the testicle.

The parasympathetics from the pelvic nerve also enter the gland, but are not the activating fibers. Activity of secretion on the part of the testis is favoured by sympathetic stimulation. The internal secretion of the testes is sympathicotropic. This has been shown by Wheelon and Shipley.[1]

6. The Kidney. The kidney which arises from a bud from the Wolffian duet, carries an innervation which differs markedly from the other structures which are embryologically related to it. Both sympathetic and parasympathetic nerves go to the kidney, but it is supposed that the control of the blood supply rather than a truly secreting nervous system is the chief factor in altering the secretion of urine.

The sympathetics go to the kidney as nonmedullated fibers from the renal ganglion, which is supplied by connector fibers from the 6th thoracic to the 1st lumbar segments, some of which pass through the semilunar ganglion in their coulee peripheralward. The chief source of nerve supply, however, is the 11th to 13th thoracic and 1st lumbar segments (dog). The sympathetics furnish both vasoconstrictor and vasodilator fibers. The 11th to 13th thoracic segments furnish the principal vasodilator fibres.

The parasympathetics which supply the kidney come from the vagus, but there is no definite data on which to base an opinion that they have a vasodilator effect. They are important, however, in accounting for many of the reflexes which mediate with other parasympathetic fibers when the kidney is inflamed. Fig. 69 from Cushney shows the nerve supply of the kidney.

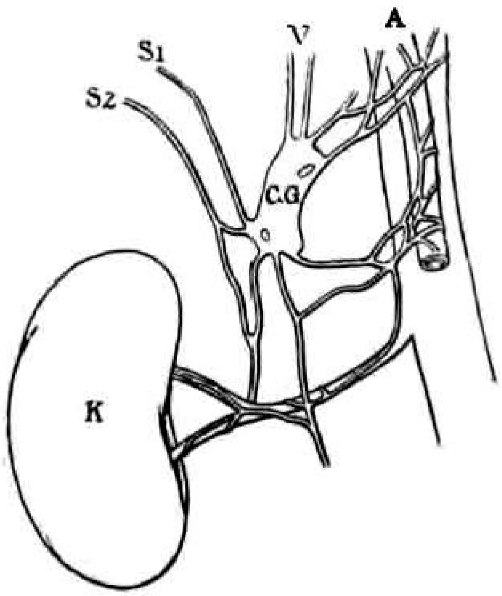

Figure 70. Nerve supply of the kidney (After Renner).
K – Kidney; s_1, s_2, major and minor splanchnics nerves; V – vagus; c. G. coeliac ganglion; A – aorta.

II. The Urogenital Tract: Clinical Consideration

1. Fallopian Tubes, Uterus, Vagina, Vas Deferens, and Seminal Vesicles. The reflexes which arise from some of these structures have not been carefully analyzed. If, as seems evident, they are supplied only by sympathetic nerves, one type of reflex— the sympathetic — alone will be found. Clinical observation of the pains and sensations which arise from these structures must of necessity be more or less uncertain.

It has been a common clinical observation that nausea and vomiting and other digestive disturbances, follow inflammations of the uterus and tubes. The vomiting impulse is readily stimulated by inflammations in all structures belonging to the enteral system, yet vomiting is a complex act which is presided over by a definite vomiting center, which is found in the floor of the fourth ventricle, and may be induced by stimuli which reach this center from many sources and from varied diseases. Severe pain is at times sufficient to discharge this center, so is a foul odour, a "sickening" sight, and even thoughts of the same. So while there may be no direct sensory parasympathetic nerves to carry the impulse from the organs directly to the vomiting center in the floor of the fourth ventricle, as there is in the intestinal canal and other tissues supplied with vagus sensory nerves, yet the impulse might be carried by sympathetic nerves to the cord and lie transmitted through higher centres to the various neurons which produce the act of vomiting. Vomiting, like coughing and ejaculation of semen, is a complex act.

Motor Reflex. The motor reflex from these structures belonging to the genital system is not very pronounced, in spite of the fact that the uterus is one of the very important organs of the body.

Sensory Reflex. The sensory reflex from some of these organs is definite and well recognized, in others it is not as yet well defined. Pain is a common symptom of uterine disease and of considerable importance in tubal disease.

Uterine pain is found in many women who have or who have had, uterine disease, particularly those who are below par from both a physical and a nerve standpoint. This pain is usually located in the lumbar region and lower abdomen. Uterine pain, however, may be located an>'where in the areas from the 10th dorsal to the 5th lumbar zones or even in sacral zones. At times there are pains present which seem to be definitely of uterine origin, which are referred to the sacral region, the back of the hip and the thigh. These make it appear as though there is nerve connection with the sacral nerves. However, the impulse which originates these reflexes might originate in the cervix which is innervated by filaments from the sacral segments, which is most probable, or by transferred in the cord in the same manner as those from the lung to the cervical portion of the cord. The location of uterine, ovarian, and tubal pain is shown in Fig. 70 from Behan.

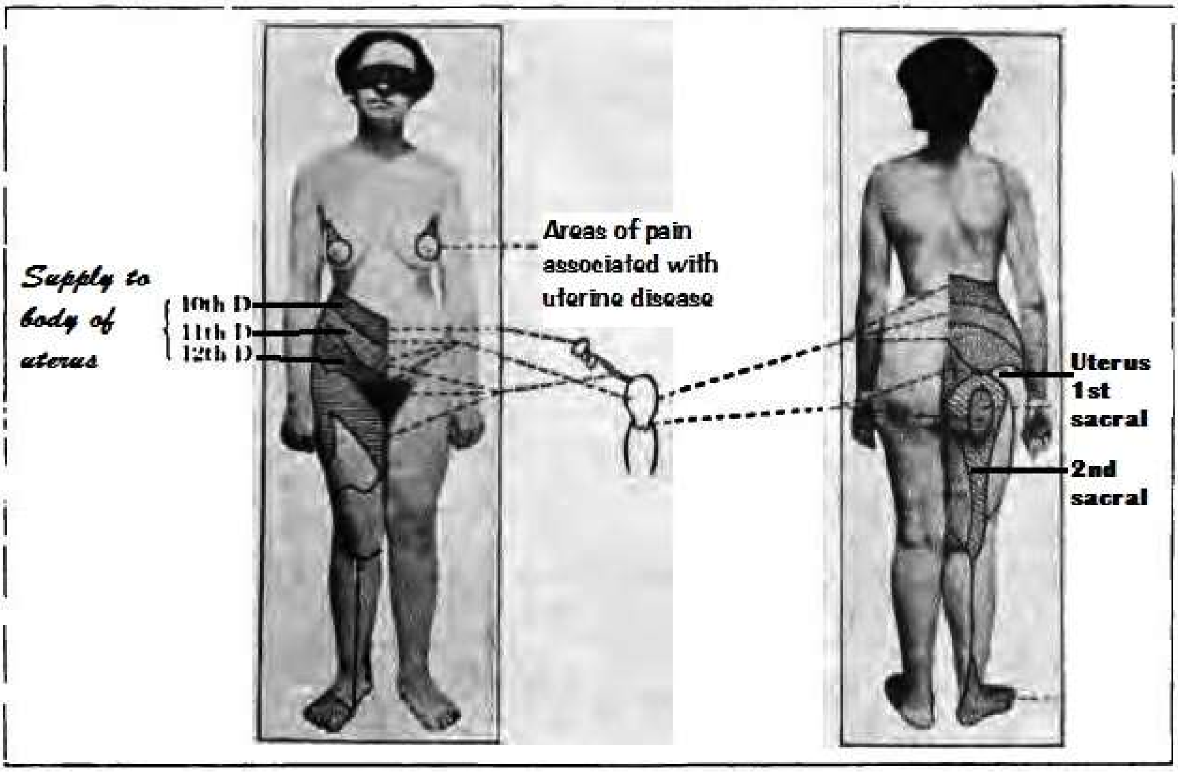

Figure 71. Areas of distribution of cord segments involved in uterine, ovarian and tubal diseases. The body of the uterus is supplied by the 10th, 11th, 12th, dorsal segments; the cervix by the 3rd and 4th lumbar and sometimes by the 1st and 2nd sacral; the ovary by the 10th, and the fallopian tubes by the 11th and 12th dorsal and the 1st lumbar segment (Behan)

There are several centres in the central nervous system from which the uterus may be influenced, one of them lies in the lumbar portion of the cord from which the sympathetic connector neurons, which supply the uterus, arise. It is in these areas of the cord that the uterus has its main reflex connection with the spinal nerves, particularly the ischiadictis and cruralis. The uterus is easily stimulated to contraction by ovarian irritation. The impulse which causes this reflex is probably carried to the cord through sensory fibers of the sympathetic connector neurons arising from the 9th, 10th and 11th thoracic segments, and transferred downward in the cord by association fibers to the lumbar segments. Some observers claim that the uterus receives its sympathetic supply from areas as high in the cord as the 10th thoracic. If so, reflexes which arise from it may take place in the same nerves as receive the afferent sensory impulse from the ovary.

Stimuli which cause reflex contraction of the uterus may be carried from any portion of the spinal cord according to some writers. Irritation of the mamma' and nipples exerts a strong uterine contraction. Stimulation of the central portion of the brachial plexus is also followed by uterine contraction according to Schlesinger.

In the medulla oblongata there is also a center which presides over uterine contraction. It is not impossible, as mentioned above, that this reflex act, like vomiting, may be reflexly precipitated through intercalated neurons between the sensory cell body in the lumbar portion of the cord and the center in the medulla.

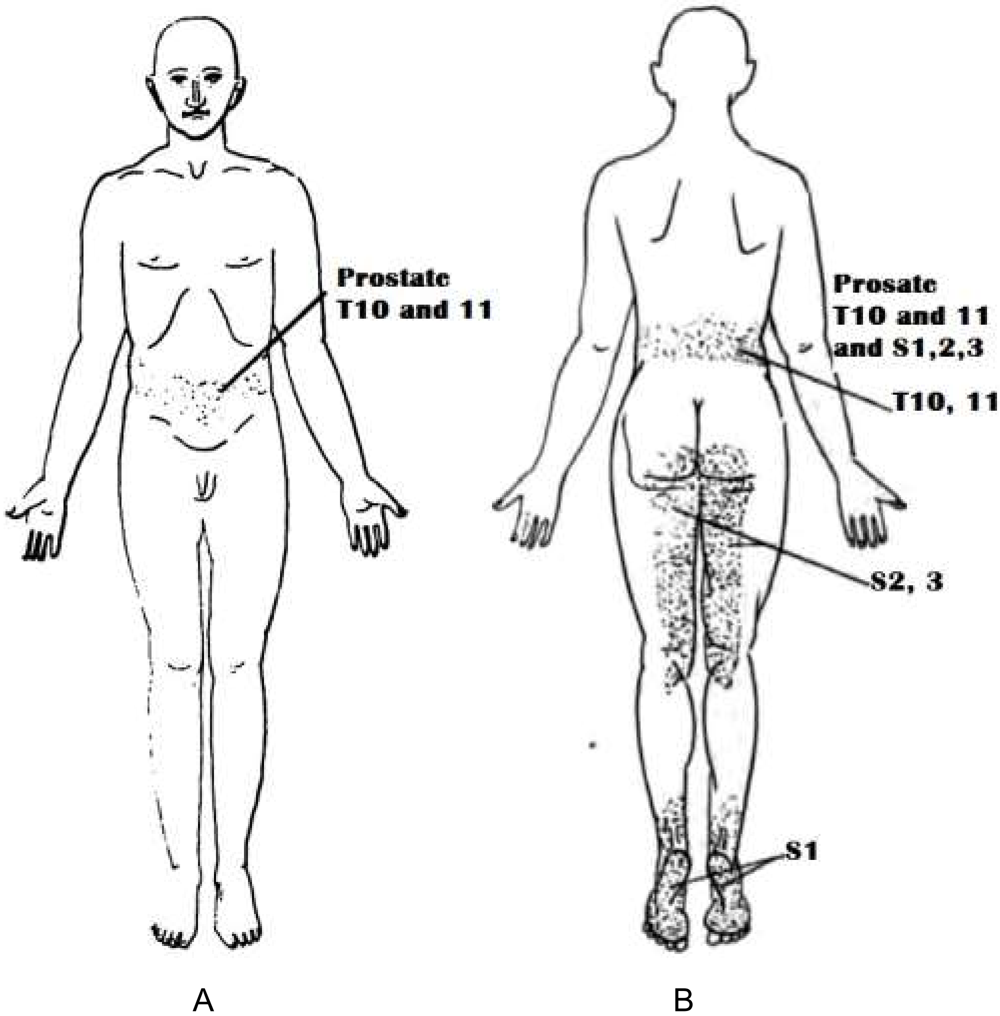

Figure 72. Illustrating area of pain in prostatic disease.
A – Anterior view. The prostate shows both a sympathetic and parasympathetic reflex. Pain anteriorly is entirely above the pubis and of sympathetic origin.
B – posterior view. Pain, posteriorly, expresses itself not only in the 10th and 11th thoracic segments, but also in the sacral segments of the region of the buttocks and the inner surface of the thigh.

2. Prostate. The prostate shows viscerosensory reflexes in which, according to Head, the afferent sensory impulses apparently travel centralward over both the sympathetics and parasympathetics; because the reflex pain originates in both thoracic and sacral spinal sensory nerves. It would seem that the sympathetic connector fibers going to the prostate should emerge from the upper lumbar segments, but the reflex is shown in the areas of the 10th and 111th thoracic. The parasympathetic reflex, through the pelvic nerve, expresses itself in sensory disturbances in the 1st, 2nd and 3rd sacral sensory zones. Pain may also be felt in the glans penis; and frequency of urination and discomfort in the rectum may be noted. These reflexes are readily understood because of the connection of the tissues with the pelvic nerve. The areas of pain which are most frequent in prostatic disease are shown in Fig 71 A and B and Fig. 72, page 185.

3. Penis. The penis is more often the subject of reflex sensation than the cause of it. It is closely bound to the urogenital and rectal structures by the filaments of the pelvic nerve, and is the seat of reflex sensory disturbances during inflammations of the kidney, ureter, bladder and prostate, and at times when the cloacal tissues are involved.

4. Bladder. The bladder having a double Innervation of spinal origin, one from the 2nd, 3rd and 4th lumbar segments — sympathetic; and one from the 3rd and 4th sacral segments — parasympathetic; has two routes over which afferent sensory impulses may travel to the cord to combine with sensory and motor neurons in the production of reflex action.

Visceromotor reflex. The bladder, when severely inflamed, at times produces spasm of the lower recti according to Mackenzie. Pain, however, is the chief and most characteristic reflex phenomenon.

Viscerosensory reflex — the pain from diseases of the bladder is reflected through both the sympathetic (2nd, 3rd and 4th lumbar) nerves, and the parasympathetic (2nd, 3rd and 4th sacral) nerves. The pain from the former is usually found in the areas near the pubis and is not marked, while that from the latter is found in the region of the perineum and penis and is very important. Fig. 65A and B shows the common location of reflex pain when the bladder is diseased. Fig. 22, page 185, should also be consulted.

The bladder is influenced reflexly by inflammation in such neigh- boring structures as the appendix, kidney. Fallopian tubes, uterus, ovary, prostate, and rectum.

5. The Ovary and Testicle. The ovary and the testicle are supplied by sympathetics whose connector neurons arise from the 9th and 10th, or 10th to 12th thoracic segments of the cord. The fact that their innervation comes from a higher plane in the cord than that of most of the genital organs is probably significant of the higher position that they occupy in the abdomen in foetal life. The reflexes for the ovary and testis manifest themselves in the structures above the pubis, the ovaries higher than the testes.

Motor Reflex. The visceromotor reflex from the ovary and testis is of little diagnostic aid. The lowest portion of the abdominal muscles shows rigidity at times when these organs are involved.

Sensory Reflex. The viscerosensory reflex from the ovary and testicle is of greater clinical importance. They produce their pain in the groin in the 10th to 12th thoracic sensory zones. This at times seems to radiate down the thigh, and the skin may become hyperalgesia. Fig. 71 illustrates the common position of pain in diseases of the testicle and ovary.

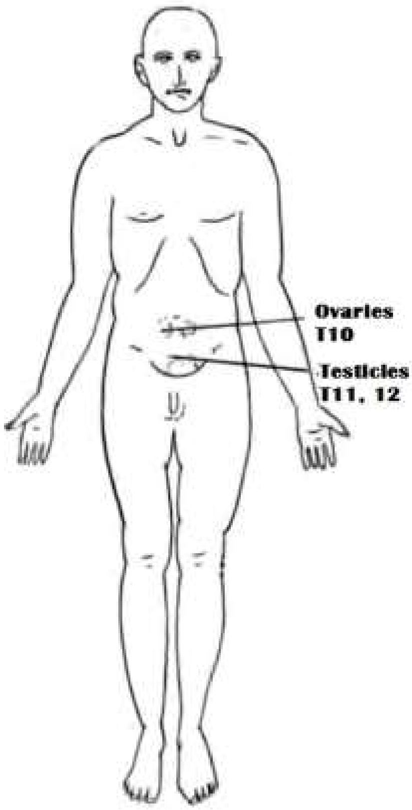

Figure 73. Common areas of pain when the testicles and ovaries are inflamed.
It will be noted that the pain from the ovary is higher than that of the testicle. Both express themselves near the median line.

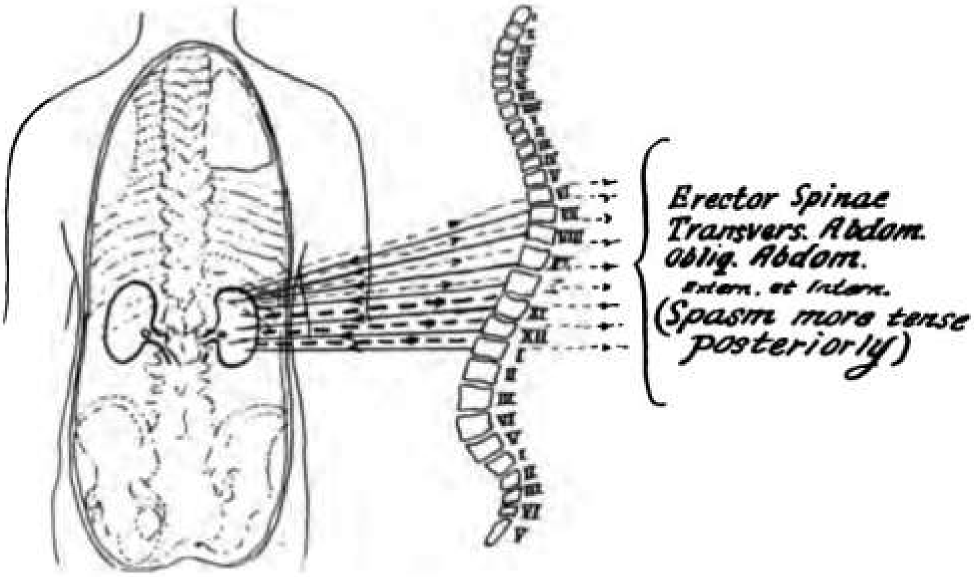

Figure 74. Renal visceromotor reflex. Lines connecting the kidney with segments of the cord from the 6th thoracic to the 1st lumbar segments represent sympathetic nerves. Solid lines represent the sympathetic nerves supplying the kidney. Broken lines the sensory sympathetic nerves which carry afferent impulses from the kidney to the cord. Broken lines on the other side of the cord represent corresponding spinal nerves which receive the sensory sympathetic nerves and transmit them to the muscles shown, producing the renal visceromotor reflex.

6. Kidney and Ureter. The kidney and ureter show both visceromotor and viscerosensory reflexes. The kidney receives its sympathetic innervation from the 6th thoracic to 1st lumbar segments. The chief source of nerve supply, however, comes from the lower thoracics, 11th and 12th and 1st lumbar, and it seems from clinical observation that the visceromotor and viscerosensory reflexes which occur when the renal tissue is involved, are produced from the nerves arising from these lower segments.

Renal Visceromotor Reflex. I described a spasm of the lumbar muscles which I noticed when the renal tissue is infiltrated by tuberculosis in 1912.[2] This reflex is present in inflammatory conditions of the kidney of nontuberculous as well as those of a tuberculous nature. In order to detect it, the patient should be seated on a stool with the feet resting on the floor, and the lumbar muscles relaxed as much as possible. Palpation will then reveal the increased tonus in those muscles which show the motor reflex. This increased muscle tonus is of great value in determining the condition of the other kidney before removing one because of tuberculous infection. This reflex is of great diagnostic value in all inflammatory processes affecting the kidney. This is a truly renal reflex and differs from that observed in so-called renal colic, which belongs to the ureter rather than to the kidney. As long as the stone remains in the pelvis of the kidney, neither muscle spasm nor pain are prominent but as soon as the stone is engaged in the ureter, both are present. Fig. 72 shows the muscles which are involved in the renal reflex.

Renal viscerosensory reflex. The renal viscerosensory reflex as a rule seems more like an ache than a pain. It often expresses itself in the back alone and may be felt in any sensory zone from the 6th thoracic to 1st lumbar. It is unlike that of the ureteral colic which usually extends from the lumbar region and the iliac fossa into the front of the abdomen and down into the scrotum. Fig. 73 A and B shows the common site of pain arising in the kidney.

Renal Viscerotrophic Reflex. The same muscles, skin and subcutaneous tissue, that show the motor and sensory reflex when the kidney is first inflamed, show degenerative changes when the disease becomes chronic. This degeneration of the lumbar muscles and subcutaneous tissue and skin covering them becomes an important diagnostic sign in tuberculosis or other chronic inflammation involving the renal tissue.

Ureteral Visceromotor Reflex. The abdominal, erector spinae and cremaster muscles become tense during an attack of renal colic. The fibers arising from the last thoracic and first lumbar spinal nerves are stimulated and cause those portions of the muscles which are supplied by them to contract. The probable explanation of the more extensive and more marked muscle spasm when the ureter, as compared with the renal tissue, is the seat of inflammation, is furnished by the fact that one is n simple inflammation of tissue while the other is an inflammation associated with a tonic spasm and dilatation of a muscle belonging to an inflamed hollow organ. The latter condition affords the maximum nerve irritation. Fig. 74 shows the muscles involved in the reflex from the ureter.

Ureteral Viscerosensory Reflex. The pain which accompanies renal colic is for the most part a ureteral pain. When the stone in the pelvis of the kidney first engages the ureteral orifice, there is a dull pain in the back which passes out over the iliac fossa toward the front of the abdomen and sometimes down over the anterior aspects of the thigh; and in the male passes down into the testicle as the calculus engages the walls of the ureter. This pain may be slight, or it may be one of the severest pains known. Sometimes the pain is accompanied by a marked hyperalgesia of the skin and muscles in the areas involved. Fig. 73 show the common areas of pain when the ureter is inflamed as in ureteral, so-called "renal colic”.

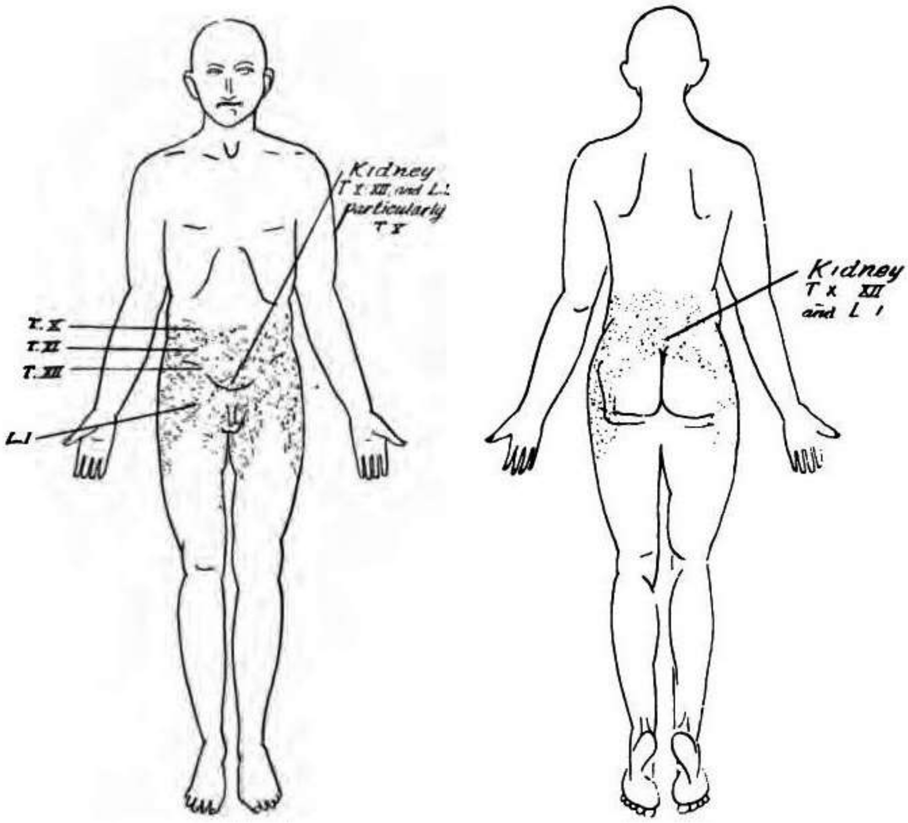

Figure 75. Renal viscerosensory reflex.
A – Anterior view. It will be noted that the pain might be expressed anywhere below the naval and on the inner and external portion of the thigh, including the scrotal area. The severest pain, however, is in the 10th thoracic zone, which lies immediately beneath the umbilicus.
B – posterior view. The pain may be expressed anywhere across the entire lumbar region and extending down the external portion of the thighs.

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Chapter XXVII

The Subdermal Musculature

I. The Pilomotor Nerves

The pilomotor muscles lie immediately under the skin and when contracted cause the hairs to rise. The motor cells which supply them are found in the grey rami which come from motor cells in the lateral ganglia. Each ganglion of the gangliated cord sends its grey rami to the corresponding spinal nerve and the fibers pass to the pilomotor muscles by way of its cutaneous branches. As the cutaneous sensory branches of the spinal nerves follow out the segmentation of the body in their distribution, so do the sympathetic fibers to the pilomotor muscles. The segmental distribution is not followed, however, by the connector neurons going to the lateral ganglia, tor they send off collateral brandies to ganglia other than the one corresponding to the segment of the cord from which they rise. A stimulation of the motor cells in a given ganglion of the gangliated cord will stimulate only the pilomotor muscles in the segment supplied by the sensory nerves arising from the corresponding spinal segment; but a stimulus applied to the connector fibre before it reaches the lateral ganglion, may through its collateral fibers stimulate several lateral ganglia and cause an erection of hairs in several spinal segments.

It is to Langley that we owe much of our knowledge of the sympathetic system. The following table worked out by him and quoted from Gaskell[1] shows the extent to which each connector fibre from the 4th thoracic to the 3rd lumbar through its collateral branches and lateral ganglia, influences sensory body segments through spinal sensory nerves. It will be noted that each spinal nerve is followed by several sympathetic ganglia, which send nonmedullated fibers to it. Each of these sympathetic ganglia sends, through its grey rami, fibers to its corresponding spinal nerve; so that stimulation of the connector fibers from one spinal segment often causes widespread pilomotor action.

Connection of the Spinal Nerves of the Cat from the 4th thoracic to the 3rd lumbar with those lateral ganglia of the sympathetic included between the ganglion stellatum and the coccygeal ganglia.

Spinal Nerve		Sympathetic Ganglia			
			Thoracic	Lumbar	Sacrum
Thoracic	4	Stellate Ganglion			
	5	Stellate Ganglion			
	6	Stellate Ganglion			
	7	Stellate Ganglion	4,5,6,7,8,9		
	8	Stellate Ganglion	4,5,6,7,8,9,10		
	9	Stellate Ganglion	4,5,6,7,8,9,10,11		
	10		8,9,10,11,12,13		
	11		12,13	1,2,3	
	12		13	1,2,3,4,5,6,7	1
	13			1,2,3,4,5,6,7	1
Lumbar	1			2,3,4,5,6,7	1,2
	2			3,4,5,6,7	1,2,3
	3			4,5,6,7	1,2,3. coc

Figure 76 Connection of spinal nerves with sympathetic ganglia

Not only do the pilomotor muscles of muscles which have hair belong to this system, but also the entire subdermal smooth musculature — that which moves the skin causing (goose flesh when contracted ; the smooth subdermal musculature around the anus and vagina; and the retractor penis muscle.

II. The Sweat Glands

The innervation of the sweat glands is a very puzzling subject for physiologists and clinicians to determine. Langley has shown definitely that secretion of sweat is produced by stimulation of the sympathetics. Gaskell says in speaking of the nerves of the sweat glands, that it has been conclusively shown." (1) that these nerves belong to the sympathetic system, and (2) that their connector fibres are in anterior roots."

The sweat glands are supplied by smooth muscles which when stimulated cause an expression of sweat, and Gaskell says that the action of these smooth muscles must be considered as a part of the secretion of sweat.

Pharmacologically, the secretion of sweat does not take place following the injection of adrenin. In this it differs from all other supposedly sympathetic actions. It is stopped by atropin which acts strongly upon the vagus secretory nerves', and is induced by pilocarpine which is distinctly vagotropic in action. In spite of this, Luciani[2] says: “But the experimental data adduced are ambiguous and do not prove the existence of a double order of nerves for the regulation of cutaneous secretion."

Clinically, we find sweating in toxic states, usually after the temperature has reached its maximum and is receding. It does not accompany the early vasoconstriction or the pilomotor stimulation which precedes chill or is present in the early stage of temperature rise. When vasodilatation is occurring, and heat is rapidly dissipating, sweating which accompanies such toxic states as those found in tuberculosis and malaria, ensues.

Sweating often accompanies severe fright, but is not so prone to occur in moderate degrees of fright. It comes in those conditions which we designate as neurasthenic or psychasthenic, whenever the nerve equilibrium is disturbed. Vagotonics are prone to it.

We also see it in severe pain, which acts strongly on the sympathetics. Abdominal conditions such as often follow rapid peristalsis are a<'companied at times by marked sweating. This could be through sympathetic connection with the spinal sensory nerves in the cord. Sweating, such as occurs in cases of asphyxia and in death agony, is due, most likely, to stimulation of nerve centres rather than peripheral irritation according to Luciani.

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Chapter XXVIII
Endocrine Glands

The present monograph is not intended to treat of the problems of endocrinology as they affect growth and development, hut is greatly concerned with those phases of the subject which particularly affect the vegetative nervous system.

Studies of visceral neurology and endocrinology are inseparable, as must be apparent from the fact that the vegetative nervous system and the endocrine glands furnish the two controls of all vegetative functions within the body. It is still further evident from the developmental relationship that exists between these two systems. The endocrine system, furnishing (he normal chemical control, is older; in fact, in lower life, it is the only control of activity in smooth musculature and secreting glands. As the living organism became more complex, however, a more rapid response in the correlation of vegetative activities became necessary and so the vegetative nervous system was evolved. Primarily all action and all inhibition of action was carried out by the chemical control (internal secretions) but later this was supplemented by the nervous control. So the endocrine and vegetative nervous systems are supplementary to each other. Any disturbance in the balance of the vegetative nerves unless compensated, causes a disturbed equilibrium in the endocrine system, and any uncompensated endocrine imbalance is reflected in the vegetative nerves.

While these facts may seem to be of greater importance in the discussion of general influences which affect the visceral nerves than in the study of visceral reflexes, yet it must be evident that reflexes depend to quite a degree upon the stability of the neurons which form the reflex, A patient with a hyperirritability of the sympathetic system will show sympathetic reflexes when the neurons of this system are acted upon by stimuli which would not cause action in the normal. The same is true with the parasympathetic system. Those parasympathetic reflexes which are usually recognized as "functional disturbances" are much more common and more serious m those of vagotonic disposition than in normals or in those who are sympathicotonia.

Overaction on the part of such sympathicotropic glands as the adrenals, and thyroid, must heighten sympathetic reflexes, while overaction on the part of such parasympathetic glands as the pancreas, and parathyroids increases parasympathetic reflexes.

In the near future many of the clinical problems which, at present, are beyond solution, will be simplified by a better understanding of the normal and pathologic physiology of the vegetative nerves and the endocrine glands.

It is of the greatest importance to the study of the function of tissues to understand them in their phylogenetic and embryologic relationship. Jelliffe and White[1] thus classify the endocrine glands:

1. Those derived from the buccal cavity
    a. Thyroid (phylogenetically gonadal)
    b. Pituitary (Posterior lobe of hypophysis)
2. Those from nervous tissue
    a. Hypophysis (anterior lobe)
    b. Chromaffin Tissue (adrenal)
3. Those from branchial arches
    a. Parathyroids
    b. Thymus
4. Those from intestine

   a. Parathyroids
   b. Mucosa from the intestines
5. Those form the mesothelium of the genital ridge
   a. Gonads (sex glands)
   b. Interrenal bodies

Certain endocrine glands stimulate the sympathetics, others the parasympathetics. Certain glands, on the other hand, are stimulated by the sympathetics and others by the parasympathetics.

Unfortunately we know little of the innervation of the endocrine glands aside from that of the thyroid, adrenals, pancreas, testicle and ovary, and the glands of the intestinal mucous membrane. The testicle and ovary have been discussed with relation to their ability to produce reflexes in Chapter XXVI; the intestinal mucosa in Chapter XII; the pancreas in Chapter XIV; and there remains yet the thyroid and adrenal to be considered among the structures which properly come in for our consideration.

I. Innervation of the Thyroid Gland

The thyroid gland is of special interest to students of endocrinology because we are familiar in our clinical experience with conditions which represent both a hypoactivity and hyperactivity of the gland.

While this gland has no excretory duct, yet it has secreting cells and furnishes to the venous blood which leaves it, substances which are essential to the life and growth of the individual. The gland is one of an important group whose function we imperfectly understand, but which has the power of producing a substance or substances which influence other glands and other structures in the parts of the body which are not in direct nerve connection with it. Since all nerve control in vegetative structures is either that of activation or inhibition, whether manifested in secretory, motor or sensory phenomena ; and, since Gaskell authoritatively says that he cannot conceive of a single muscle being activated except by nerve action, we must assume that the secretion of all endocrine glands acts through nerves centrally or on the structures innervated by them peripherally (as in the case with adrenalin) producing actions which are identical with nerve stimulation. Therefore, we are probably warranted in assuming that the secretion of an endocrine gland acts with and reinforces one or the other division of the vegetative nervous system in its action on the smooth muscles and glandular structures of the body, and that wherever it seems to depart from this rule it is only for the purpose of maintaining a normal equilibrium of action. Thus while the secretion of the thyroid g3and seems at times to show a preference for stimulating the parasympathetics, it at the same time is classed among the sympatheticotropic group of glands and stimulates the adrenals which produce the sympathicotropic adrenin.

It has recently been taught that the secretion from the thyroid acts by sensitizing nerve cells generally, but particularly the sympathetics. Plummer believes that the chief action of thyroxin as isolated from the thyroid gland by Kendall, is upon the tissue cells where it acts as a catalytic agent and controls their energy output. The work of these investigators disproves the theory, which is generally held, that the secretion of the thyroid is wholly dependent upon iodine for its action. They show that iodine is not even essential to the action of thyroxin but only (but it acts better in its presence. According to Plummer's views the varied effects upon the nervous system noted in hyperthyroidism are accompanying manifestations, and do not represent the primary effect of the thyroid substance upon the tissues.

The thyroid gland is supplied by both sympathetics and para-sympathetics.

Sympathetic. The sympathetic supply of the thyroid conies from the three cervical ganglia, the connector fibers arising in the upper thoracic segments of the cord. The sympathetic fibers not only supply the blood vessels but also go to the secreting cells which they activate. Stimulation of the sympathetics causes an increased secretion on the part of the glandular structures of the thyroid. This has been proved by Cannon and Cattell,'

Parasympathetic. The parasympathetic nerves arise from the superior and inferior laryngeals and a branch from the main vagus nerve. Stimulation of the vagus fails to produce secretion. We are probably justified in assuming that they oppose the action of the sympathetics because the glandular portion of the thyroid arises from the hypoblast of the pharyngeal structures in which such antagonistic nerve action is evident; yet, Cannon failed in "obtaining any evidence of any influence of vagus impulse on the thyroid gland," and further states that the interpretation of ten experiments "proves that the vagus has been neither an excitor nor an inhibitor of thyroid activity."

II. Innervation of the Adrenals

Sympathetics. The adrenals consist of two portions, the cortex and the medulla. In some of the lower forms of life these portions are two distinct organs. In man, however, the}' are combined in one. The cortical substance is formed from the Wolffian duct, while the medulla is derived from the phaeochromoblasts, one of the two groups of embryonic cells into which the primary sympathetic cells which migrate from the central nervous system become differentiated. Therefore, the medullary portion is derived from the nervous system and must be looked upon as being a tissue very closely related to the motor cells of the sympathetic ganglia. In fact, cells of the medulla are connected directly with the cord by medullated connector fibers, which pass from the 5^{th} to the 9^{th} thoracic segments of the cord through the lateral and the semilunar ganglia without meeting their sympathetic motor ceils until the chromaffin cells of the medulla are attained. In this the cells of the medulla have the same function as motor cells in sympathetic ganglia. This direct innervation of the chromaffin cells in the adrenal medulla, without the intervention of a sympathetic ganglion is shown schematically in Fig. 71.

Stimulation of the splanchnics activates the chromaffin cells of the adrenal gland and causes them to secrete adrenin, a product which enters the blood stream and acts peripherally (either on the ganglion cells or at the myoneural junction) on all structures supplied by the sympathetic nerves, except the sweat glands. It produces and prolongs the same action as results from sympathetic stimulation. Adrenin also stimulates the thyroid gland to secretory activity and inhibits the internal secretion of the pancreas.

Parasympathetics. Parasympathetic fibers from the vagus also supply the adrenals, but have no part in the production of adrenin,

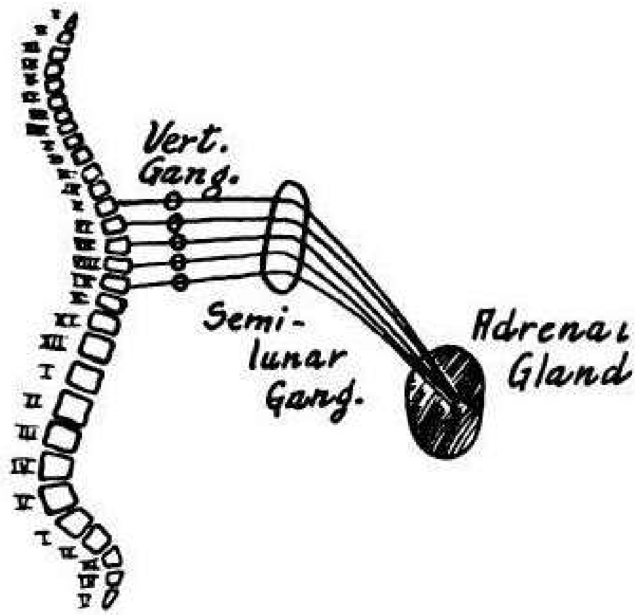

Figure 77. Showing the direct connection of chromaffin cells to the adrenal medulla. The connector neurons pass through the vertebral ganglia and the semilunar ganglia and do not meet their motor cells until they reach the adrenal medulla of the adrenal body itself.

The Endocrine System: Clinical Consideration

It would carry mc far afield to enter into a discussion of the relationship of the thyroid gland and adrenal bodies to clinical medicine. While these important organs exert a tremendous influence upon the physiologic activity of the organism, at least under pathologic conditions, and have an important bearing upon the subject of visceral action, yet they rightly come in for discussion in this monograph only to the extent that they are able to produce reflexes in other organs and be influenced reflexly from other organs, and to the extent that they activate and are activated by stimulation of the visceral nerves.

While I am referring only to the thyroid and the adrenals, it is not because the remaining members of the endocrine group are not of great importance, but rather because of the paucity of our knowledge of their nerve control. We know that the thyroid and the adrenals are activated by stimulation of the sympathetic nerves, the former through the cervical sympathetics, and the latter through the splanchnics. We further infer from experimental observation that the testicle secretes a substance which acts upon the sympathetic nerves; and from clinical observation that the ripening of the Graafian follicle preparatory to menstruation is accompanied by an increase of sympathicotropic substances, as is shown by the rapid heart and slight elevation of temperature. This is further strengthened by the fact that the menopause which comes on with the cessation of ovulation and the ovarian secretion, is accompanied by general symptoms as well as symptoms throughout the enteral system, in which parasympathetic irritability is heightened. It seems that the adrenals, thyroid, genital glands, and hypophysis are closely related to sympathetic stimulation; while the pancreas, thymus and the glands of an epithelial nature, which produce internal secretions, are related to the parasympathetics.

The major emotions, as shown by Cannon and Crile, stimulate the sympathetic nerves; so do toxins as pointed out by the writer. These emotional and toxic states are followed by increased activity in both the thyroid and the adrenals. The activity is further followed by a hastened metabolism.

The Thyroid. Increased stimulation of the thyroid produces a hypersecretion of the active substances of this gland (thyroxin, Kendall); and a general disturbance in the metabolic equilibrium of the patient of the nature of an increased energy output results. The analysis of the symptoms which result from a hyperthyroidism offers one of the most interesting studies in visceral disease, because it requires an analysis from every phase of body control, nerve, chemical and psychic. No matter what the final clinical picture of hyperthyroidism, the cause is a stimulation which must conic from some reciprocally acting internal secretion, such as adrenin ; some other chemical products; or through stimulation of the cervical sympathetics. The latter might be a part of a general sympathetic stimulation such as occurs in states depending upon the major emotions or the action of toxins.

There are no definitely recognizable reflex symptoms either of sympathetic or parasympathetic origin which arise from the thyroid gland. There is a pathologic change which occurs in the cervical sympathetic ganglia when the patient suffers from toxic goitre. This has been recently described by Wilson[3] and Wilson and Durante.[4] In our analysis of the symptoms of exophthalmic goitre, in a recent paper, the writer discussed the possibility of the symptoms on the part of the heart and exophthalmos being a reflex from the thyroid gland through the sympathetics, the reflex being mediated in the cervical ganglia. While I realize that the weight of physiologic evidence is against this occurring, there are certain authors who believe it possible as described on page 233 et seq. and I consider it worthy of mention at least.

Plummer's idea of thyroxin acting as a catalytic agent upon tissue cells and controlling energy output does not necessarily combat the idea of the thyroid sensitizing the cells of the sympathetic system. It may do both. We know it produces a sympathicotropic substance; and we further know that sympathetic stimulation favours energy output as is seen in fear and the preparation for flight or defence.

The Adrenals. Adrenin probably has no influence upon the body economy during normal states. The adrenin producing cells probably exert much the same influence upon the physiologic economy during normal life as the sympathetic ganglion ceils to which they are embryonically related. This has been pointed out by Swale Vincent, Hoskins and Stewart; but when conditions arise which stimulate the splanchnics, then the chromaffin cells and the medulla of the adrenals partake of the stimulation and produce adrenin. This being thrown into the blood stream, circulates and acts upon sympathetically innervated structures and exerts the same influence as though the sympathetic nerves were centrally stimulated. Adrenin is not normally in control of blood pressure as has been generally believed; but in times of stress produces a varying influence according to the degree of stimulation.

Adrenin does not act with equal force upon blood vessels in all structures. Its action also differs according to the dosage. Small doses of adrenin cause vasoconstriction in the vessels of the skin, mucous membranes and abdominal organs, and drive the blood into the vessels supplying the skeletal muscles which are dilated. In larger amounts the splanchnic vessels dilate as is shown in the quotation from Hartman, page 163

Adrenin and thyroidin are reciprocal substances, as shown by Hoskins. One gland cannot be activated without the other, for their secretions are reciprocally stimulating. Likewise, adrenin and the internal secretions of the pancreas; and thyroid secretion and the internal secretion of the pancreas exert a reciprocally antagonistic action.

It would be extremely interesting to discuss other endocrine problems in their relationship to the visceral nerves such as: the influence of splenic extract in activating the pancreatic ferment; the sugar regulating secretion of the pancreas; the antithrombin action of the liver secretion; the tetanizing hormone produced by the thymus and corrected by the parathyroids;" and the many problems presented by the hypophysis, and sex glands; but these sub- jects are foreign to our theme.

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Part III
The Vegetative System
Chapter XXIX
The Vegetative Nervous System: General Consideration

In writing the following chapters I have been compelled to rely entirely on the works of others. Frequent reference will be made to these various authors, but exact citations will only be given where they are quoted literally. My material has been drawn from such works as those of Gaskell,[1] Langley,[2] Sherrington,' Lucas,* Bechterew," Lewandowsky,* Higier,' Jelliffe and White," Starling," Bayliss,'" Luciani,[3] Tigerstedt,[4] Eppinger and Hess,[5] Cannon,[6] Keith,[7] Bailey and Miller,[8] Biedl,[9] Falta,[10] Paton,[11] and Gley.[12]

My only hope is that I may be able to present to the clinician the important facts of vegetative neurology- in such a manner that they may be understood and applied in the everyday practice of medicine.

Control of Protoplasmic Activities. A study of body activity resolves itself lately into a study of nerve control. The nerves of the body are divided according to their particular function, into motor and sensory. These are further subdivided according to the control exercised over them by the will, into voluntary and involuntary. The stimulation of a nerve brings about action. This action, through motor nerves, may result in the contraction of muscles, an increased secretory activity, or an inhibition of these; and activity of a sensory nerve may result in some form of sensation or an impulse which starts reflex action. Wherever a muscle comes intimately in contact with the outside world, it is innervated by voluntary nerves. Such control seems necessary for the protection of the orgaiii.sm.

The voluntary system consists of some of the cranial nerves and the spinal nerves. These nerves supply muscles which are under the direct control of the will; and because of this they are spoken of as voluntary muscles. The voluntary muscles consist of those belonging to the skeletal or somatic system. They differ from those belonging to the involuntary or vegetative system in being striated.

While the power to net in the skeletal muscles is given them by nerves that belong to the voluntary nervous system, at the same time the metabolism of these structures is presided over by the vegetative system, the same as it is in all other structures of the body. All internal viscera and the vascular system of the entire body, including that of the skeletal structures, are innervated by the vegetative or in- voluntary nerves. From this the importance of the vegetative nervous system to the physiologic activities of life is evident.

The phenomena of life are manifestations of activity in a colloid system which is controlled by chemical and nerve force. Child" states that: "Protoplasm, instead of being a peculiar living substance with a peculiar complex morphological structure necessary for life, is on the one hand a colloid product of the chemical reactions, and on the other a substance in which the reactions occur and which influences their course and character both physically and chemically."

Protoplasmic activity under physiologic and pathologic conditions is the subject under investigation in scientific medicine. Not only the activity in cell but the correlation of activity in all cells must he considered, if we would understand body activities. This leads to the study of that particular part of the nervous system — the vegetative — through which processes necessary to life and tissue change, or metabolism is controlled.

Noel Paton[22] calls the forces which act in embryonic life "Hereditary Inertia" or "Inherited Developmental Tendencies." He assumes that these unknown and uncomprehend tendencies are working to shape a definite form and determined action prior to the appearance of the regulating forces which later control the organism. Later in the period of growth they become less important in their control and are replaced by definite forces, nerve and chemical, which act because of, and are subject to change by, conditions which are partly under the control and partly beyond the control of the individual's will.

While, as just mentioned, the control of body activities is largely nervous. Yet there are chemical substances in the form of internal secretion which normally alter this control. As yet, physiologists have not definitely determined whether all chemical control acts through the nervous system, or whether some of it is entirely independent of nerve action. Some authors speak of the chemical control as though it were a definite independent control of body activities. At the same time, students should bear in mind that the chemical substances which are formed in the body and which control activities, either act through the nerves, or with the nerves, in such a close relationship that it is impossible as ^'et to separate the activity of the two.

Stimuli may be either physical or psychic in origin. Psychic conditions affect body activities through both the nervous system and the products of internal secretion in much the same manner as sensory stimuli which arise in physical structures. The importance of this fact has not yet been sufficiently appreciated by practitioners of medicine; yet every practitioner has seen the equilibrium of the nervous system as thoroughly disturbed from psychic as from physical causes. I have referred to this subject briefly in Chapter IX: but since it is so intimately connected with activities of the vegetative nerves and their influence on protoplasmic activity, I deem it best to discuss the subject more fully at this time.

Chemical Control of Body Activities. With our newer study of physiology, we are learning that there are many substances circulating in the body fluids which have to do with metabolic activity. Some of these are the products of physiologic action, others are the products of pathologic action. Some influence the body favourably, and when provided in normal quantities keep up normal physiologic activity, and produce harmful effects only when produced in pathologic quantities; others influence it in a harmful way and produce functional disturbances even if present only in small amounts. We now know that the so-called "ductless glands" have a very important physiologic function. They produce so-called "internal secretions" which influence many body activities and have a marked effect upon growth and repair.

Aside from the so-called "ductless glands," many other glands, such as those of the gastrointestinal mucosa, the liver and the pancreas, produce internal secretions which exert an influence upon physiologic activity. In fact, we may not be far from the truth if we state that probably every tissue of the body produces an internal secretion or chemical substance which has some physiologic action. Pathologic chemical action which results from substances being thrown into the circulation when tissues are injured is also extremely common in disease conditions.

The higher organisms are complex structures made up of many independent cells. In order to bring the whole to any degree of efficiency, it is necessary that the action of these cells be correlated. This is brought about through chemical substances and the nervous system. The chemical control is a much slower, and a much less efficient control than that produced by the nervous system. It is slower in action. Although it cannot produce a quick response, yet its action is extremely definite. This may be illustrated by secretin (Bayliss and Starling), a substance which is produced by the duodenal glands when stimulated by the acid contents of the stomach. Secretin passes into the circulation, and, circulating through the body, comes in contact with cells of the pancreas and increases the flow of pancreatic juice. It also has a lesser effect upon the cells of the liver, producing a flow of bile. The marvellous part of this action is its selectivity, as emphasized by the fact that secretin must pass through the liver, right heart, lungs, left heart, and then the systemic structures it must pass through practically ail structures of the body, — but stimulates only the pancreatic and liver cells. Thus bile and pancreatic juice, two substances which are necessary to further digestion, are stimulated by a secretion which is brought about by the acid when poured into the duodenum. Secretin will produce the flow of pancreatic juice when all the connector neurons going to the pancreas are severed. This does not necessarily mean that the action is independent of nerves, for it may act upon the parasympathetic cells in the organ.

One of our best known internal secretions is adrenin. This is a chemical substance which is produced by the chromaffin tissue found in the medulla of the adrenals. It passes into the blood stream, circulates with it and stimulates most of the structures which react to central stimulation of the sympathetic nerves. Adrenin acts peripherally at the junction of the sympathetic filament and the muscle cell or in the lateral or collateral ganglia as shown by Hartman, page 163. When adrenin is thrown into the blood stream, it produces the effect on structures on which it acts as though the sympathetic nerves were centrally stimulated. According to Swale

Vincent, Hoskins and Stewart,[23] adrenin is not found in the circulating blood in normal states of health.

There has been much discussion regarding the secretion from the thyroid. Thyroxin as isolated by Kendall acts, according to Plummer, as a catalytic agent upon the tissue cells and controls their energy output. This is a different action from that which has generally been accepted in recent times, in which it has been considered as a substance which sensitizes nerve cells so as to make them more sensitive to stimuli. Hypophysin is thought to act more peripherally than adrenin. An illustration of a chemical substance which results from general body activity is that of CO_2, which is a product of all tissue activity. It acts on the respiratory center in the medulla; and the frequency and depth of respiratory effort is automatically governed by it. See Chapter XXVIII for further discussion.

Nerve Control of Body Activities. While a slow coordination of body activity such as that maintained by the "internal secretions," may be carried on by chemical substances circulating in the blood, yet, if a quick response and a rapid correlation is required, that must be brought about more directly. Such action is brought about through the nervous system.

In nerve action there is a difference between the voluntary system and the vegetative system. In the voluntary system the response is almost immediate. In the vegetative system it is somewhat delayed. In all cases where a quick response is necessary, nerve conduction must be provided. Acts of defence, such as closing the eyelids at the approach of dust, drawing the hand away from the fire, the contraction of muscles for escape from danger, all depend upon rapid eon-elation of action. The rapidity with which such action is produced may be illustrated by the muscle response which is necessary in order to remove the foot from a harmful stimulation. Within a very small fraction of a second, a stimulus arising from an injury applied to the toe may be carried through the sensory nerves to the cells in the ganglion on the posterior root of the lower spinal nerves, thence be conducted through other fibers to the thalamus, and then by another neuron to the sensory cortical area. By a complicated route it is transferred from the cortical sensory area to the cortical motor area. An act of will results. The impulse is sent out over a fibre to the motor cells in the spinal nerves, which send fibers to the muscles of the leg, and the leg is withdrawn. The control of the internal viscera is through reflexes brought about by sensory stimuli which are not necessarily transferred to the sensory areas in the cortex. While the path of the reflex is often shorter, the response is not as rapid.

In the voluntary system, action and inhibition of action are performed through the will, nerves supplying different sets of muscles coming into play. In the vegetative (involuntary) system, on the other hand, there are two methods by which action and inhibition of action are produced. Ono is through a single system of nerves in which the excitability varies according to the strength of the stimulus applied; the other is through two opposing sets of neurons, the one belonging to the sympathetic, the other to the parasympathetic system. When the same tissues are supplied by both sets of nerves, one activates and the other inhibits action. The pilomotor muscles and the blood vessels for the most part are controlled by the sympathetic nerves only, and relaxation and contraction depend on the decree of the stimulus. In all structures belonging to the enteral system except the oesophagus and the cardiac end of the stomach (lungs, pyloric end of stomach, small intestines, colon, liver, pancreas, and body of the bladder) equilibrium is maintained by the excitability of the cells of the sympathetics and parasympathetics, equalling or approaching each other; equilibrium is destroyed, producing functional derangement, when one overbalances the other.

There are a few structures in the body for which an active control has not been established, but it is probable that more complete study will show that these also are under nerve control. Gaskell says that he cannot conceive of a muscle without a motor nerve.

At the beginning and end of the intestinal tract there are some structures which have a combination of voluntary and involuntary nerve control.

Psychic Influence on Body Activities. One of the features in which man differs from other animals is in the development of the faculty of reasoning. The psychic side, by which he is able to perceive, enjoy, hope and desire, is able to greatly affect and modify both nerve impulses and chemical secretions; consequently, the psychic state of the individual assumes great importance in the human being. Its impress upon the physical body is made for the most part through the nervous system, and will he referred to from time to time in that connection. Its effect upon the physiologic activity of the organism through altered secretion of the endocrine glands is also well recognized.

Significance of the Nervous System. Each body cell has its own action and each organ its own function. If each cell or organ should functionate without regard to the other cells or organs, it would be equivalent to all citizens of a state living and acting without regard to others. A state of anarchy would result. Harmonious activity can only come through correlation of action. In the animal organism this correlation is brought about partly through chemical substances but mainly through the nervous system, as previously mentioned. Through it the action of every cell is subordinated to the good of the whole.

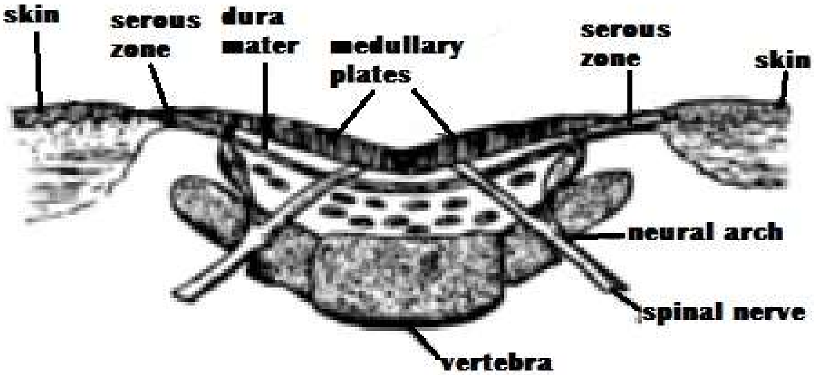

Figure 78. Diagrammatic section across the back of an anencephalic child. Here the medullary plates were exposed on both head and spine (Keith)

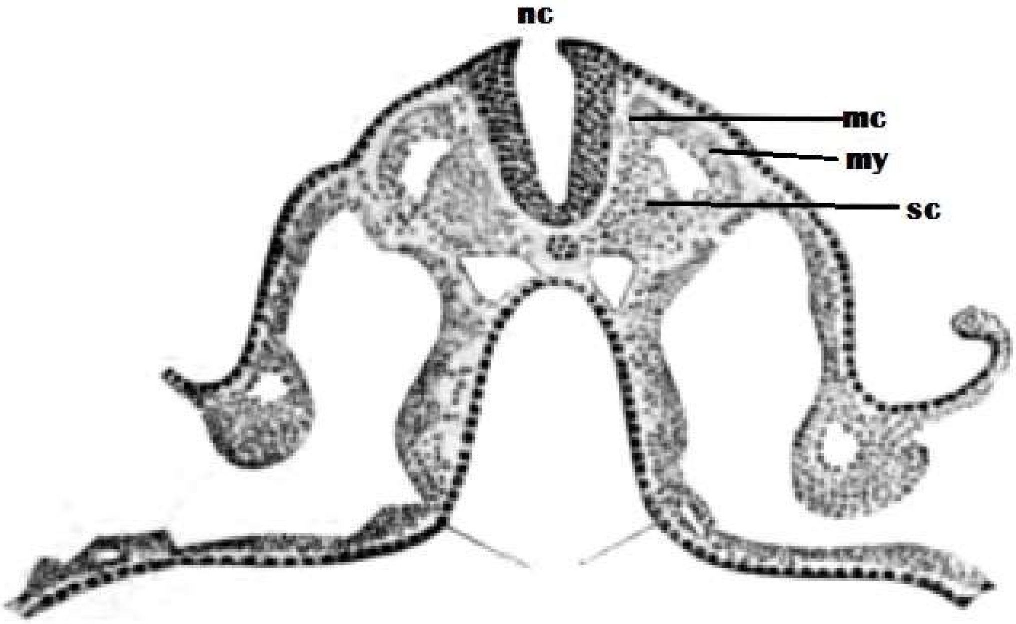

Figure 79. Transverse section of human embryo at 2.4.mm. This shows the developing neural canal (T.H Brice from Starling); nc – neural canal; mc – muscle plate; my – outer wall of somite; sc – sclerotome

The central nervous system in its development is closely related to the surface of the body. This is exceptionally well shown in Fig. 78 from Keith, which represents a diagrammatic section across the back of an anencephalic child, in which the medullary plates were exposed on both head and spine. From this illustration the relationship of the medullary plates to the skin is evident and appear as modified parts of the ectoderm. The formation of the neural canal of the human embryo is well illustrated in Fig. 79, in which the infolding of the ectoderm is shown. Fig. 80 from Keith, shows diagrammatically the differentiation of the ectodermal cells of the medullary plates into nerve cells or neuroblasts and supporting cells or spongioblasts: and further gives a clear idea of the development of the various cell components of the cord.

In order that the organism may live and multiply, it must be endowed with means for preserving its life. This function becomes more important and more difficult as evolution proceeds. It is in connection with this function of self-preservation that the central nervous system has developed.

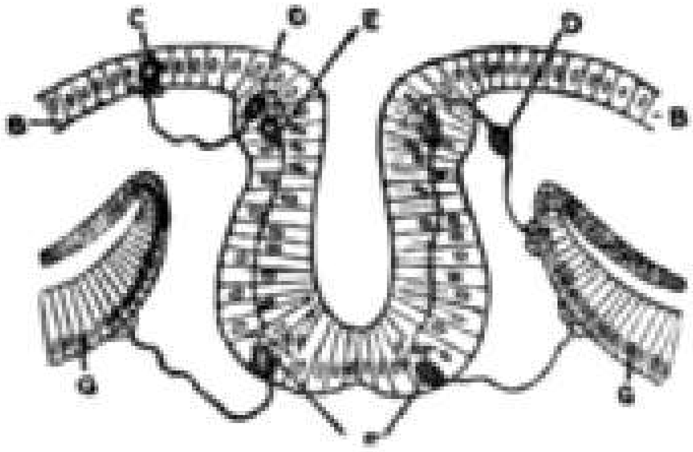

Figure 80. Diagram to show how the ectodermal cells of the medullary plates are differentiated into nerves cells or neuroblasts and supporting cells or spongioblasts. The central canal os being encircled by an upgrowth of the medullary plates. B, B. – ectoderm; C – sensory cell in ectoderm; D, D. – cells which become encircled in posterior root ganglion; E, E. – nerve cells which connect the sensory and motor cells; F, F. – motor cells in the anterior horn; G, G. – muscle plates (Keith)

If one would form an idea of what is going on within the body, he must know something of his nervous system. The normal body is continuously adapting itself to its environment. The environment contains many hostile elements: but through various methods of defence which have been devised, deleterious influences are quickly - perceived and a proper method of rendering them harmless is instituted.

The animal learns of harmful influences through its senses: sight, hearing, smell, taste, and touch. Aside from the organs of special of sense, sensory nerves are distributed to every portion of the surface of the body and also to all internal tissues. Impulses which come to the organism through the sensory nerves are translated into action; so a second group of nerves is necessary, which are known as motor nerves. The impulse of the sensory nerve is not always transmitted directly to the motor nerve, but must pass through other connecting fibers before it reaches the motor nerve. In the voluntarily nervous system these impulses must be carried up to the higher centres in order to call the will into judgment before action results.

The vegetative system comprises both motor and sensory nerves. Unlike the voluntary system, the sensory neurons of the vegetative system possess the power of expressing pain only to a slight degree. (Mackenzie says, not at all.) They transmit sensory impulses, however, and join with sensory spinal nerves to form reflexes, causing them to express the pain on the surface of the body. This is dis- cussed more fully in Chapter VI,

The life of the individual is largely determined by sensory stimuli received and the correlation of the action which results from them.

The actions of the body may be divided into those which are absolutely essential to life, and those which are not. Those essential to life must be carried on continuously without interruption, the others may be interrupted without harm resulting.

The essential difference in these two classes of action calls for a difference in the type of nerve control, the one under the will, the other independent of it.

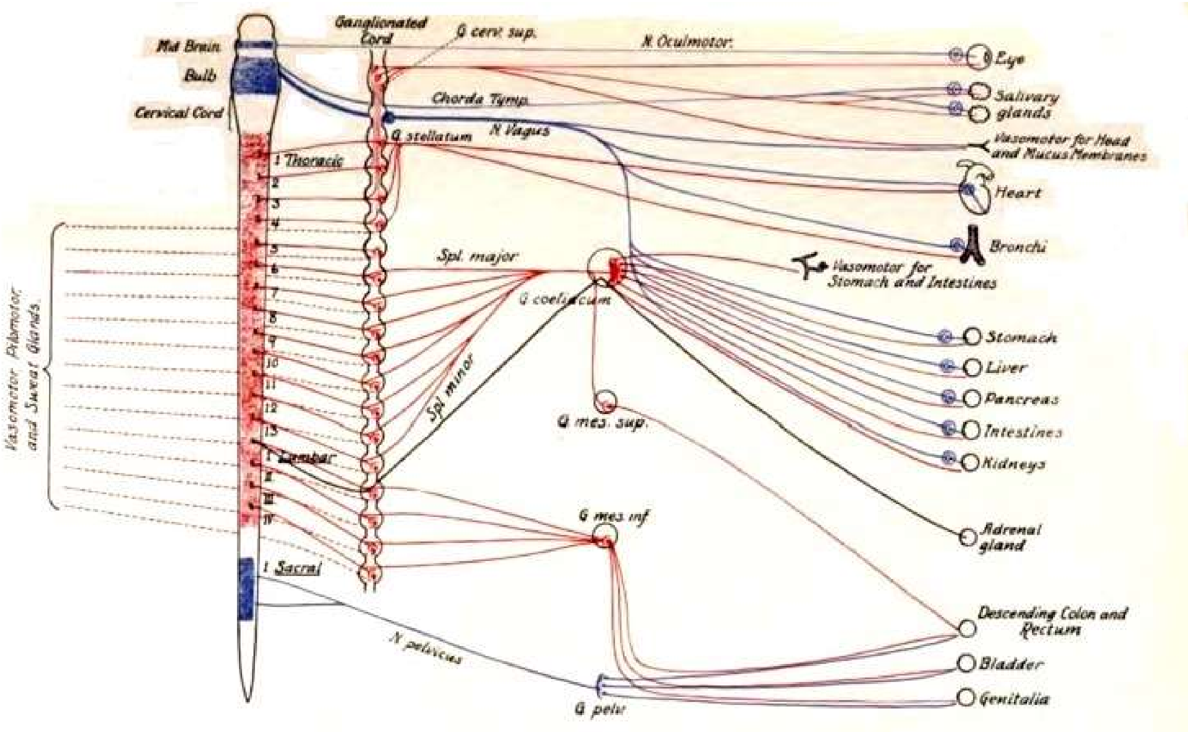

Figure 81. Plate VII Diagrammatic illustration of autonomic nerve distribution

Significance of the Vegetative Nervous System. As previously mentioned, the acts which are essential to life are carried out independently of the will. Under all ordinary circumstances the human machine is so regulated by its neurons and its centres presiding over essential functions that, whether awake or asleep, these functions are carried on in such a manner that life is maintained and the purpose of the individual is carried out. The scheme of the vegetative or involuntary nervous system is shown in Plates I and VII.

The vegetative system presides over all smooth muscles of the body and all secreting glands. The parts supplied by it are:

1. Certain subdermal structures; the pilomotor muscles and muscles of the sweat glands, possibly the glands themselves,

2. The heart and blood vessels.

3. The gastrointestinal tract, with the liver and pancreas.

4. The upper and lower respiratory tract.

5. The genitourinary tract.

6. Certain parts of the eye {pupil, ciliary body, Müllerian muscle, and lachrymal glands).

7. All other smooth muscles and secretory glands of the body.

The vegetative nervous system consists of three distinct groups of neurons, one with its origin in the midbrain and bulb; one in the thoracic and upper lumbar segments of the cord; and a third in the sacral segments of the cord, as shown in Plates I and VII.

From these three groups of neurons, all of the unstriped muscle, the heart and all the secretory glands of the body, receive their motor power. As will appear from our later discussion, the neurons which take their origin from the thoracic and upper lumbar portions of the cord (sympathetics) are opposed in their action in all structures and organs supplied by both divisions of the vegetative system, by the neurons which take origin from either the midbrain, bulb or sacral portion of the cord (parasympathetics) and vice versa. One group is the activator, the other the inhibitor. There are some structures, such as the pilomotor muscles, most of the blood vessels, and the structures derived wholly from the Müllerian and Wolffian ducts; viz.. Fallopian tubes, uterus, vagina, vas deferens, seminal vesicles and ureter, which are supplied by filaments from only one division, the sympathetics; likewise the cardiac end of the stomach, the oesophagus and the ciliary muscle seem to be innervated wholly by the parasympathetics. It is well to make clear the nerve action in each of these groups.

As will be made plain as our discussion proceeds, there is a very close relationship between the sympathetic system and the chromaffin system of the lower vertebrates and invertebrates. Unstriated muscles which arc brought into activity by stimulation of the sympathetic neurons, with a few exceptions, are also activated by adrenin. This unstriated musculature consists largely of the musculature of the walls of the blood vessels and that lying immediately under the skill. A musculature related to the dermal musculature forms the sphincter system and the musculature of the genitourinary tract. From this fact Gaskell suggests that the name "vasodermal" would be more appropriate than "sympathetic" for this system of nerves.

The dermal muscles supplied by the sympathetic are:

1. The pilomotor muscles and muscles of the sweat glands.

2. The urogenitodermal system, which includes all the involuntary muscles which originally surrounded the "Wolffian and Müllerian ducts.

3. The alimentary canal system of involuntary fibers which go to make up the sphincters of the gut, which probably according to Gaskell arc of dermal origin.

Whether the involuntary musculature of the vessel walls is related to the dermal involuntary muscles embryologically, cannot be stated. The fact that both systems are activated by adrenin and by the stimulation of the sympathetic nervous system, might suggest it. Adrenin, however, does not influence the secretion of sweat, although the muscles of these glands are supposedly activated by sympathetic neurons.

There is another widespread group of involuntary muscles belonging to the alimentary canal and those organs derived from it. This may be called in contradistinction to the "dermal," the "endodermal" (Gaskell) musculature. This is found throughout the intestinal canal, the bronchial walls, the liver, gall bladder, pancreas, and urinary bladder, except the trigone. In order to understand these relationship, one must bear in mind that the lungs, gall bladder, liver, and pancreas, are formed from diverticula from the oesophagus and small intestine and that the body of the urinary bladder is formed from a diverticulum from the rectum. The innervation of these organs, therefore, is the same as the original enteral system from which they are derived.

This "endodermal" system of involuntary muscles is supplied with motor power by the cranial, bulbar and sacral neurons of the vegetative system, and Gaskell has suggested that the entire system be called the "enteral system" to denote its embryologic relationship.

Aside from the endodermal structures just enumerated, there are certain structures in and about the eye and nasal chambers, and the salivary glands, which arc innervated by the vegetative fibers which pass through the IIIrd, VIIth and IXth cranial nerves.

Confusion in Names. There is so much confusion in the terms descriptive of that portion of the nervous system which is not under the control of the will, that it is necessary to make clear at the outset what is meant by the terms used.

The system as a whole is called by various writers: "Involuntary," "vegetative," "autonomic" and sometimes the "sympathetic."

The term "involuntary" is excellent except that all the acts performed by this system are not wholly independent of the will, for example, respiration may be either voluntary or involuntary; so may vomiting, defecation, urination and many other acts. If this term is employed it is not fully descriptive of the system.

The term "autonomic" means self-governing and has been suggested by Langley because those structures which are supplied by this system, although normally receiving impulses from the spinal cord through connector neurons, will continue for a time to functionate after they have been separated from the spinal cord; but this term has the same objection as "involuntary," in that it is not wholly adequate to describe the conditions. This system is not wholly independent. Another objection is that this term "autonomic" i.e. applied both to the system as a whole and also used to designate one of the two divisions of the system, the bulbo-sacral outflow, the one opposing the action of the sympathetics. Some physiologists speak of the entire system as the "sympathetic," but since there is almost general agreement in calling one definite division, the one arising from the thoracic and upper lumbar segments of the cord, the "sympathetic," this term should be limited to that system, al- though the term "sympathetic" is without a rational meaning in a neurophysiologic sense.

"Vegetative," meaning pertaining to the functions which are necessity to life, is the term which characterizes this system best; and now that we are beginning to study this subject in clinical medicine it would be well to arrive at some definite use of terms so as to avoid confusion. I shall use this term "vegetative" through- out this monograph in speaking of the system as a hole.

Divisions of the Vegetative System. The vegetative system is made up of several different parts taking their origin from widely separated portions of the central nervous system. Some of the fibers come through certain cranial nerves, the IIIrd, VIIth, IXth, and Xth. Others arise from the spinal cord. Those coming from the thoracic and upper lumbar segments of the cord are called the *sympathetic,* but those from the sacral portion constitute the *pelvic* nerve. The pelvic nerve is functionally related to the vegetative fibers in the IIIrd, VIIth. IXth and Xth cranial nerves.

Functionally these various groups of nerves may be divided into two definite and distinct systems which, in the structures in which they meet, antagonize each other in action. Just as there are flexor and extensor actions in the superficial muscles supplied by the voluntary nervous system, so there are activating and inhibiting impulses carried to the structures supplied by the vegetative system. Sometimes these two types of impulses are carried by the same nerves, at other times by different systems (sympathetics and parasympathetics).

From their similarity of function we may divide the vegetative nerves into two groups. In one of these groups we place the fibers given off from the thoracic and upper lumbar segments of the cord, the sympathetics; in the other group those arising from the midbrain, bulb and sacral portions of the cord, the parasympathetics.

Considerable confusion arises also in the nomenclature of this latter group. A common characteristic of the neurons which make up this group is that, in any tissue supplied by any member of the group and likewise by the sympathetics, the action produced by its stimulation is antagonistic to the action of the sympathetics. Another characteristic is that the motor cells of all the neurons belonging to it lie within or on the structures supplied. It seems fitting then to group the vegetative fibers in the IIIrd, VIIth, IXth and Xth cranial nerves and those in the sacral or pelvic nerve, together. Various names have been applied to this group, "autonomic," "greater or extended vagus" and "parasympathetics." The use of the term "autonomic" will only confuse. "Greater or extended vagus," as used by Eppinger and Hess, classifies the neurons as being, in action, similar to the vagus, but confuses and should be discarded. "Parasympathetic" has much in its favour, the prefix "para" meaning alongside of, or against. These fibers act against the sympathetics. In this monograph I shall use the term "parasympathetic" to designate the bulbosacral outflow of vegetative nerves.

Reflex. One cannot proceed far in the study of visceral neurology without understanding the principles of reflex action. Luciani" defines a reflex thus: "The reflex act is the involuntary transformation of a centripetal into a centrifugal nerve impulse by means of a central organ represented by a group of nerve cells." A reflex is made up of at least two components, an afferent and an efferent neuron. The afferent neuron is always sensory and carries the impulse to the cell bodies in the central nervous system. The cell bodies of the afferent neuron in the spinal cord are found in the ganglion of the posterior root. They are situated in this same ganglion, whether the afferent fibers which belong to them come from the somatic or from the visceral structures. The efferent component of a somatic motor neuron has its nerve bodies in the anterior horn of the cord and in the motor nuclei of the cranial nerves while the connector neurons of the vegetative system lie in the lateral horn and the motor nuclei of cranial vegetative nerves.

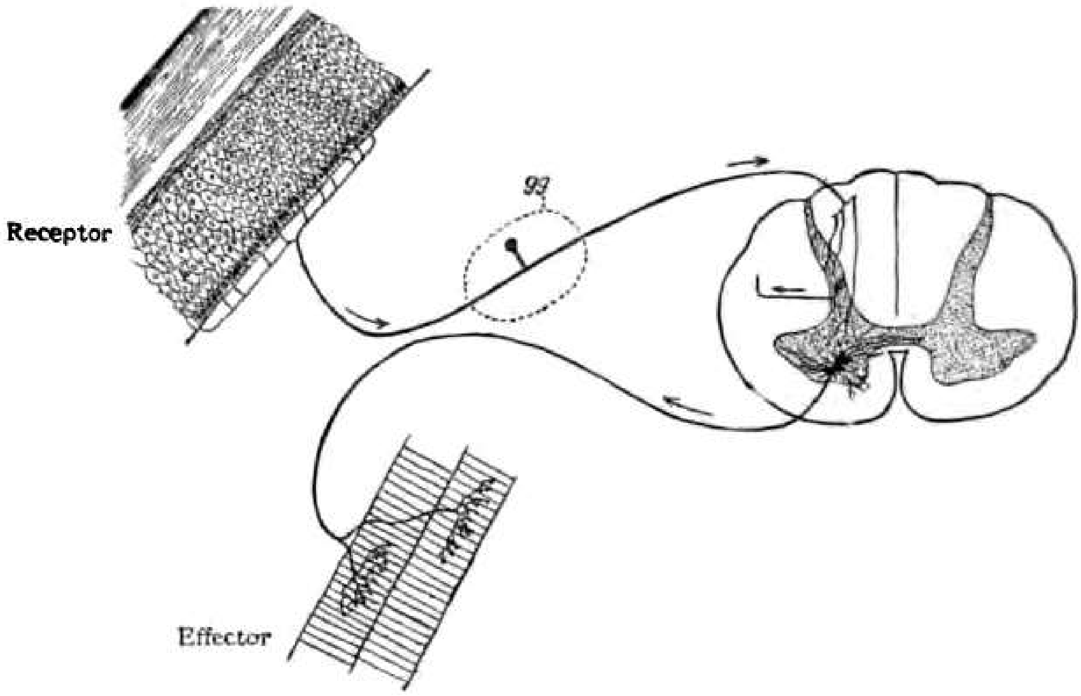

Figure 82. A two neuron reflex in a vertebrate. gg – ganglion (Van Guhuchten). The receptor, or sensory neuron, receives the impulse and transmits to, or through, the ganglion on the posterior root to the cells in the anterior horn of the cord. It transmits them to a motor or effector nerve which produces action in another tissue. This is the simplest type of reflex, probably not found in clinical medicine.

The connection of the two components of the reflex may be direct, but it is probable that such simple reflexes are comparatively rare. Other neurons lie usually interposed between the two. The union which takes place between the axon of one neuron and the dendrites and cell bodies of another neuron in the reflex is called the *synapse.* Some reflexes arc extremely complex, others very simple. This is illustrated in Figs. 75 and 76, in complex reflexes, several neurons are interposed between the afferent and the efferent components of the reflex. Starling,[25] in speaking of this complex nature of reflexes, says "When we study the structure of the central nervous system more fully, we find that although there are certain shortest possible paths, i.e. ones involving few neurons, for every impulse arriving at the central nervous system, yet so extensive is the branching of the entering nerve fibres and so complex are the neuron systems with which they come in connection, that an impulse entering along one given fibre could spread to practically every neuron in the spinal cord and brain." This does occur in strychnia poisoning, in which the resistance of the synapse is broken down and an afferent impulse from any source may cause general con- traction of muscles. While it is thus seen that a sensory stimulus conveyed to the cord might produce a very widespread motor response, yet this is not the rule. There is for each afferent nerve root some efferent root which offers the least resistance to impulses which arc conveyed centralward by it, and this is the one which usually completes the reflex act. This is often in the same segment of the cord, but as in case of the sympathetic afferent nerves from the lung, it may be found in segments somewhat removed, following out, however, the developmental segmental arrangement of the viscera in their relationship to the segments of the body. See quotation from Sherrington on page 46.

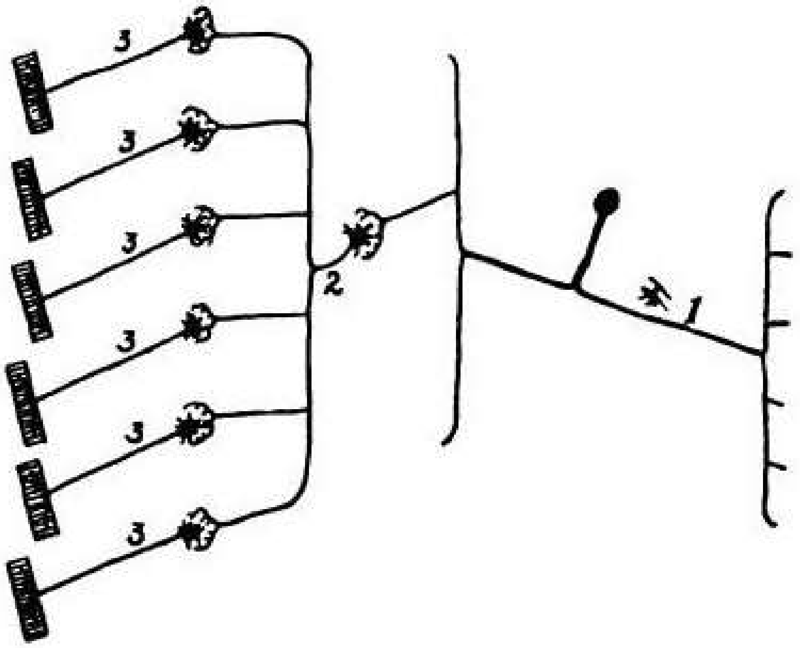

Figure 83. A three neuron reflex arc (Van Guhuchten).
1 – afferent, peripheral neuron. 2 – intermediate, or central, neuron. 3 – efferent peripheral neurons. The impulse is carried to the ganglion the posterior root by the sensory neuron – 1, and there, or in the cord, is transmitted to the second neuron – 2. It is then transmitted to the final effector neuron – 3. different types of complex neuron are shown in Fig 9.

The extent of the reflex is influenced by the strength of the stimulus. If the stimulus is slight, it might pass over only those efferent neurons which are particularly adapted to it; but if it is stronger, the reflex spreads to other efferent fibers. This is important in clinical application of the reflex, for it shows why, at times, a large area of muscles is contracted; when again, with the same organ inflamed, a smaller muscle area is influenced, and probably the muscle tone is much less.

Vegetative Nervous System Embryologically Considered. One can best understand the vegetative system and its action in the tissues, if he is familiar with its embryologic development. The development of the vegetative nervous system can best be studied in the thoracicolumbar portion of the cord from which the sympathetic neurons originate. As previously mentioned, the neural tube is made from an infolding of the ectoderm The tube is closed during the early days of the embryo by certain cells which form a band between the posterior borders of the neural plate as shown in Fig. 82. These cells are known as the neural crest.

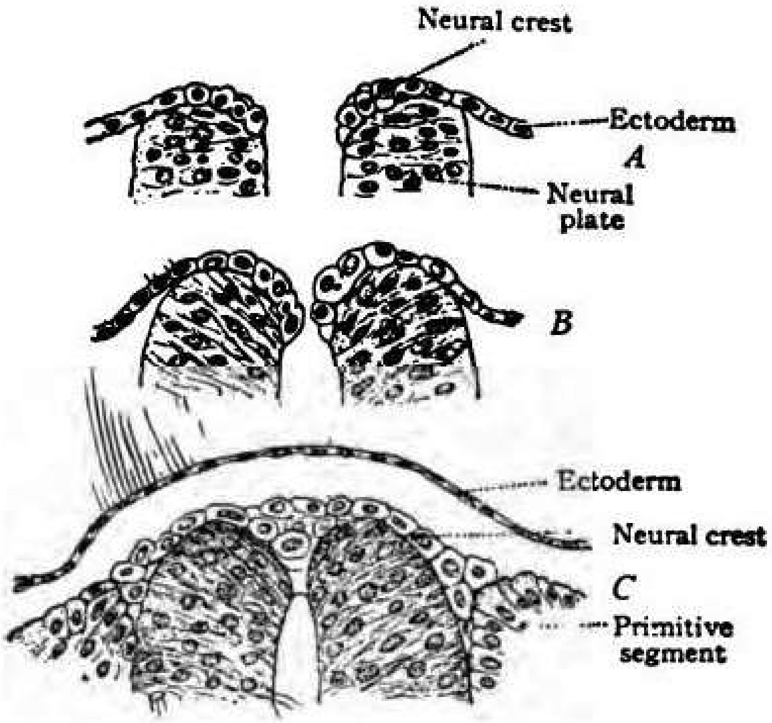

Figure 84. Three stages in the closure of the neural tube and the formation of the neural crest (spinal ganglion rudiment).
From transverse sections of a human embryo at 2.5mm length, with 13 pairs of primitive segments. 14 – 16 days Von Lenhossek (Bailey and Miller)

The neural crest separates from the cord when the embryo is three weeks old, and forms two longitudinal bands running lengthwise of the cord. The ventral borders of these bands show segmentation, the cells arrange themselves into clumps, which later become completely separated, forming the spinal ganglia. These cells continue to proliferate, and then a differentiation takes place from which the components of the spinal nerves as well as the white ramus communicans of the sympathetic system are formed. Many of the cells from the neural crest continue their migration as well as proliferation, and become deposited still further peripheralward, forming the sympathetic ganglia. Some of these are deposited near the spinal column and after segmentation has taken place at the seventh week, form the gangliated cord of the sympathetic system. Later the cells of the gangliated cord proliferate and migrate still farther away, being deposited near the organ or organs which they will later supply. Further differentiation takes place and they form the ganglia of the various sympathetic plexuses, such as the pulmonary, cardiac, celiac, renal and pelvic. In the para- sympathetic system the cells come to rest in contact with or into the tissues of the organs themselves, forming such plexuses as those found in the walls of the gastrointestinal canal (Auerbach's and Meissner's).

While this relationship can best be studied in the thoracicolumbar portion of the cord, the same relationship in peripheral nerves holds for those which take their origin from the midbrain and bulb.

The cell bodies of the *afferent neurons* of the sympathetic system are without the neural tube, lying in the ganglia of the posterior root, while the cell bodies of the *efferent* connector fibers are centrally located in the anterior portion of the lateral walls of the neural tube. These efferent connector fibers connect the central nervous system with the sympathetic motor cells which are found in the sympathetic ganglia. It will then be seen that none of the true motor cells belonging to the vegetative system lie within the central nervous system, but that they are connected with it through the connector fibers which course in the IIIrd, VIIth, IXth, and Xth, cranial nerves; in the white rami communicantes of the thoracicolumbar segments; and in the pelvic nerve.

During this stage of migration, when the motor cells of the vegetative system are separating from the central nervous system, it should also be mentioned that some of the sympathetic cells differentiate into sympathoblasts which become cells in sympathetic ganglia; and others phaeochromoblasts, from which arise the chromaffin cells of the adrenal bodies. This is the embryologic reason for the similar action of the sympathetic motor cells and adrenin, Adrenin is a secretion from cells belonging to the sympathetic system. The chromaffin cells arc so named because of their property of being stained with chrom salts. We know them in physiology as belonging to the sympathetic nervous system and being the producers of adrenin. They are found for the most part in the medulla of the suprarenal glands, although lesser deposits are found in some mammals at the branching of the aorta and carotids. In the lowest groups of vertebrates there are many scattered, segmentally arranged masses of chromaffin cells and few sympathetic cells; but in the higher vertebrates these are replaced by sympathetic cells which form the sympathetic system.

Development of Afferent and Efferent Neurons. Not only do the cells from the neural crest differentiate into ganglia and the chromaffin cells of the suprarenal glands, but also into the nerve fibers which complete the afferent and the efferent neurons of the vegetative system.

There are two morphologic differences between afferent and efferent vegetative neurons. The afferent neuron cell bodies lie in the posterior root ganglion, and the fibers enter the posterior part of the lateral walls of the tube; while the cell bodies of the efferent connector neurons lie within the lateral horn of the neural tube, and the fibers pass out from the central part of the lateral walls to join with motor cells in the various ganglia.

While the neurons belonging to the voluntary and involuntary systems are alike in that they both possess those of an afferent and efferent character, they differ in some particulars. The afferent or sensory neurons, whether of the voluntary or vegetative (involuntary) systems, have their neuron bodies alike in the ganglia of the posterior root. The efferent neuron bodies of the voluntary or somatic system, lie in the anterior horn of the neural tube, while the efferent neuron bodies of the vegetative or visceral system lie without the neural tube in ganglia, lateral, collateral and terminal, which have wandered from the neural canal. These ganglia are brought into connection with the neural tube, however, by fibers which pass out from the central positions of the lateral walls in the white ramus communicans. Gaskell has given these fibers the name of "connector fibres." They connect the receptor with the effector neurons.

Relationship Between Cerebrospinal and Vegetative Nervous Systems. The vegetative nervous system belongs to a lower stage of development of the animal than does the voluntary system. Its neurons, however, carry sensory, motor and trophic impulses the same as the neurons of the cerebrospinal system, except the sensory neurons arc endowed only with a modified power of expressing pain. To express pain, however, they call into action the sensory spinal and Vth cranial nerves which are segmentally bound in reflex relationship with them. This is discussed more fully in Chapters V and VI.

While the neurons of the vegetative system are capable of carrying on the activities of the tissues supplied by them for a time, in such a manner as to sustain life, independently of the cerebrospinal system; and the cerebrospinal system is able to carry on the functions presided over by its neurons in a certain sense independently of the vegetative system, yet these two systems are more or less intimately connected.

We must conceive that there is a continuous flow of sensory impulses (afferent) passing to the central nervous system from the surface of the body. These not only make their presence known to the brain and cause action in the skeletal tissues; but also through their intimate connection with the cell bodies of the visceral nerves, cause an outflow of impulses {efferent) through the vegetative nerves to the unstriped muscles and the secretory glands of the viscera.

We must also conceive that there is a continuous stream of sensory impulses (afferent) traveling centralward from the viscera over the sensory neurons of both divisions of the vegetative system which are capable of expressing themselves involuntarily through efferent impulses to produce action in the tissues supplied by both components of the vegetative system some of which are described in Chapter VII; and also, through mediation between vegetative and cerebrospinal neurons, in action in the skeletal tissues. Stimuli coming from the surface of the body may affect the function of internal viscera; and impulses coming from the viscera may influence the skeletal structures.

Adequate Stimulus. A certain strength of sensory impulse is required in order to make its presence known to the higher centres or in order to call out a reflex nerve respon.se in the skeletal or somatic structures. This is known in physiology as the adequate stimulus. Sensory impulses continuously How centralward through the -somatic nerves without being recognized by the sensorium Light only causes a protective response when a certain degree of brightness has been attained ; pound only when unusually loud ; and the sensation of touch only when marked. The sensory impulses which flow to the central nervous system through the sensory fibers of the vegetative system, do not call forth a voluntary response, but produce reflexes which express themselves in widely separated structures through a system of coordinated neurons. The brain takes far less cogni7Ance of stimuli from the vegetative structures than it does from the voluntary structures. Only when function is quite markedly disturbed in our viscera do we become aware of it. The vegetative nervous system was separated from the central system that it (the central nervous system) might be relieved of presiding over ordinary vegetative acts, and the more effectually be able to take care of that relationship which the organism bears to the outside world. In the vegetative system the same as in the voluntary nervous system, we must understand that every impulse does not call for action. The stimulus must be adequate or no response occurs. This is discussed more fully in Chapter VI.

Afferent Impulses over Sympathetics and Parasympathetics Cause Different Reflexes. The reflex responses which are dependent upon afferent impulses flowing over the sensory neurons of the two divisions of the vegetative system, differ in a very important particular. Recognized responses which result from sensory afferent impulses flowing centralward over sympathetic neurons are expressed largely by reflex action in the skeletal structures which receive their sensory' and motor nerve supply from the spinal cord. But reflexes in the internal viscera in which both afferent and efferent impulses flow over sympathetic neurons, mediation taking place in the cord, are probably much more common than we are inclined to believe. It is probable that contraction of sphincters, dilatation of intestinal segments and many vasomotor disturbances are of this nature. The responses which result from impulses flowing centralward over the sensory neurons of the parasympathetics express themselves reflexly in action which flows outward over other neurons of the same system, or through either the cranial, or the sacral spinal nerves, and produces reflex action commonly recognized in visceral structures.

From this the following two observations which are fundamental in the study of clinical aspects of visceral neurology- and which are of great diagnostic import may be made:

1, Reflexes resulting from sensory afferent impulses from the internal viscera which flow centralward over the sympathetic neurons, express themselves through the spinal nerves and manifest themselves in sensory, motor, and trophic changes in the skin, subcutaneous tissue and muscles and in many visceral disturbances which we have as yet not learned to recognize.

2. Reflexes resulting from sensory afferent impulses from the internal viscera which flow centralward over the parasympathetic neurons, express themselves for the most part through other neurons of the parasympathetics and manifest themselves in a disturbance in function of other internal viscera.

While there are parasympathetic reflexes which are expressed through the spinal accessory nerve as spasm of the sternocleidomastoideus and trapezius muscles when the lung is inflamed; and other reflexes in the tissues of the head and face through the Vth, VIIth and Xth cranial nerves, yet these make np only a small proportion of the sum total of parasympathetic reflexes, and do not affect the principle here stated.

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Chapter XXX
The Vegetative Nervous System Anatomically Considered

In order to understand the relationship between the activities of the body and the visceral nerves it is necessary for one to familiarize himself with the anatomy and physiology of the vegetative nervous system. In our discussion we shall be brief, yet we shall attempt to state a sufficient number of the more important facts to make the subject intelligible.

Sympathetic Nervous System

We shall first describe the sympathetic system. It takes its origin from that portion of the spinal cord which extends from the first thoracic to the third or fourth lumbar segments. By the term "origin" we are to understand that the motor neurons of the sympathetic system which have meandered out to supply the viscera as described on page 190 and whose motor cells lie in the sympathetic ganglia, originally came from this portion of the cord; and, that they are still connected with these segments by connector fibers whose cell bodies lie in the lateral horn of this section of the cord, but which have followed them out, so to speak, in order to keep them connected with the central system.

The sympathetic system consists of:

1. A chain of ganglia lying on each side of the vertebral column, there being as a rule one ganglion for each spinal nerve root. These ganglia are called lateral ganglia or vertebral ganglia.

2. Numerous ganglia situated farther away from the spinal canal which are termed collateral ganglia or prevertebral ganglia: and still others lying on or in the muscle of the viscera, as in the genital organs, which are termed terminal ganglia.

3. Numerous plexuses of fibers which supply the various tissues.

4. White rami communicantes.

5. Gray rami communicantes.

Gangliated Cord. The *lateral* or *vertebral* ganglia are arranged in two rows along the ventral surface of the vertebral column, extending its full length. These ganglia are arranged for the most part segmentally, corresponding to the segmental spinal nerves. The connector fibers passing from the spinal segments to the sympathetic ganglia are known as the white rami communicantes, and the fibers passing from lateral sympathetic ganglia back to the spinal nerves to be distributed to the skeletal vessels, subdermal structures, and the blood vessels of the spinal cord, are known as the grey rami communicantes. The fibers passing from one of the lateral ganglia to another, form a definite cord and taken in conjunction with the ganglia from the gangliated cord, which extends from the atlas to the coccyx. Fig, 85 shows the gangliated cord. It is also shown schematically in Fig. 10, page 39.

The sympathetic ganglia are masses of nerve cells. These cells with the nonmedullated fibers originating in them, form the motor neurons of the sympathetic nervous system.

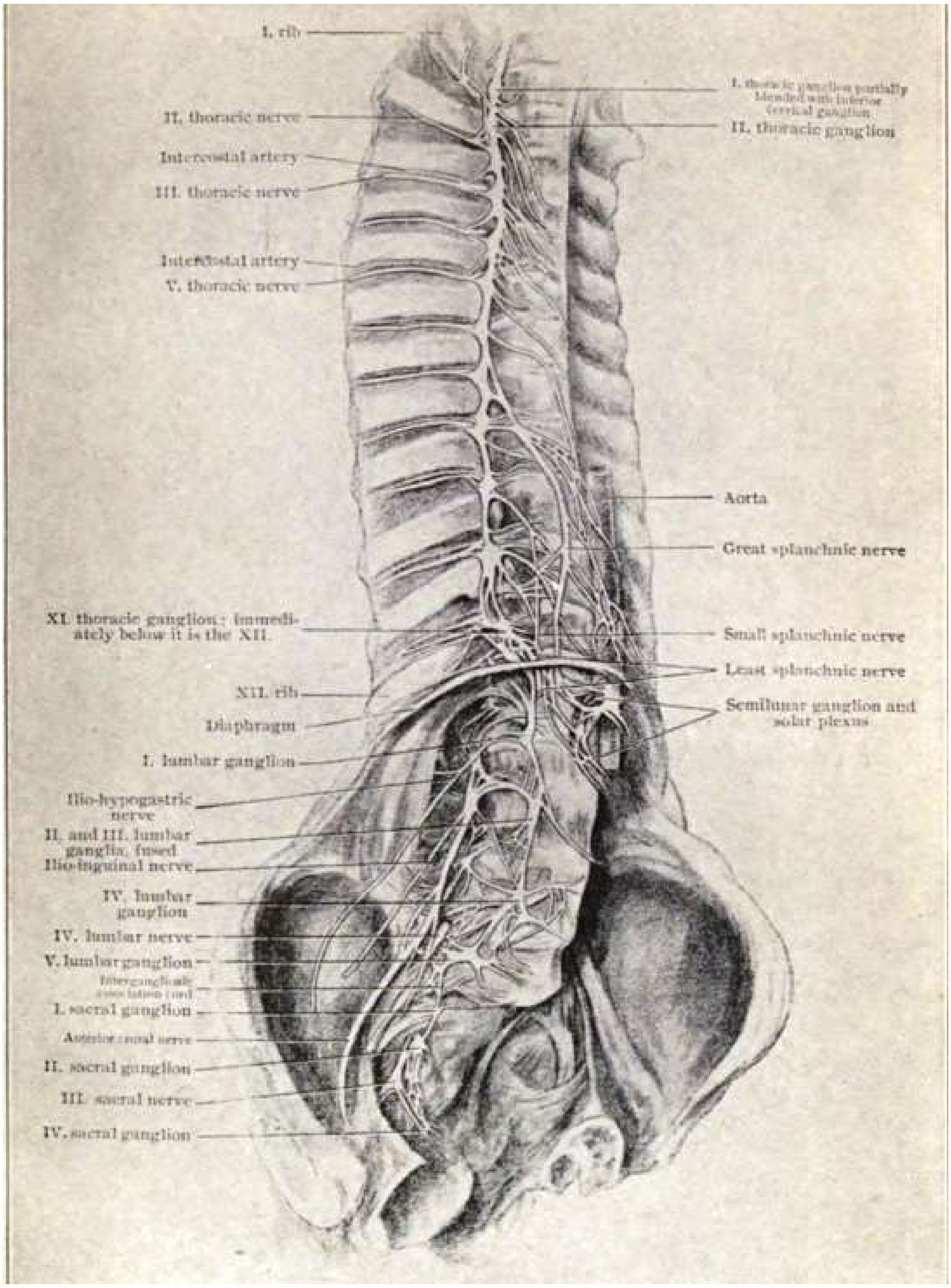

Figure 85. Dissection showing thoracic, lumbar and sacral of right gangliated cord and their branches. (Piersol)

The ganglia of the gangliated cord in certain areas fuse together. Thus the upper three or four thoracic ganglia fuse and form the stellate ganglion: the ganglia of the cervical portion are arranged sometimes in a superior and inferior, and sometimes a third, the medium ganglion, is interposed; the lumbar and sacral portions sometimes have three, sometimes four ganglia. The lower ends of the two gangliated cords either unite in a common ganglion behind the coccyx, called the ganglion of Walter, or unite by a simple loop. The sympathetic ganglia are relay stations, so to speak, where impulses arc transmitted from one neuron to another. Fibers will often pass through one or more ganglia without connecting with or forming relays with the neurons whose cells are found in those ganglia. Fibers which end in cells in a given ganglion enter it as white medullated fibers, while the fibres of the neuron which carry the impulses onward emerge from the ganglion as *nonmedullated* fibres. *The only truly sympathetic motor fibers, then, are nonmedullated fibers; while all medullated motor fibers belonging to the sympathetic system are connector in function,* joining the ganglionic motor cells with the motor cells in the spinal cord.

The vertebral ganglia are the first relay stations. Many of the impulses transmitted from the cord are directed to the tissues which they supply by the nerve cells in the vertebral ganglia. Here arise the sympathetic fibers which supply the skeletal blood vessels, the subdermal musculature and the blood vessels of the spinal cord. Many more pass through these ganglia and onward, to activate motor cells in some of the peripheral ganglia. This has a very important bearing upon the study of the paths of sympathetic reflexes and will be disclosed more fully later.

Collateral and Terminal Ganglia. The fibers of the sympathetics often form large plexuses before innervating the viscera. The fibers which make up these plexuses are nonmedullated, having originated from motor cells in the collateral ganglia. The more important collateral ganglia are: The ciliary, celiac which is formed by the union of the semilunar and superior mesenteric, the inferior mesenteric, the renal and the ovarian or spermatic.

The sympathetic fibers pass to the viscera along with the blood vessels.

Some of the More Important Sympathetic Ganglia. One should familiarize himself with a few of the more important ganglia of the sympathetic system.

The Superior Cervical Ganglion. The superior cervical ganglion receives its fibers from the 1st, 2nd, and 3rd dorsal (some say as low as the 7th) segments of the cord. It innervates the vessels of the head, the muscles of the hair bulbs and sweat glands of the head, and the musculus dilator papillae; and the smooth orbital muscle of Müller.

It connects by means of grey rami communicantes with the 1st, 2nd, 3rd, and sometimes 4th cervical nerves. Aside from these fibers to the head, there are branches which go to the pharynx and larynx, and the superior cardiac nerve which must be considered.

In the superior cervical ganglion we find the following branches which are of interest in exophthalmic goitre.

1. The branches which go to the orbit supplying the muscle of Müller, the contraction of which produces exophthalmos.

2. The plexus thyroideus and communicating branches to the plexus thyroideus inferior, stimulation of which causes hypersecretion of the thyroid gland.

3. The superior cardiac nerve which carries accelerator fibers to the heart and also sends fine fibres to the plexus thyroideus inferior. Fig. 86 shows the structures supplied by the superior cervical ganglion

The Medium Cervical Ganglion receives its fibres from the 1st, 2nd, 3rd, 4th and 5th dorsal segments. It communicates by its grey rami communicantes with the 5th and 6th, sometimes also the 4th cervical nerves. When the medium ganglion is absent, which it often is, the corresponding part of the cord takes its place. Fibers from the medium ganglion go through the nervus cardiacus medius to the heart, to the plexus thyroideus inferior, and to the plexus caroticus communis as shown in Fig. 87.

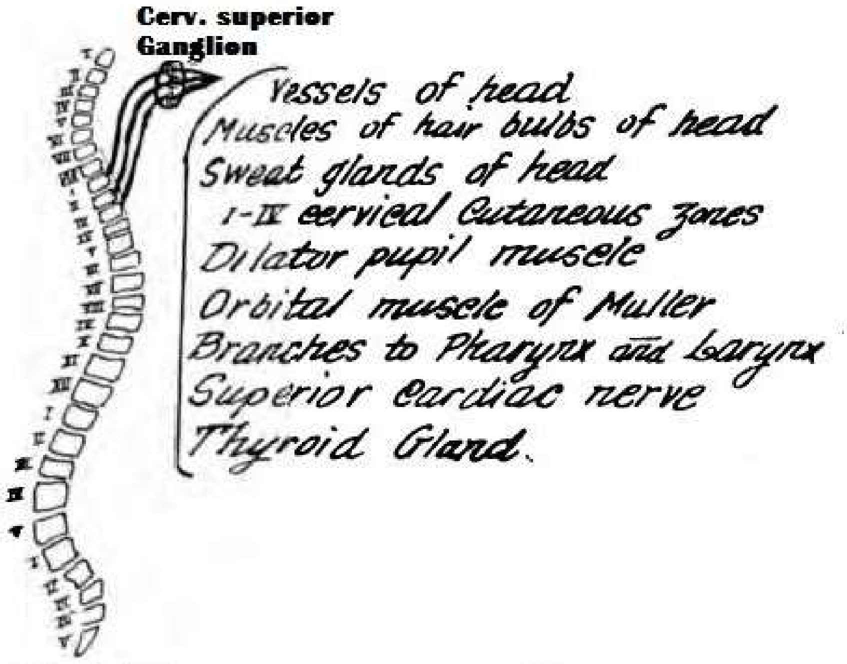

Figure 86. Superior cervical ganglion and the structures supplied by it.
The connector fibres for the superior cervical ganglion arise from the upper three cervical segments

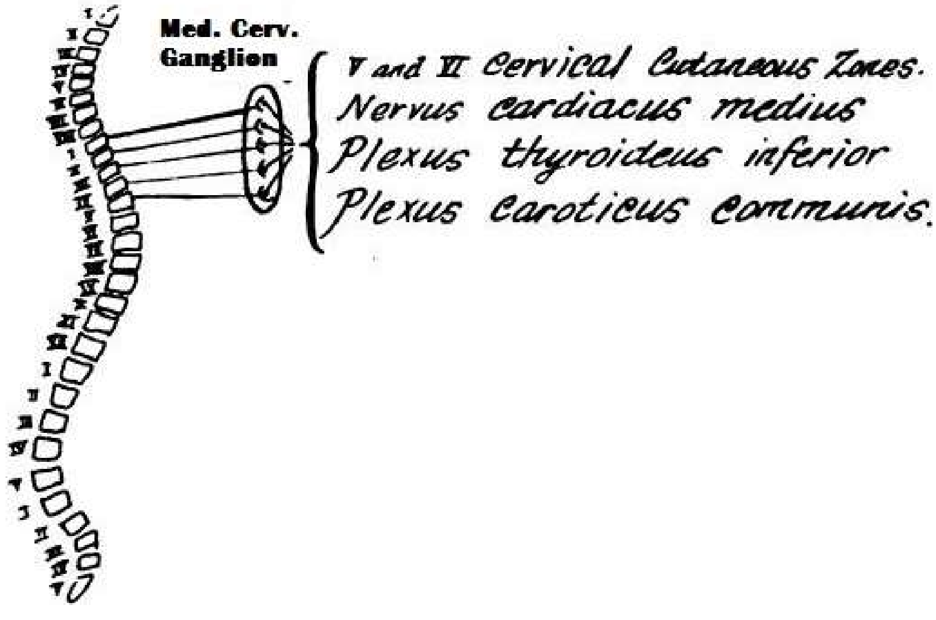

Figure 87. Structures supplied by the medium cervical ganglion.
The connector fibres arise from the 1st, 2nd, 3rd, 4th, and 5th thoracic segments.

The Inferior Cervical Ganglion through grey rami sends communicating branches to the VIIth and VIIIth cervical and 1st dorsal nerves. It sends vascular fibers to the plexus thyroideus inferior, plexus subclavicus, plexus mammarius internus, and plexus vertebralis. It also, in conjunction with the upper dorsal ganglia, gives origin to the nervus cardiacus inferior as shown in Fig. 88.

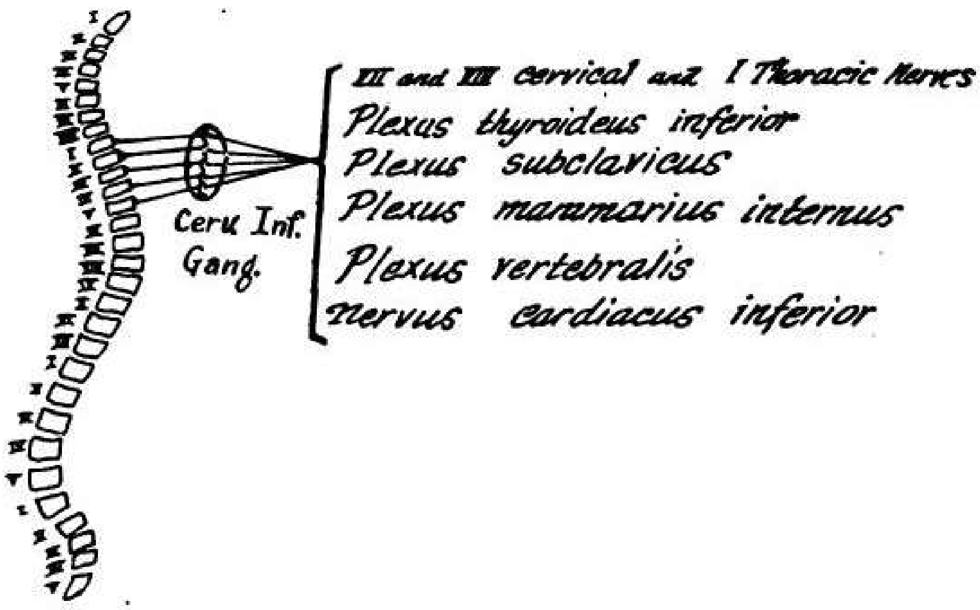

Figure 88. Structures supplied by the inferior cervical ganglion.
Connector fibres to the inferior cervical ganglion arise from the 1st, 2nd, 3rd, 4th and 5th thoracic segments

Stellate Ganglion. The upper three or four thoracic ganglia join together and form the stellate ganglion. The inferior cervical ganglion is also fused with this at times. This gives off visceral branches to the lungs, heart, aorta, and oesophagus, and grey rami to the subdermal musculature and blood vessels of the arms as shown in Fig. 89.

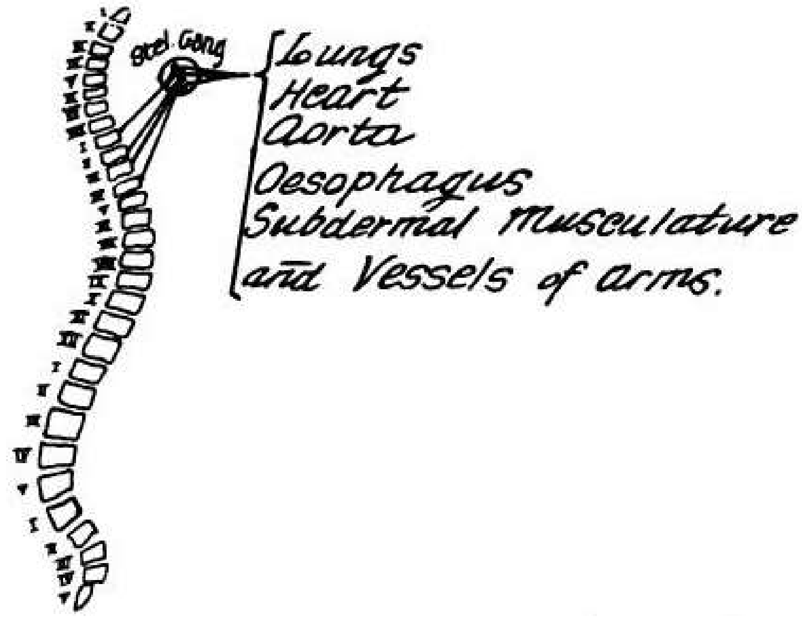

Figure 89. Structures supplied by the stellate ganglion.
Connector fibres that supply the stellate ganglion arise from the 1st, 2nd, 3rd, and 4th thoracic segments

The Celiac Ganglion is the most important of the abdominal sympathetic ganglia. It is formed by a union of the semilunar aorticorenal and superior mesenteric ganglia. It is connected with the cord by the greater and lesser splanchnic nerves; the former arising from the 5th, 6th, 7th, 8th, and 9th thoracic segments, the latter from the 9th and 10th, or 10th and 11th.

Sympathetic, nonmedullated fibers from the celiac ganglion supply the stomach, liver, pancreas, spleen, kidney, suprarenal gland, ovary, testicle, and the intestines as far as the descending colon. This is shown in Fig. 90.

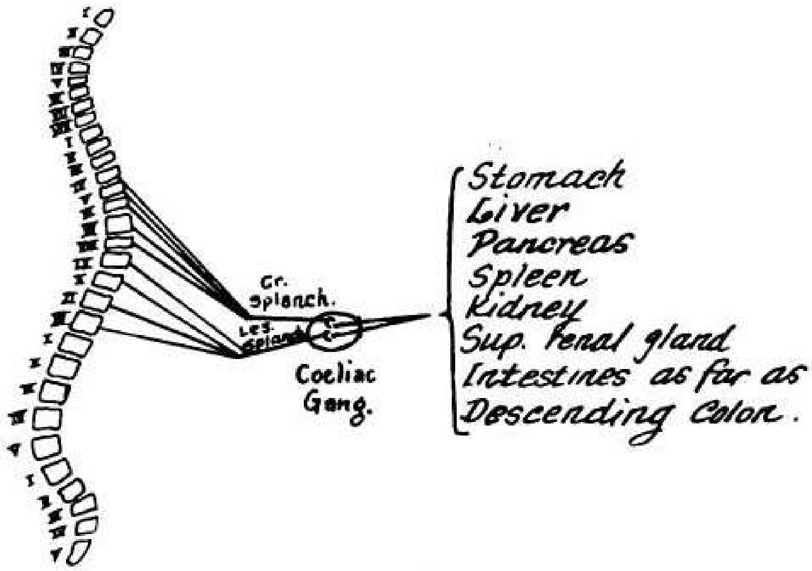

Figure 90. Structures supplied by the coeliac ganglion.
Connector fibres run through the greater splanchnic nerve, arising from 5th, 6, 7th, 8, and 9th thoracic segments and from the lesser splanchnic arising from the 9th and 10th, or 10th and 11th thoracic segments.

The Inferior Mesenteric Ganglion receives its connector fibers from the 1st, 2nd, and 3rd lumbar segments. It sends nonmedullated fibers to the descending colon and through the hypogastric nerves to the rectum, bladder, sphincter of the bladder, and genitals, as shown in Fig. 91.

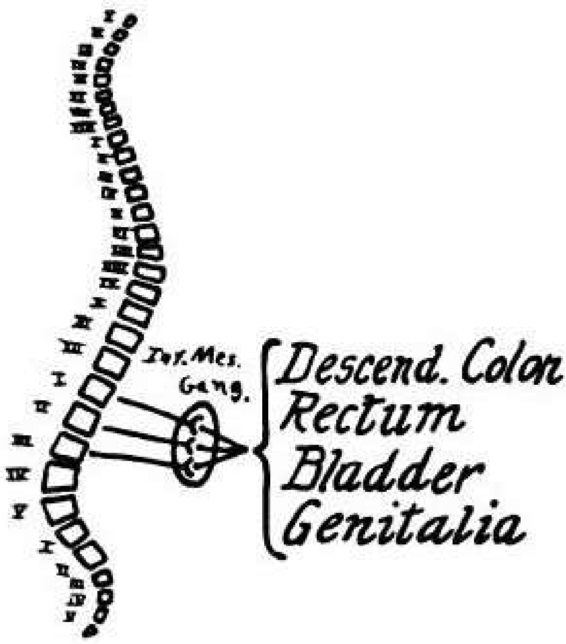

Figure 91. Structures supplied by the inferior mesenteric ganglion.
Connector fibres arise from the 1st, 2nd, and 3rd lumbar segments.

Difference in Number of Preganglionic and Postganglionic Fibers. While the impulses which travel from the central nervous system to the sympathetic ganglia are all transmitted through fourteen white rami communicantes, eleven from the thoracic segments (2 – 12) and three from the lumbar (1 - 3) as shown in Plate VII, before the tissues have been supplied the impulses have travelled over thousands of fibres which have originated from the motor cells in the various ganglia, lateral, collateral and terminal. Before supplying the tissues, these fibers collect in networks of fibers which arc known as plexuses and then follow the blood vessels to the structures to be supplied.

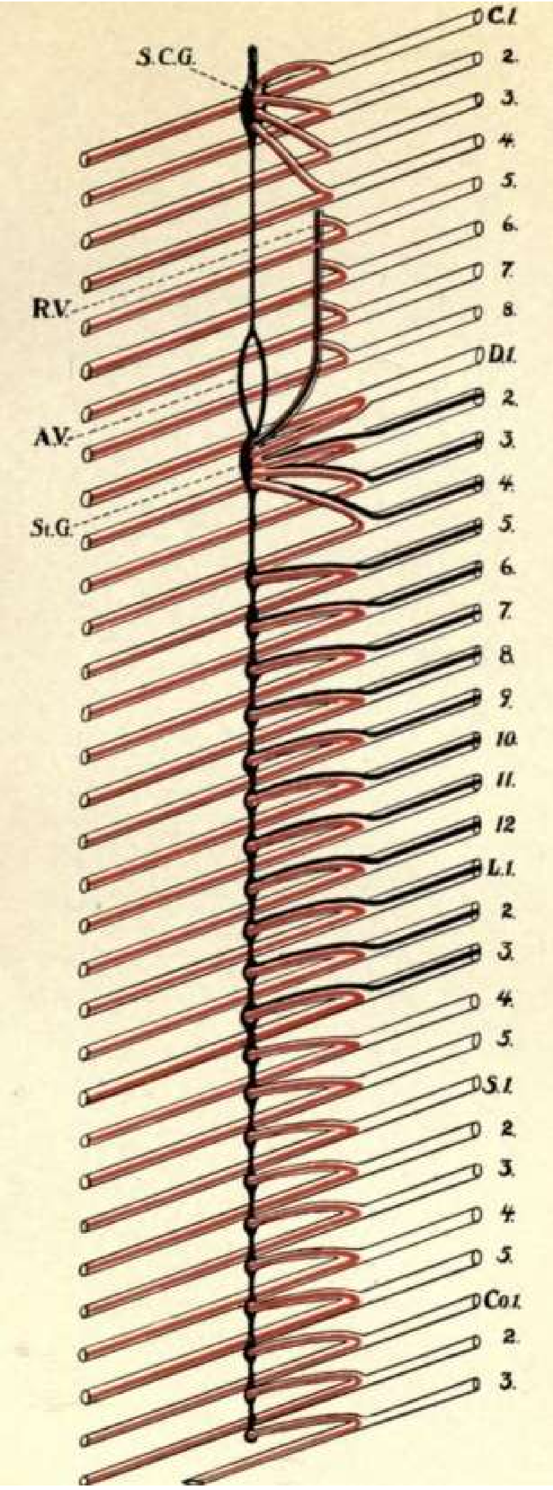

Figure 92. Plate VIII The arrangement of the connector fibres (black) and the excitor neurons (red) of the sympathetic system in the spinal region.

All the spinal nerves are shown from the 1st cervical to the 3rdt coccygeal.

All the connector neurons leave the spinal cord in the thoracicolumbar outflow which extends from the 2nd dorsal (D2) to the 3rd lumbar (L3). The lateral chain of sympathetic ganglia are connected together by further prolongations of these processes which run from ganglion to ganglion, connecting three or more of them with the excitor neurons. The lateral chain is therefore made up of a series of excitor neurons connected together by the processes of connector neurons. Certain ganglia have become fused, those corresponding to the first four cervical nerves being aggregate into the superior cervical ganglion (SCG) and those of the last four cervical and the first four dorsal aggregated into the stellate (StG), which lies just caudal to the annulus of Vieussens (AV). For the sake of simplicity, the ganglia on this annulus and the inferior cervical ganglion have been omitted and considered part of the stellate ganglion. The processes of the excitor neurons belonging to any ganglion run out in the grey ramus communicantes to join the spinal nerve and be distributed with it. The excitor neurons for the first four cervical nerves this arise from the superior cervical ganglion (SCG); the excitor neurons for the last four cervical nerves arise from the stellate ganglion (StG) and at first all run in the ramus vertebralis (RV), they finally branch from this and join their respective nerves. similarly, the excitor fibres of the first four dorsal nerves all arise from the stellate ganglion (StG), to which the first three white rami communicantes run. The rest of the spinal nerves are supplied with sympathetic excitor fibres from their corresponding sympathetic ganglia. (Gaskell)

White Rami Communicantes. It is impossible to understand the vegetative nervous system without understanding the connector neuron. The connector neurons of the sympathetic system course in the white rami communicantes. There is no other efferent connection between the cerebrospinal system and the sympathetic ganglia. They connect the sympathetic ganglia with the central nervous system and communicate to the motor cells of those ganglia impulses intended for the sympathetic system, which have been brought to the central cells in the segments of the cord from which they originate. The fibres terminate in these ganglia around the cells which supply motor power to structures such as the vascular, dermal, sphincters of the gut and bladder, and parts of the eye muscles; and inhibitory power to structures such as the muscles of the vast enteral system and those structures which originated embryologically from it, such as the respiratory tract, liver, pancreas and urinary bladder.

The connector neurons of the sympathetic system take their origin in a group of small nerve cells in the lateral horn of the thoracic and upper lumbar portions of the cord. They emerge from the spinal nerves as medullated fibers, and remain as such until they have terminated in ganglia around the motor cells which give origin to the fibers that go to supply the tissues. At this point they change, and beyond the ganglion they course as nonmedullated fibers. Sometimes these fibers will pass through several ganglia before they terminate. Thus the fibers from the upper thoracic segments pass through the stellate and medium cervical ganglia, but terminate around motor cells in the superior cervical ganglion. From there on they course as nonmedullated or true sympathetic fibers.

Aside from these efferent motor connector fibers, the white rami contain medullated fibers whose nutrient centres are in the posterior root ganglia. These are sympathetic, sensory or afferent fibers. They carry impulses from the peripheral tissues supplied by the sympathetics to the central nervous system, where they are transmitted to other neurons and manifest themselves as visceral reflexes in the skeletal tissues. These are medullated throughout their entire course from the cells in the posterior root ganglion to the tissues in which they terminate.

While the motor cells of the sympathetic system lie in outside ganglia, the nutrient cells of its sensory neurons lie in the posterior root ganglion the same as those of the voluntary system. The sensory fibers have no connection with the sympathetic ganglia, hut pass through them in their course from the peripheral tissue to the posterior root ganglia.

Gray Rami Communicantes. The lateral ganglia as previously stated are arranged segmentally. This arrangement corresponds to that of the spinal nerves. Each ganglion sends sympathetic fibers to its corresponding visceral segments and also to its spinal nerve. These latter course with the spinal nerve for a time and then are distributed to the smooth muscle which is supplied by the given spinal segment, Langley has shown that the fibers to the pilomotor muscles course in the sensory spinal nerves.

While the white rami are limited to that portion of the cord between the first thoracic and third or fourth lumbar segments, the, grey rami pass from the vertebral sympathetic ganglia lo all spinal nerve roots as shown in Plate VIII.

In the greater portion of the thoracic and upper lumbar segments of the cord, the relationship between the grey rami of the sympathetic ganglia and the corresponding spinal nerve la regular; but in the upper portion of the thoracic and cervical portions, where the ganglia have fused, there is a certain degree of irregularity. The superior cervical ganglion sends grey rami to the 1st, 2nd and 3rd and sometimes the 4th cervical nerves, and the inferior cervical ganglion and the ramus vertebralis from the stellate ganglion when the medium ganglion is absent, supply the 4th, 5th, 6th, 7th and 8th cervical nerves and segments. When the medium is present, it sends grey rami to the 5th and 6th.

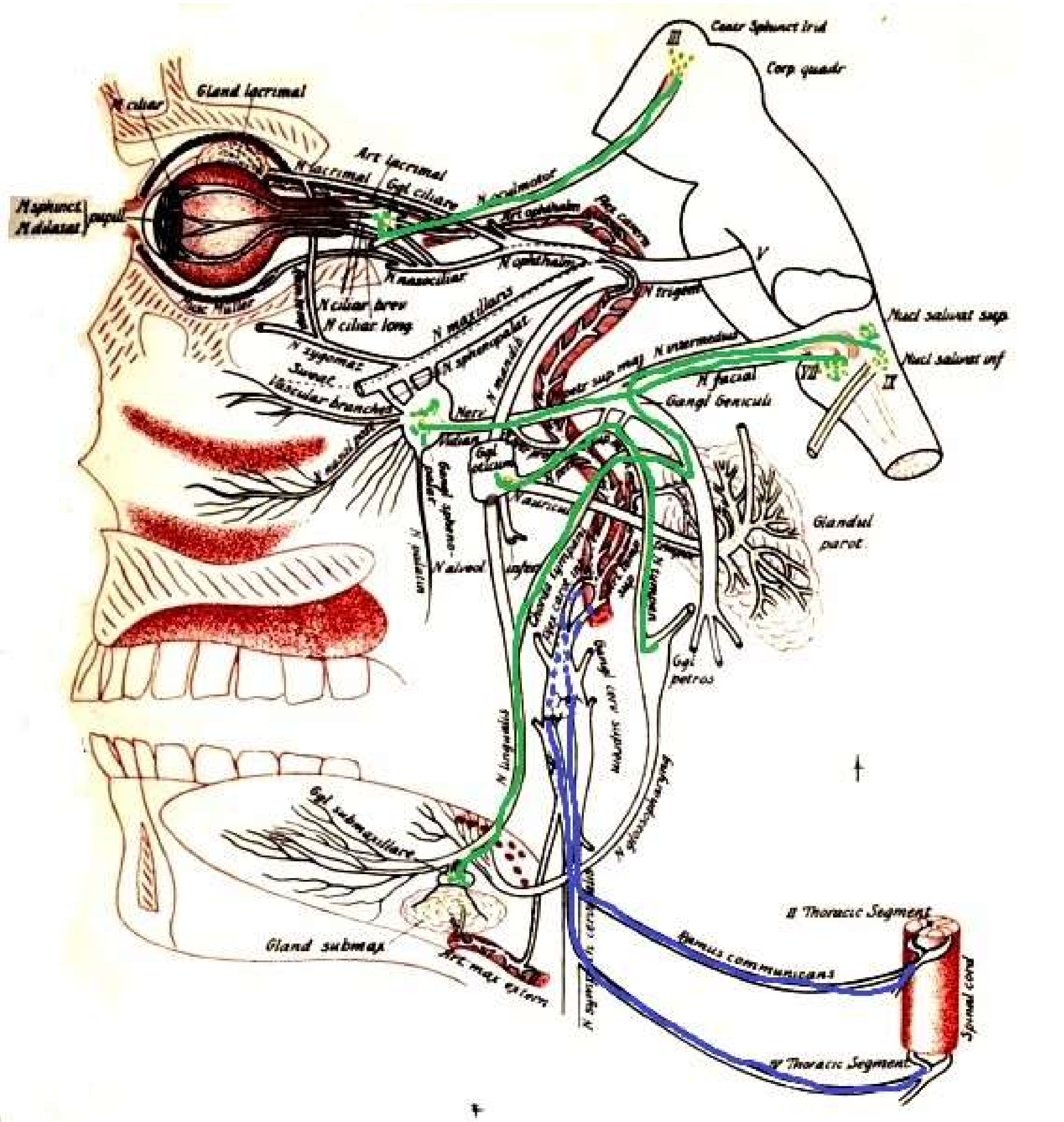

Figure 93. Plate IX. Illustration of the distribution of the vegetative nervous system in innervation of the tissues of the head.
(From Higier, after Mueller and Dahl). The parasympathetic fibres from the midbrain and medulla are shown in blue; the visceral and sympathetic ganglia are in blue; the parasympathetic in green; the preganglionic fibres are shown in continuous lines; the postganglionic in broken lines.

Sacral Vegetative Nerves. The sacral outflow is entirely different from the thoracicolumbar outflow. It belongs to the enteral instead of the vasculodermal system. It passes out through the 2nd and 3rd sacral nerves. These fibers do not pass through lateral ganglia like the sympathetics, but unite to form the pelvic nerve, also called nervus erigens, and then pass directly to ganglia lying on the surface of the bladder, rectum, and other structures supplied by them. In this, as well as physiologically, they resemble the craniobulbar outflow.

Cranial Vegetative Nerves. It is characteristic of the cranio- bulbar outflow, the some as of the sacral, that the motor ganglia lie near or within the organs innervated, while the connector neurons run from the centres in the brain to the organ itself without passing through ganglia.

The IIIrd, VIIth, IXth and Xth cranial nerves carry fibers which belong to the vegetative system. These are spoken of as belonging to the craniobulbar outflow.

The vegetative fibers of the IIIrd nerve pass to the ciliary ganglion, and from there fibers go to innervate the sphincter papillae, musculus cilairis, and musculus levator palpebrae.

The visceral fibers which course in the VIIth cranial nerve (facialis) are found in the chorda tympani, which carries vasodilator and secretory fibers to the sublingual and submaxillary glands, also to the mucous membranes of the no.se and its accessory sinuses, soft palate and upper pharynx. The fibers in the IXth cranial nerve (glossopharyngeal) give vasodilator and secretory fibers to the parotid gland. The vegetative fibers in the IIIrd, VIIth, and IXth nerves are shown in Plate IX from Higier.

Vagus. The arrangement of the nuclei of the vagus in the medulla corresponds to the ventral, lateral and posterior horns in the spinal cord. The *nucleus ambiguus* corresponds to the ventral horn from which arise the spinal nerves. It gives origin to those fibres of the vagus which supply the voluntary muscles of the larynx, pharynx, and oesophagus.

The *nucleus solitarius*, which lies in a more dorsal position, gives origin to the sensory fibers which supply the pharynx and larynx.

The *nucleus dorsalis*, the largest nucleus of the vagus, gives origin to the visceral fibers and its ganglion cells correspond in form and size to the cells found in the lateral horn of the cord.

All of the fibers from these three nuclei pass through the ganglion Jugulare and ganglion nodosum. They unite and form the vagus or Xth cranial nerve. The vagus is illustrated in Plate X.

The ganglion nodosum resembles the spinal ganglia and has no cells which resemble those of the sympathetic in it; the ganglion jugulare, on the other hand, seems to be a mixed ganglion and contains cells resembling both the spinal and sympathetic cells.

The sensory fibers of the vagus supply:

1. The entire mucous membrane of the respiratory tract from the epiglottis downward.
2. The heart.
3. The following portions of the digestive tract: The base of the tongue, the palate, the pharynx and other portions of the mucous membrane of the throat, the oesophagus, stomach, duodenum, jejunum and ileum.
4. The mucous membranes of the biliary passages.
5. All musculature of viscera supplied by the vagus.
6. That portion of the dura mater around the foramen jugulare.
7. The concave surface of the auricular and the external auditory meatus.

The motor fibers of the vagus supply:

1. Muscles of the soft palate (azygos uvulae)
2. Musculi constrictores pharynges.
3. The oesophagus.
4. The stomach.
5. The small intestine.

6. The cricothyroideus; and, in conjunction with the accessorius fibres, all other muscles of the larynx.
7. The muscles of the bronchi.
8. The muscle elements of the liver and spleen.
10. The muscle elements of the suprarenal bodies and kidneys.

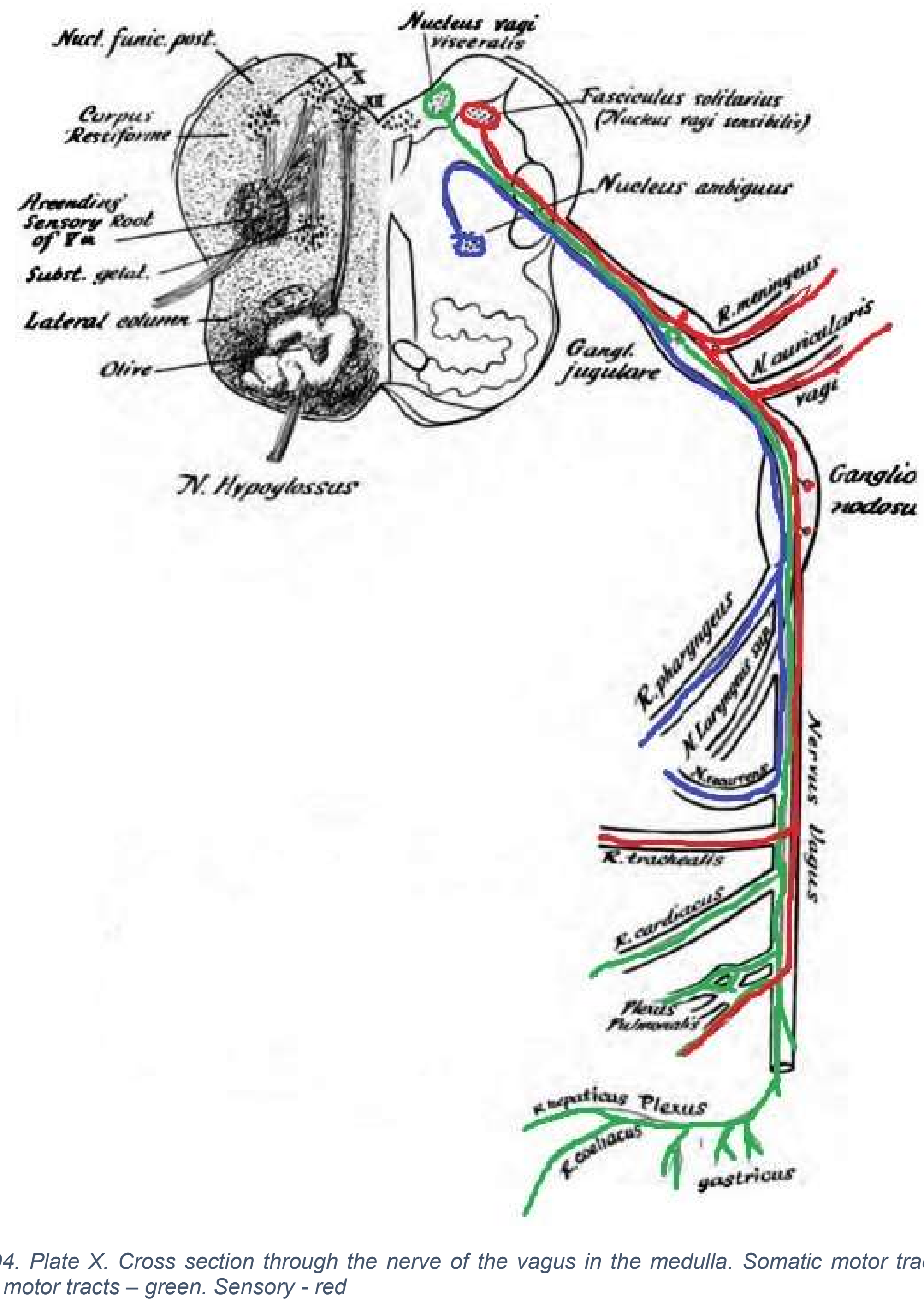

Figure 94. Plate X. Cross section through the nerve of the vagus in the medulla. Somatic motor tracts – blue. Visceral motor tracts – green. Sensory - red

One must realize that the sensory and motor nuclei of this nerve are closely bound by connecting fibers which cause reflex action to be readily transmitted from afferent sensory fibers from one viscus to efferent motor fibers in another, A similar connecting relationship exists between all nerves of craniobulbar origin which carry vegetative fibers. There is also a close reflex relationship between the cranial parasympathetics and the sensory portion of the Vth cranial nerve. These furnish the basis for the parasympathetic motor, secretory, and trophic reflexes which I have described in Chapter VII. The reflex relationship between the various cranial nerves is shown in Plate I, page 40, which should be carefully studied.

As an illustration of this relationship we have the slowing of the pulse by pressure on the eyeball, the afferent impulse traveling through the sensory fibers of the Vth cranial nerve and being transferred through connecting neurons to the cardiac branches of the Xth nerve; or provoking bronchial spasm (asthma) by nasal irritation, the afferent impulse traveling through the sensory fibers of the Vth cranial nerve and being transferred to the pulmonary branches of the vagus.

Chapter XXXI

The Vegetative Nervous System: General Physiologic Considerations

Relationship Between the Vegetative and the Central Nervous System

As the animal ascends in the scale of development from the simple to the more complex forms, greater demands are made upon it in its relationship to its environment as well as in the various relationships which are concerned with its own body functions. This increased complexity is met by an expanded and more intricate nervous system and a greater degree of coordination of action.

Advancement is particularly associated with development of integration of action and of the higher centres. Quickness of action becomes essential. As greater demands arc made upon the organism to adjust itself to the outside world, it becomes more necessary that there should be a separation of acts which are directly concerned in the maintenance of life, such as respiration, digestion and circulation from those which are more particularly concerned in the performance of work, protection, flight, or in the enjoyment of beautiful surroundings. Therefore, the division of the muscular system (the system of action) into voluntary and involuntary, was gradually evolved as a necessity; and these two systems have likewise evolved two nervous systems, which while connected, are more or less independent.

The control of the voluntary muscles and the nerve cells which give origin to the fibres of the voluntary system, lie wholly within the central nervous system. The control of involuntary muscles on tile other hand is more or less independent of the central nervous system; and the nerve cells which give origin to the motor fibers of this system lie wholly without the central nervous system. These motor cells travel out from the central nervous system in early embryonic life. They collect at points and form ganglia, some of which, like the *lateral* ganglia of the sympathetic, remain near the .tie segments of the cord from which they came; others, like the cells of the superior cervical and celiac ganglia, lie farther away from their points of origin; and still others, like the motor cells in the ganglia within the heart and those within the intestinal wall, lie within the organ innervated.

The independence of the vegetative system is shown by Langley's experiment, in which he severed the spinal connector neurons between the central nervous system and the motor ganglia which give origin to the true vegetative fibers, and still the animal lived and carried on the functions necessary to life, (See page 216.)

As the cells of the ganglia drifted away from the central nervous system, they were still held in connection with it by fibers, which Gaskell has termed "connector fibers," to indicate their function. We must look upon all the fibers of the vegetative system which connect the central nervous system and the motor cells of the vegetative system, whether they be in the lateral, collateral or terminal ganglia of the thoracicolumbar system; or in the walls of the organs innervated by the craniosacral system, as being "connector fibers" only, and not an integral part of the vegetative system. Thus, the vagus fibers are not in reality a part of the vegetative system, but instead furnish the link which binds the motor cells of the vegetative neurons which lie in the walls of the organs with the nuclei in the bulb.

Response in Voluntary and Vegetative Systems Compared

The response to sensory stimuli in the voluntary system is immediate. The stimulus is received by the receptor neurons, and carried to the higher centres where it mediates to produce reflex action or is converted into action by the will in a fraction of a second. The sensory impulse calls for a definite and immediate action in definite and limited structures.

In the vegetative system, the response is slower and less definite, and varies in the two divisions of the system.

The nonmedullated fibres of the thoracicolumbar segments give off many branches which go to supply tissues in widely separated structures ; therefore stimulation of a “connector neuron” of the sympathetic system may be confined to a single segment of the cord, and yet action be expressed in many widely separated and different structures. Each sympathetic ganglion must be looked upon as a place where the impulses which are transmitted to its motor cells are divided and transferred to many fibres to go to many structures.

The craniosacral outflow is far more selective than the sympathetic in its action. A stimulus which starts peripheral ward over a definite neuron in the parasympathetic system is not changed in its course, but goes directly to the motor cells in the structure to be innervated, and the only spreading of the action that can take place is through the plexuses which lie in the walls of the tissues themselves. This is evident from the fact that the true cells of the parasympathetics are in the tissues of the organ innervated. This is also true of certain sympathetic neurons found in the genitourinary tract.

Distribution of the Neurons of the Thoracicolumbar and Craniosacral Outflows

If we consider the body as a tube, and the skin and superficial tissues as the outside of the tube, and the gastrointestinal tract and the structures which belong to it embryologically (the bronchi and lungs, liver, pancreas and bladder) as the inside of the tube, then we have two particular groups of structures which are activated, one by the thoracicolumbar outflow, and the other by the craniosacral outflow.

These structures are very different. The outside of the tube is formed from the epiblast, the inside of the tube from the hypoblast. From the former are developed the epidermal tissues, the pilomotor muscles and muscles of the sweat glands which are innervated by the sympathetics. From the latter are developed the smooth musculature and secretory glands of the gastrointestinal tract, and the glands which open into it, the musculature and epithelium of the respiratory system, the bladder except the trigone, the prostatic portion of the male urethra, and possibly the entire female urethra. These structures make up what Gaskell terms the "enteral system" of smooth musculature. They are all activated by the craniosacral outflow {parasympathetics) and receive inhibitory fibers from the thoracicolumbar outflow (sympathetics). The male urethra seems to be almost wholly activated by the sympathetics.

The structures between the epiblastic tissues or the epidermal, and the hypoblastic tissues or endodermal, are derived from the mesoblast. These include the vascular p^^stem, the muscles, and other skeletal tissues, the generative and excretory organs, except the body of the bladder, prostatic portion of the male urethra and possibly the female urethra. The muscles and other skeletal tissues are innervated by the voluntary nervous system, while the vascular system, the generative and excretory organs, except as above noted, are innervated by the thoracicolumbar outflow of the vegetative system.

There are certain other structures, those belonging to the sphincter system, innervated by the thoracicolumbar outflow, which seem to be an exception to this division; yet instead of being an exception it may point to the fact as Gaskell stales that the sphincters are really an infolding of the epidermal tissues. This can be readily understood as far as the internal anal sphincter, and the sphincter of the urinary bladder are concerned, but it is more difficult to explain in case of the iliocaecal sphincter ; yet when wo consider that the length of the entire gastrointestinal tube in the lower forms of life is very short and that it lengthens as the body increases in size, and the nutritional needs become greater, we can readily understand Gaskell's suggestion of the displacement of this one-time dermal tissue.

Another peculiarity of vegetative innervation is that while each division of the thoracicolumbar and the craniosacral outflows furnishes motor or activating fibers for certain definite tissues, as just mentioned, they also both send inhibitory fibers to certain other structures; and when this occurs, the fibers of one system prove to be activating fibers, the others inhibiting fibers.

Antagonist Action of the Thoracicolumbar and Craniosacral outflows

The principle of equilibrium continuously manifests itself in the human machine. The normal individual is the one in whom the activity of all organs and structures are existing in a state of equilibrium; such an individual, if he existed, would have a perfect nerve balance. Many viscera, as is now clear, are innervated by both divisions of the vegetative nervous system, one activating and the other inhibiting action, equilibrium being maintained by preserving this normal antagonistic action. Whenever one system is stimulated to such an extent that it overbalances the other, a disturbance in function ensues and symptoms manifest themselves. Symptoms may further result from a disturbance in the normal controls of the body: *chemical,* as a result of altered internal secretion and nerve, either in the voluntary or vegetative system. The stimuli may be either physical or *psychic* in origin. The body activities are so accurately connected and integrated, that it is impossible for any marked and continuous disturbed equilibrium to take place in any one mechanism of control without disturbing or destroying the integrity of the other; yet he must conceive of this same integrative force as continuously operating to maintain equilibrium.

This difference in the sympathetics and parasympathetics is further shown in their general control of body function. The sympathetic is often called the destructive or katabolic system as applied to the human body and the parasympathetic, the constructive or anabolic system. The parasympathetics, in their control over salivary and gastrointestinal action (and in this we include lungs, liver, pancreas, and bladder) build up energy and conserve the forces of the body; while the sympathetics as shown by Cannon serve to prepare the body for struggle under conditions of stress. While the sympathetics dilate the pupil, quicken the heart, and drive the blood from the splanchnics into the heart and skeletal muscles and brain in order that the body may expend its energy to greater advantage, they at the same time inhibit the action of the gastrointestinal tract, that no unnecessary energy may be expended. They prepare the body for a supreme struggle depending on force already stored up. The parasympathetics, on the other hand, prepare the food for digestion and assimilation and thus look after the continuous needs of the organism.

Tonus

Tonus is the condition of tissues in physiologic balance. We must understand it as an active condition. It is maintained by an active force.

In vegetative neurology, we are forced to assume that in some structures such as the muscles of the sweat glands and pilomotor muscles, as well as in mo.st of the vascular system, the sphincters and most of the urogenital structures, this tonus is maintained by the action of one system of nerves (sympathetic) alone, since we, as yet, do not know of fibers from the craniosacral outflow going to these tissues. In other structures, such as the heart, the pupil, the salivary glands, the respiratory system, the digestive tube and other structures which have been derived from it embryologically, the tissues seem to be maintained in physiologic equilibrium by two opposing nerve forces, the one activating, the other opposing or inhibiting. In fact, we tend that in all structures which are innervated by both the thoracicolumbar and the craniosacral outflows, that one of these systems is the activating, the other the inhibiting. In the heart and the sphincters, the sympathetic activates while the vagus of the craniosacral outflow (parasympathetics) inhibits. In the pupil, the salivary gland, the respiratory tract and the digestive tract with the structures derived from it, the cervix uteri and the body of the bladder, the craniosacral system activates while the sympathetic furnishes the inhibiting force.

This antagonistic action of the two divisions of the vegetative system becomes a very important force in visceral neurology. Harmful impulses which influence the vegetative nerves centrally are more or less selective in their action and express themselves usually in one division more than in the other or to the exclusion of the other, as is illustrated in the action of toxins through the sympathetics and anaphylactic substance, through the parasympathetics, We are also led to believe that the various internal secretions and all physiologic as well as pathologic chemical substances are selective in their action.

Carbon dioxide acts through the vagus in controlling respiration, while adrenin produces the same action as stimulation of the sympathetics. The toxins (Vaughan) derived from protein produce a train of symptoms which is characteristic of general sympathetic stimulation as described in Chapter III.

While toxins influence nerve cells generally, yet the peripheral expression of toxemia in visceral structures is that of sympathetic stimulation. The most prominent symptoms, varying according to the degree of toxemia present, are: Malaise, aching, chilliness or rigor, nerve instability, lack of appetite, digestive disturbances (hypo- motility and hyposecretion), constipation, loss of weight, rapid pulse, vasoconstriction, particularly of the superficial blood vessels; increased blood pressure, sweats, rise in temperature, blood changes (leucocytosis in which polynuclears predominate), lack of endurance, loss of strength. If the toxemia becomes very severe, vasodilatation, sweating, subnormal temperature and collapse may appear.

The substances derived from the sensitizing or anaphylactic producing molecules (Vaughan) on the other hand, produce symptoms which indicate a predominance of stimulation in the craniosacral system.

Tonus is a physiologic condition of tissue which depends upon a certain degree of stability in nerve cells, and a certain degree of limitation of stimulation. A tissue may preserve its normal tonus even though the cell bodies of the neurons supplying it are subject to the action of stimuli. Tonus may be disturbed whenever the cell bodies, upon which the tissue in question depends for its activity, become hypersensitive to stimuli or when the stimuli are sufficiently strong to overcome the normal resistance in the cells. There are many conditions in the human body, some probably constitutional; others due to conditions of education ; and still others due to pathologic conditions within the body, which increase the irritability of nerve cells beyond that which is found in normal individuals. In the vegetative system this is so pronounced that two groups of individuals may be recognized : One in whom there is an increased irritability in the cell bodies of the parasympathetics, and another in whom there is an increased irritability in the cell bodies of the sympathetics, Eppinger and Hess have called the former "vagotonics," and the latter "sympathicotonics" Sometimes this increased irritability is shown in certain groups of neurons belonging to one or the other division of the vegetative system instead of in the division as a whole. Thus, in hay fever the cell bodies of the neurons of the VIIth cranial nerve seem to show hyperirritability above that of the parasympathetic cell bodies generally.

In transferring the idea of *tonus* from the tissues to the divisions of the nervous system as in the terms "vagotonia" and "sympathicotonia", there is a distortion of the true meaning of the term tonus as used in physiology. What is really intended to be conveyed by these terms is a condition of hyperirritability. Vagotonia means a condition of parasympathetic hyperirritability; and sympathicotonia a condition of sympathetic hyperirritability. A literal translation of these terms, on the other hand, would be a vagus physiologic balance and a sympathetic physiologic balance, conditions which fail to convey any idea. The terms vagotonia and sympathicotonia are now well established in medical terminology, and it is probably unwise to attempt to change them. It is desirable, however, to assign to them the idea of hyperirritability instead of physiologic equilibrium.

The antagonistic action of the two divisions of the vegetative system in the production of normal equilibrium (tonus) in internal viscera and their disturbed relationship as a cause of many of our common symptoms in diseases of those viscera, affords us a subject which will well repay most careful and painstaking investigation.

Methods and Results of Studying Thoracicolumbar Control of Body Structures

There are several ways in which the nerves have been studied; one by severing the fibre from its nutrient centre and following out the degeneration according to the law of Waller; another by stimulating the end of a severed fibre and studying the parts activated. These methods have been used in studying the white rami communicantes and have shown that the sympathetic system is in connection only with that portion of the cord between the 1st thoracic and 3rd lumbar segments. It has also shown that no white rami are given off from the cord in those segments which give origin to the nerves in the fore and hind limbs, the cervical and lower lumbar segments: and further that all true vegetative motor (nonmedullated) fibers ari.se in ganglia without the cord.

It readily can be seen, however, that a study of the true sympathetic fibres cannot be made by studying the effects of stimulation of the white rami after degeneration has taken place; because these are only connector fibers. The true sympathetic fibers are the nonmedullated fibers which arise from the motor cells which lie in the various lateral, collateral and terminal ganglia. It would be necessary to cut or stimulate the fibers after they emerge from their nutrient cells in the ganglia in order to determine the structures innervated by them; and further, it is impossible to observe the degenerative changes in them because they are nonmedullated, and degeneration shows in changes in the medullary sheath.

Langley devised the method of employing nicotine for the study of the sympathetics. He showed that nicotine either paralyzes the motor cells in the ganglion or interferes with the synapse; and that, whereas a ganglion so treated fails to transmit stimuli which are applied to the fibres proximal to the ganglion, stimulus applied to the fibers distal to the ganglion are transmitted to the end structures.

By the employment of nicotine Langley was able to trace the connector fibers from the cord to the ganglion in which they end, and then follow the nonmedullated sympathetic fibers to the structures innervated by them. lie termed the fibers proximal to the ganglion in which they end (connector fibers of Gaskell) "preganglionic;" and the nonmedullated fibers which arise in the ganglion, "postganglionic;" and was able to show that all "preganglionic" fibers end in ganglia and that none of them go to the tissues direct. The connector fibers to the medulla of the adrenals might be considered as an exception to this, because the fibers do not end in a ganglion prior to entering the gland; hut the cells of the medulla themselves are sympathetic cells and must be considered the same as other groups of sympathetic motor ceils (ganglia), Langley further showed that many fibers which enter a ganglion are not influenced by the application of nicotine to that ganglion, but that they go on and end in a more distally situated ganglion. In this manner it was shown that all "preganglionic" or connector fibers of the sympathetic system which innervate internal viscera, pass through more than one ganglion before ending in the true motor cells of the sympathetic system.

By this method it has been shown how far the sympathetic motor cells have travelled from their original place in the spinal cord. While motor fibers going to skeletal muscles pass directly to the muscle fibers from the motor cells in the cord, every efferent sympathetic connector fibre arising from the cord is interrupted by one (and only one) ganglion. It may send off many collateral branches to cells in other ganglia on its way, but no fibre is ever interrupted by ganglion cells more than once before reaching the end organ supplied by it. The collateral branches, therefore, which are responsible for the wide distribution of the sympathetic impulses are all given off from the "preganglionic" fibers. The collateral ganglia supply the viscera only and send no fibers to the spinal nerves to be distributed to such structures as the pilomotor muscles, muscles of the sweat glands and the blood vessels of the skeletal structures. The fibers supplying these structures arise from motor cells in the lateral ganglia.

The great majority of the nonmedullated fibers from the lateral ganglia, run back as grey rami to the corresponding spinal nerves or 1o the spinal nerves next higher or next lower. They then follow the spinal nerves to their destination and are distributed to the dermal tissues, pilomotor muscles and muscles of the sweat glands. In the neck and trunk the dermal tissues supplied by the grey rami overlap very little, the segmental relationship of the spinal nerves being preserved. In the fore and hind limbs, however, the segmental relationships are not preserved.

The ganglia of the sympathetics have no special arrangement accounting to the function of the tissues innervated by them. The cells of a ganglion send out their nonmedullated fibers to take care of all the tissues supplied by the sympathetics in a certain region, no matter what their character, whether muscular or secretory.

Sensory, Sympathetic and Craniosacral Nerves

Visceral organs are comparatively insensitive to pain, yet they are supplied by sensory neurons. (See page 74.) We must conceive of a more or less continuous flow of sensory impulses traveling centralward from tissues supplied by the vegetative system, the same as from the voluntary system. *Sensory impulses from the internal viscera supplied by the sympathetics, are conveyed centralward by the afferent sensory neurons of the sympathetic system; but those from the skeletal structures supplied by the sympathetics are conveyed to the cord by way of the spinal nerves.*

The internal viscera contain so-called "Pacinian corpuscles" which have the function of sensory end organs. A sensory stimulus arising in viscera is transmitted to the cord through sympathetic fibers, and then expressed through the spinal sensory nerves upon the surface of the body. Such reflex sensory impulses are segmental in character. As "viscerosensory" reflexes they are very important in the study of visceral disease. (See Chapters V and VI,} There are other sensory stimuli passing from the viscera centralward, which do not evoke pain. They are not sufficient to awaken consciousness. In fact, the viscera normally carry on their function without their impulses coming within the field of consciousness. Other visceral impulses on reaching the cord are transferred to the motor cells instead of the sensory cells. The result is a "visceromotor" reflex (see page 51). Like the "viscerosensory" and "viscerotrophic" reflexes (pages 46 and 64) this is also segmental in character, and also of great value in the study of diseases of internal viscera. These are fully discussed in the clinical chapters.

The transmission of sensory impulses in the thoracicolumbar outflow and the craniosacral outflow, differs in several important particulars.

1. The craniosacral outflow supplies all structures innervated by- it with both afferent and efferent fibers; while, as mentioned above, this is only true of the viscera among the structures

supplied by the thoracicolumbar outflow, the afferent fibers from the peripheral vessels and dermal structures proceeding to the cord through the spinal nerves.

2. Sensory afferent fibers from all viscera supplied by both thoracicolumbar and craniosacral outflows, which are connected with the skeletal structures by efferent viscerosensory or visceromotor reflex paths, connect almost entirely through the thoracicolumbar nerves and rarely through the craniobulbar and sacral nerves,

3. Sensory impulses which travel centralward in the craniobulbar and sacral outflows, confine their resultant reflexes for the most part to other organs supplied by the same outflows. An important exception is the sensory portion of the Vth cranial nerve which stands in much the same relationship to the parasympathetics as the spinal sensory nerves do to the sympathetics.

4. The reflexes from the sacral afferent impulses are shown for the most part in efferent effects through the sacral spinal nerves.

From this distinction it can be seen that many visceral reflexes expressed through the sympathetic system will be expressed in the skeletal structures. All sympathetic reflexes, however, are not expressed in skeletal tissues. No doubt there are many disturbances in viscera and many vasomotor disturbances in which both afferent and efferent impulses are carried over the sympathetic nerves.

Reflexes produced by stimuli from tissues supplied by the craniobulbar and sacral outflows on the other hand, will be expressed largely in other infernal viscera instead of the skeletal structures. This is a very important fact because of its bearing on the study of the symptomatology of inflammation of internal viscera. The most evident exceptions to this are (1) the spasm of the trapezius and sternocleidomastoideus muscles in which a "visceromotor" reflex is caused through afferent sensory fibres in the vagus and efferent motor fibers in the spinal accessory; (2) the many visceral sensory reflexes (headaches) paused by afferent parasympathetic impulses from the viscera expressing themselves peripherally through the sensory fibers of the Vth cranial nerve; and (3) the sensory reflexes in the sacral spinal nerves which result from inflammation of viscera supplied by the pelvic nerve.

Functions of the Sympathetic Ganglia

From the discussion which ha^ preceded, some of the functions of the sympathetic ganglia are very evident. There is one very important relationship, however, which requires to be inquired into, that of the true relationship between the ganglia and the central nervous system.

If the ganglia are cell masses which have travelled out from the central nervous system, do they still retain the characteristics and have the function of the cells of the central nervous system. Do the cells within them have the power of mediating reflexes without the impulse going back to the cord?

From physiologic data which have been obtained so far, it seems that this question can be answered almost without doubt in the negative; yet there are observers who take the opposite view. On this point it is well to quote opinions.

Gaskell says:

"All the afferent fibres have their nutrient centres in the posterior root ganglia. No peculiarities, therefore, exist on the afferent side; the course of the sensory fibers is the same in all sensory nerves, viz: direct to the cells of the posterior root ganglia with no connection with any cells in sympathetic ganglia. Seeing then that all the fibers entering into the posterior root ganglia are medullated, it follows that all nonmedullated fibres are efferent, none afferent, and that the *so-called sympathetic system is not a complete central nervous system, but consists purely of excitor neurons."* [Italics not in original.]

Langley discusses the phenomena which seem to support the theory of the ganglia being true reflex centres but comes to the conclusion that they are due not to the impulse being transmitted from a sensory sympathetic fibre to a motor sympathetic fibre through the mediation of the ganglion cells, but to branches which are given off from the medullated fibers prior to the time that they end in the ganglion cells.

This opinion of Langley is discussed so well by Luciani that I will quote it extensively:

"Are we to regard these masses of ganglion cells as portions of the cerebrospinal axis which have been displaced to the periphery, but are still endowed with the functions of the centres? The earlier anatomists seemed to incline to this view when they gave the name of *cerebrum abdominal* to the solar ganglion. We have learned that the fundamental property of the central nervous system lies in its capacity for subserving reflex acts, so in order to decide this question we must ascertain whether the ganglia of the sympathetic system are capable of subserving reflexes,

"From the above conclusions on the course of the afferent fibers of the sympathetic, any such possibility must a priori be excluded, seeing that all or nearly all the afferent paths run without interruption to the spinal ganglia, and never enter into direct relations with the sympathetic ganglia. The excitations which they transmit must therefore reach the centres of the cerebrospinal axis before they can be reflected again to the periphery.

"This logical conclusion is apparently contradicted by a series of observations which seem to show that under certain conditions the spinal ganglia may function as true reflex centres. Claude Bernard (1864) was the first to describe these phenomena. After dividing the lingual nerve above the point at which it emerges from the chorda tympani, and thus cutting off all connection with the central nervous system, he artificially stimulated the peripheral end of the lingual nerve, and saw an abundant secretion from the submaxillary gland. We have already recorded the experiments of Sokowin who observed that after cutting off all direct communication with the spinal cord, stimulation of the central end of the hypogastric nerve induces contraction of the bladder on the opposite side. This observation, subsequently confirmed by Nussbaum, Nawrocki and Skabitschewski, and others, was interpreted to imply that the inferior mesenteric ganglion was able to function as a reflex center.

"Other similar facts were observed in the sympathetic nervous system by Langley and Anderson. They saw on repeating the experiment of Sokowin that stimulation of the hypogastric also produced contraction of the internal anal sphincters, ischemia of the rectal mucosa, slight pallor of the cervix and body of the uterus on the opposite side, etc. Langley (assisted partly by Anderson) obtained similar results for the pilomotor muscles and the cutaneous blood vessels in the thoracic and lumbar regions.

"But, according to Langley, none of these reactions, in which excitation of the central end of a sympathetic trunk after separation from the higher centres causes motor or secretory effects, are true reflexes. His arguments and interpretation will be better understood by giving a specific example:

"If the lateral strand of the sympathetic be cut in the eat immediately above the 7th lumbar ganglion, and the central (cranial) end stimulated, erection of the hairs with contraction of the blood vessels will be seen in the cutaneous regions innervated by the 4th and 5th lumbar roots. The same effects may be obtained many days after, when sufficient time has elapsed for the degeneration of afferent nerve- fibres with trophic centres below the level of section. It follows that the excitation in this case is not conducted by fibers whose trophic centres lie in the lower portion of the sympathetic. If the nerve roots of the 4th or 5th lumbar ganglion are now cut the reaction described disappears after five days. We must, therefore, conclude that the excitation was transmitted by preganglionic efferent fibres.

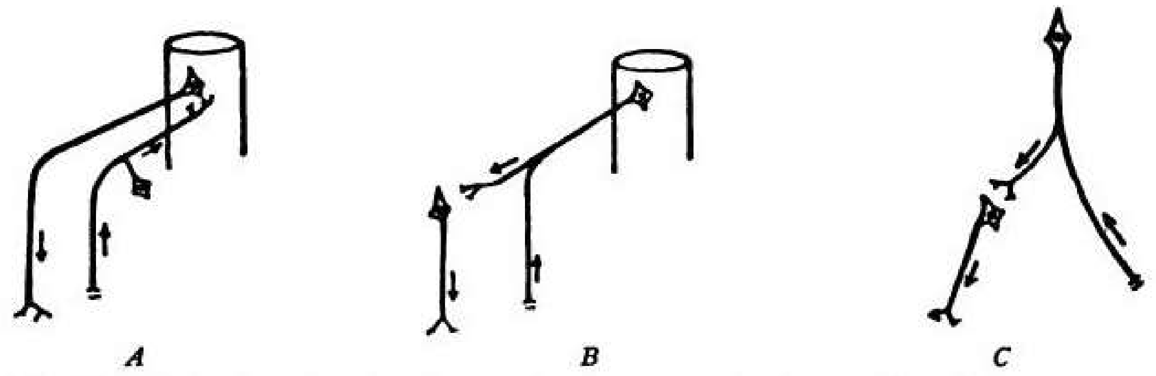

Figure 95. Mechanism of action of reflexes.
A – true reflex; B – pseudo-reflex; C – Common diagram for A and B

"This striking fact that the supposed reflex ceases on degeneration of the preganglionic fibers is, according to Langley, common to all so-called 'sympathetic reflexes' hitherto described.

"The only possible explanation he can find is that each preganglionic fibre divides into several collaterals, and sends branches to different ganglia. Stimulation of the central end of one of these fibers causes an excitation that is at first propagated backwards along the cut fibre, and then to another twig, until it reaches the ganglion which gives origin to the postganglionic fibers that evoke reaction. In other words, this is a similar process to that described by Kühne in his experiments on the conduction of motor nerve in both directions. Langley has proposed to call this special phenomenon by the name of *pseudoreflexes* or *preganglionic axon reflexes*. Fig. 198 [94 in this text] is a diagram of the course of the excitation as compared with a true reflex. Langley utilized these pseudoreflexes for the purpose of experimentally determining which preganglionic fibres are connected with different ganglia."

He concludes: "In my opinion none of the 'apparent' reflexes of the autonomic ganglia depend on a reflex mechanism similar to that which subserves reflexes in which the central nervous system is concerned, as in no case is an afferent fibre concerned in the process."

"Another argument adduced by Schultz against the view that the sympathetic ganglia act as true reflex centres is that stimulation of both postganglionic and preganglionic fibers has the same effect ; and that no summation can be seen from the latter, such as is observed in the central nervous system.

"Intimately connected with the functional importance of the sympathetic ganglia is the question whether, after separation from the cerebrospinal axis, they are capable of sending ionic impulses to the peripheral organs which they innervate. This point, too, has received various answers.

"The simplest method of solving it evidently consists in severing the preganglionic fibres on one side of the body, and the postganglionic on the other, or in extirpating the whole ganglion. As the results can be compared on the two sides of the body it should be easy to deduce the influence exercised by the ganglia alone, apart from the cerebrospinal axis. The cervical sympathetic, and the superior cervical ganglion which has a dilator action on the pupil, are well adapted for this experiment, but the results obtained by various authors (Budge, Braunstein, Langendorff, Kawalewsky, Shultz) disagree. According to the three first, the pupil is contracted for some hours to one or two days after the extirpation of the cervical ganglion, which implies that the ganglion really has a tonic dilator action, on suppression of which the pupil contracts. But when the influence of the ganglion is removed without irritation, no difference is observed in the width of the pupils.

"Similar researches have been made on the ciliary ganglion. This ganglion normally exerts a tonic action on the sphincter pupils, which is maintained reflexly by the light that impinges on the retina, and excites the ganglion by way of the optic nerve and mesencephalon.

Section of both optic nerves in an animal causes dilatation of the pupil; according to Schultz and Lewandowsky the ciliary ganglion has no influence on this, for the pupil is not further dilated if the nerves to the sphincter are cut on one side or the other of the ganglion.

"Accordingly it is not possible to demonstrate that either the superior cervical ganglion or the ciliary ganglion have any constant tonic influence. Still loss can this be proved, as Langley says, for the other peripheral ganglia of the sympathetic. Nor is this surprising seeing that all the known tonic influences exerted by the central nervous system invariably take place reflexly, while the sympathetic ganglia are unable, as we have seen, to subserve reflexes independently of the cerebrospinal axis."

Bechterew takes the opposite view from Gaskell and Langley, and considers the sympathetic ganglia as having the functions of true reflex centres. He considers that when these ganglion cells migrated outward from the cord, they carried with them the true functions of the cells of the spinal cord. On this point he says:

"The functions of the sympathetic nervous system are divided, as is well known, into sensory, motor, secretory, and trophic. The sensory sympathetic fibres transmit impressions to the spinal cord and brain; the motor, supply the involuntary or unstriped musculature. Aside from this, there are mixed fibres which *establish a connection between neighbouring sympathetic ganglia*. The tonus of unstriped muscle fibers is reflexly maintained through sympathetic ganglia. The sympathetic system is also, without doubt, operative in *originating many reflexes in the sphere of the internal organs.*

"There is lacking today scarcely a single proof of the fact that cellular interruption of nerve fibers takes place in the sympathetic ganglia. With this fact established these ganglia assume at once the role of true nerve centres." It follows as a consequence from the proof of interruption as produced by Ramon Y. Cajal that the nature and manner of the relationship between nerve fibers and nerve cells in the sphere of the sympathetic system is in reality the same as in the spinal and cerebral portions of the central nervous system.

"Central Characteristics of the Sympathetic Ganglia. Langley examined the question of whether or not the sympathetic ganglia were real nerve centres from the experimental standpoint- In this he found that if the sympathetic was divided its fibers degenerated only as far as its ganglion, never beyond. Another purely physiologic proof is shown by the use of nicotine. If it is injected into the blood stream or if it is applied locally to a sympathetic ganglion, irritations which are active when applied to a nerve fibre belonging to a ganglion prior to its entrance in the ganglion are inactive beyond that ganglion, although normal excitability is preserved by the fibers.

"Especially strong proof of the sympathetic ganglia being independent nerve centres is provided by those experimental cases in which reflex phenomena appear in organs which are deprived of all connection with the central nervous system.

"In this relationship, there can be no doubt of the extreme importance of the visceral and lateral ganglia of the sympathetic system. The local centres situated in them guarantee to the viscera a certain independence in the sense that if they are separated from the central nervous system they will not degenerate, nor will they cease to functionate; but they will appear as respects their activity to be wholly free from the influence of those (higher) centres which control the activity of all body organs in the cooperative service of our physiologic economy."

Luciani,' while leaning to the view held by Langley and Gaskell, says that peripheral ganglia may survive for years after being separated from the cerebrospinal axis, and be capable of reacting to poisons and internal secretions.

There seems to be a general consensus of opinion to the effect that the ganglia are centres in which impulses coming from the central nervous system are reinforced. They are also centres for distributing the impulses widely. It has been shown that the number of fibers leaving a ganglion are always more than those which enter it. Therefore, they may be looked upon as distributing centres for impulses.

The functions of the sympathetic ganglia and their relationship to the cerebrospinal system can be best understood by studying the effect of removing the cord, upon an animal. The manner in which the functions of the sympathetic system are carried out is surprising. I quote from Luciani:*

"Since the innervation of the organs of visceral life is supplied directly by the sympathetic ganglion system, a final and interesting problem here presents itself. Are the functions of the sympathetic system subordinate to those of the spinal centres, or can they subsist independently of them?

"To solve this question it is necessary to study the immediate and remote effects of ablation of the cord. Previous to the remarkable results obtained by Goltz and Ewald in 1896, such a research would have been impossible. They first demonstrated that dogs can survive for many months in a good state of health after repeated removal of parts of the cord from below up to the cervical region; so that the opinion previously maintained by every one — that in warm-blooded vertebrates the cord is absolutely indispensable to life, as the regulator of the nutritional processes, the vascular tone, and the thermal equilibrium of the organism — is fallacious.

"As we have already seen, after simple section of the dorsal roots of the spinal nerves the tissues that become insensitive are more liable to injury than before. This is, of course, most marked in the posterior part of the dog with amputated cord. Patches of decubitus, pustules, erythema, oedema, especially near the genital organs and anus, are extremely likely to appear; but these cutaneous lesions can be avoided or cured by constant and scrupulous cleanliness. By degrees, however, the skin of the cordless animal gradually acquires an increasing resistance to external injurious influences.

"Even more important to the survival of these animals is the avoidance of a fall in the blood temperature, which is liable to occur directly after simple transection of the cord, by enclosing the animal in a chamber with double metal walls, between which warm water is continually circulated.

"The persisting activities in the posterior part of the animal that has lost its thoracic and lumbosacral cord are far more numerous than would be anticipated a priori from what we have learned experimentally with regard to the functions of the spinal cord. The immediate effects of removal of the cord are principally due to operative shock. After a few months they diminish sufficiently to give a clear idea of the great physiologic importance of the sympathetic ganglion system, in so far as it is capable of acting on the organs and tissues of vegetative life, independently of the spinal system.

"Directly after ablation of the thoracic and lumbosacral cord, the external sphincter of the anus is entirely relaxed; but after a few months (as already shown in Vol. II, p. 372) it regains its tone. It reacts to mechanical traction, to injections of cold water, to induced currents; it may also recover the rhythmical automatic contractions —independent of external stimuli — which it manifests after simple division of the cord from the higher centres. From these facts Goltz and Ewald concluded that the anal sphincter, in addition to the cerebral and spinal centres, possesses peripheral sympathetic centres, which possibly lie in the depth of the muscle.

"Unlike the sphincter, which also consists, of striated muscle, all the striated skeletal muscles atrophy. First they lose their faradic, next their galvanic excitability, lastly, they become inelastic and are reduced to bundles of connective tissue. The bones also alter and become brittle. The digestion, which is disturbed during the first days, becomes normal again in the course of a few weeks. Defecation takes place regularly once or twice a day, and the faeces are natural in appearance. The urine is clear, free from sugar and albumin. The bladder, which is paralyzed for the first days, gradually recovers its functions, and after a few months evacuates the urine collected in it, periodically and spontaneously, and when evacuation has taken place the animal remains dry for hours.

"A pregnant bitch, a few hours after extirpation of 9.4 cm. of cord, gave birth to five puppies, one of which was left to her to suckle, which she did perfectly. The puppy sucked all the mamma; in turn and even the last pair, which were entirely deprived of spinal innervation, yielded on abundance of milk.

"The tone of the blood vessels in the dog that has lost its cord recovers completely in a few days. The temperature of the denervated posterior limbs becomes the same as that of the anterior, which are still innervated by the spinal nerves from the cervical region. From this it can be seen that the vascular tone does not depend exclusively upon the bulb and cord, as was formerly supposed, but that even under normal conditions the sympathetic ganglion system must have an enormous influence over it.

"One sciatic nerve was divided in a dog that had lost the lumbosacral part of its cord; at first there was a marked difference in the diameter of the vessels and the temperature of the paralyzed hind limbs, but after a few days these differences disappeared. On stimulating the skin of the posterior part of the cordless animal, it is not possible reflexly to influence the vessels at remote parts of the skin, but all stimuli have the same local effect in the posterior as in the anterior part of the animal. Unipolar excitation by induced currents produces pallor of the prolapsed mucosa of the rectum, and heat and cold affect the cutaneous vessels of the hind limbs in the same way as those of the fore limbs.

"Owing to this local excitability of the cutaneous vessels, the cordless animal is capable of maintaining its normal blood temperature during marked oscillations of the external temperature, and though it is necessary to keep it in a chamber with constant temperature immediately after the operation, this precaution becomes unnecessary in a few weeks.

"At the season for changing the coat, a marked difference is seen in the hair of the anterior and posterior parts of the body; in the former it is new and glossy, in the latter it is dull and lifeless, and comes out at the least pull.

"From these phenomena as a whole we must conclude that the cord is not absolutely indispensable to life in warm-blooded vertebrates, but that it is important to the visceral functions.

"The absence of the spinal centres is responsible for the low energy with which these functions are carried out under the exclusive influence of the sympathetic system, and the great instability in the health and vitality of the cordless animal, which requires constant care, and easily falls ill and succumbs to slight causes.

"The closure of the anal sphincter in a dog in which the cord is simply transected is firmer than after removal of the cord, and the rhythmic reflex contractions of the anus that are easily seen in the 'spinal' animal are exceedingly rare in the 'sympathetic' animal.

"Even more striking is the diminished energy of the vesical functions in the cordless animal; the bladder, moreover, is often infected, and mo.st of the animals die of cystitis and pyelonephritis. Only in rare cases has it been possible to cuie the cystitis when it has once set in.

"Digestive disorders, again, are very dangerous to the animal that has lost its cord.

"Finally, in the cordless animal thermal regulation is only possible with limited variations of the external temperature.

"These important observations of Goltz and Ewald on the symptoms produced by removal of the spinal cord enable us to appraise the value of the early doctrine (see p. 195), by which the sympathetic system was held to preside over the functions of visceral life. Undoubtedly all such activities may subsist and function in a comparatively normal fashion after removal of all spinal influence. The office of the spinal system in regard to the functions of visceral life seems to consist in endowing these functions with greater energy', and in conferring greater stability and more solid equilibrium on the general constitution of the animal."

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Chapter XXXII

Pharmacologic Differentiation Between Neurons of the Thoracicolumbar and Craniosacral Outflow

While fibers from the thoracicolumbar and craniosacral systems both supply practically all of the important internal viscera belonging to the enteral system, their action is different. The fibers of these two systems are so closely connected in their distribution in these organs that it is impossible to differentiate them anatomically. Fortunately certain pharmacologic remedies have been found, some of which act only upon the tissues activated by the sympathetic system, others of which act only upon those tissues supplied by the craniosacral system. These substances have made it possible for us to obtain a fair working knowledge of the vegetative system. It is necessary for one to acquaint himself with the pharmacologic substances which have proved of greatest value in differentiating tissues activated by these systems, if he would study the action of the vegetative nervous system.

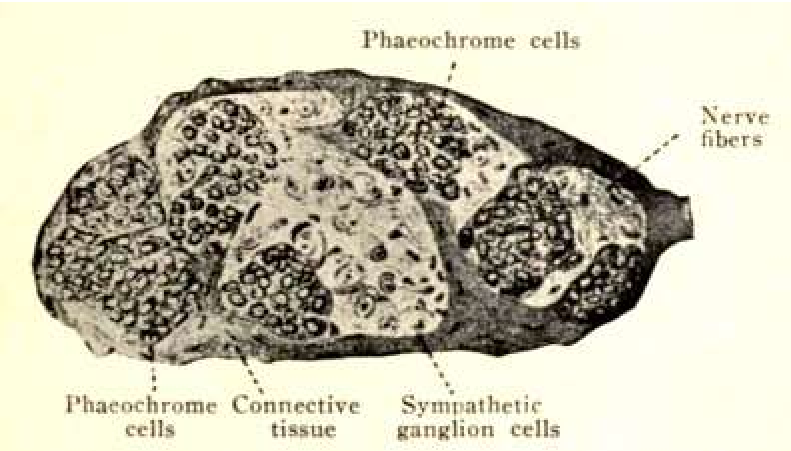

Figure 96. Section of a sympathetic ganglion in the coeliac region of a frog. (Rana esculenta) This shows differentiating phaeochrome cells. (Giacomini, from Bailey and Miller)

1. **Adrenin**. This substance is a product of the chromaffin tissue which has been deposited in the medulla of the suprarenal bodies. These chromaffin cells in the suprarenal body and the motor cells in the sympathetic ganglia are embryologically related. They belong to the same thoracicolumbar outflow from the spinal cord. Bailey and Miller[1] thus describe the formation of the medulla of the suprarenal body:

"A little later than the appearance of the cortical anlage, the cells of some of the developing sympathetic ganglia become differentiated into two types (1) the so-called sympathoblasts, which develop into sympathetic ganglion cells, and (2), phaeochromoblasts, which are destined to give rise to the phaeochrome or chromaffin cells (Fig. 387 [Fig. 95 in this text). Hence the chromaffin cells are derivatives of the ectoderm, since the ganglia are of ectodermal origin."

Gaskell in his study of the origin of vertebrates, finds that adrenalin makes its appearance with the development of a contractile vascular system and suggests that the chromaffin nerve cells of the invertebrate are the ancestors of the adrenalin secreting cells and the sympathetic ganglion cells of the vertebrate.

Elliott[2] pointed out a very important fact in establishing the relationship of the cells in the medulla of the suprarenal body and those of the sympathetic ganglia, namely; that the fibres which connect with the cells of the medulla of the suprarenal body are "connector," medullated fibres. They have not previously connected with any cells of the sympathetic ganglion system but come directly from the cells in the lateral horn of the cord, the same as all the connector fibers. From this it is but natural to conclude that these cells and the sympathetic ganglion cells are of the same system and same nature.

The particular value which adrenalin has in facilitating the study of the sympathetic nervous system, comes from the fact that central stimulation of the sympathetic nervous system and intravenous employment of adrenalin, produce practically the same effects throughout the body tissues. Adrenalin acts peripherally; in the lateral and collateral ganglia for blond control (Hartman) and at the point where the sympathetic nerve fibres come in contact with the muscle cells the myoneural junction but produces the same effect as though the sympathetic system were centrally stimulated. The only notable exception to Ibis is found in the sweat glands. Stimulation of the sympathetics will cause a flow of sweat, whether this is due to the contraction of the muscles about the gland squeezing the secretion out or to a true stimulus to secretion, is not yet known, adrenalin, however, will not cause sweating.

By the employment of adrenalin and observing its effect upon the various smooth muscles and secretory glands of the body, physiologists have been able to work out tbc action of the sympathetic nervous system with a large degree of accuracy, and to put in the hands of the clinician a basis for understanding many clinical symptoms.

2. **Acetylcholine** is a substance derived from ergot. When injected into the blood in minute doses, it stimulates the nerve endings of the cranial and sacral divisions of the vegetative system. In this way it differentiates the action of the craniosacral division from the thoracicolumbar system. In minute doses it produces vasodilation, and in the strength of 1:100.000, 000 produces inhibition in the frog's heart. Throughout the entire gastrointestinal tract it produces the same effect as that produced by stimulation of the bulbar and sacral vegetative fibres. It produces vascular dilation. Reid Hunt[3] draws the following conclusions as to the vasodilator effect of acetylcholine

"It has been shown in the above that acetylcholine has an intense vasodilator action on the vessels of the skin and of the ear; the action on the skeletal muscles is slight. It dilates the vessels of the penis, of the submaxillary gland and of the spleen: it seems also to dilate the vessels of the intestines and liver. Only slight evidence of a dilator action was found in the case of the kidney and none in that of the long. The nasal mucosa seemed relatively less sensitive to the vasodilator action of acetylcholine than many other vascular areas. The vasodilation in all of these cases was diminished or prevented by atropine.

"As little as 0.000.000, 002,4 mg. acetylcholine per Kg. caused a pronounced fall of blood pressure.

"Acetylcholine injected into the trachea or applied to the surface of the lung, kidney, liver, adrenal and various muscles was very active in causing a fall of blood pressure; similar doses applied to the sur- face of the stomach, spleen and small intestine had no effect on the blood pressure.

"The mechanism involved in the vasodilator action of acetylcholine and related bodies is different from that involved in the action of any of the nerves (posterior root, parasympathetic and sympathetic) to which vasodilator functions have been attributed. It is also different from that involved in the depressor action of epinephrine.

"This mechanism, although capable of more energetic response than any hitherto described, is not involved in the action of the depressor or of other afferent nerves causing a fall of blood pressure.

"The only substances found having the same type of vasodilator action as acetylcholine were a limited number of compounds derived from, or closely related to, choline and pilocarpine and colchicine.

"Atropine and closely related substances were the only compounds found having a pronounced antagonistic action to the vasodilator action of acetylcholine. Pilocarpine diminished the action slightly. Physostigmin intensified all of the actions of acetylcholine."

3. **Ergotoxin** is a substance derived from ergot. It is of special interest in the study of the vegetative nervous system, be- cause of a peculiarly selective action which it exercises on the sympathetic system alone. In small doses it stimulates, and in large doses paralyzes the activating fibers of the sympathetics, but seems to exert little or no effect on their inhibiting fibers. Thus ergotoxin in paralyzing doses causes dilatation of the blood vessels and inhibition of the heart, but leaves the sympathetic fibers in the respiratory and gastrointestinal systems unhindered in their opposition to the vagus and sacral nerves.

Thus in small doses, ergotoxin acts like adrenalin upon the vasodermal structures supplied by it; but unlike it on the endodermal structures. While adrenalin causes inhibition in the gastrointestinal and respiratory systems, ergotoxin fails to do this.

Ergotoxin causes contraction of the pregnant uterus. '

4. **Atropine** is of the greatest importance in its relationship to the vegetative nervous system. While ergotoxin in large doses paralyzes all structures which are activated by the sympathetic system, atropin antagonizes the action of those vegetative fibers which come from the cranial, bulbar and sacral portions of the cord, the parasympathetic fibers. Atropin does not act with the same degree of intensity upon all craniosacral fibers.

Atropin paralyzes the vegetative fibers in the IIIrd nerve which supply the pupil and allows the sympathetic fibers unopposed to dilate the pupil. It also paralyzes the ciliary muscle and destroys the power of accommodation.

Atropin opposes the action of the vegetative fibres which course in the VIIth, IXth and Xth cranial and sacral nerves; hence reduces the irritability of the nasal mucous membrane and dries the nasal secretion; checks the salivary secretion; reduces the secretion of the glands of the bronchi, pharynx, stomach, intestines, liver and pancreas; reduces the motility of the musculature of the respiratory and digestive systems; opposes the inhibiting action of the vagus on the heart. Atropin paralyzes the endings of the pelvic nerve in the lower colon, rectum, and cervix uteri.

From the action of atropin upon the sweat glands, we arc left in doubt as to their innervation. These subdermal structures, as previously discussed, seem to be activated only by the sympathetic system; yet the fact that adrenalin docs not stimulate the production of sweat, and further that the secretion is cheeked by atropin, leads some observers to the opinion that the sweat glands must be activated by parasympathetic fibers. This same innervation is further indicated by their reaction toward pilocarpine although physiologic evidence is against it.

5. **Pilocarpine** holds a similar relationship to the craniosacral outflow or parasympathetic nerve endings as adrenalin holds to the thoracicolumbar outflow or sympathetic nerve endings.

Pilocarpine shows a particularly strong action upon the secretory glands activated by the parasympathetic system, causing a flow of saliva; an increase in mucus in the bronchi; an increase in the flow of tears, and an increase in the secretions of the gastrointestinal canal.

It also acts on all smooth muscles supplied by the craniobulbar system in the same manner as though the nerves themselves were stimulated.

Contrary to what would be expected from our general knowledge of the sweat glands, pilocarpine stimulates them and causes profuse secretion.

By the employment of these pharmacologic remedies, important advances have been made in our knowledge of the vegetative system. Eppinger and Hess[4] have utilized these remedies in the study of groups of people and have been able to show that there is a tendency on the part of many individuals to have an unbalanced condition in the vegetative system, so that there is an abnormal irritability in the cell bodies of the neurons belonging to the craniosacral division. They have suggested the term "vagotonia" to describe this condition. Their discussion of the relative value of these various pharmacologic remedies and their relationships to the vegetative system deserves careful consideration.

It seems to the writer that these authors lay too much stress on the value of these remedies in differentiating between a condition of vagotonia and sympathicotonia, I have not been able to find that patients with vagotonia always react as readily to atropin and pilocarpine as would be indicated in their writings. It seems more rational to accept these remedies as having certain definite action, and if the patient responds to them, to accept the information as positive; if not, to rely on our clinical judgment. Their position regarding these various pharmacologic remedies in diagnosing or in studying the relative irritability of the nerve cells of the two components of the vegetative system is well expressed in the following quotation from Vagotonia:

"Electrical investigations have already shown that in many organs the manifestations caused by stimulation of the fibers of one system may be abolished when stimulation is applied to the fibers of the other.

"These reactions show twat many physiologic antagonists may be demonstrated in the two systems. But the fact that the different nerves of the two systems may be commingled on their way to their end -organs makes anatomic differentiation impossible and physiologic testing extremely difficult.

"In certain pharmacologic substances on the contrary, a means of getting at this differentiation is found. Adrenalin is known to be a substance which acts solely upon the 'sympathetic' nervous system. Its action is similar to that of electrical stimulation of the sympathetic fibers (Table I). One may, therefore, always regard a manifestation of the action of adrenalin as equivalent to that of stimulation of 'sympathetic' fibers,

"The 'autonomic' nervous system can also be influenced exclusively by certain drugs. The most important of these are atropin, pilocarpine, Physostigmin, and muscarine. Following the use of muscarine, pilocarpine, or Physostigmin, the same effects may be produced as are obtained by stimulation of autonomic fibres. Atropine, on the other hand, prevents many of the effects which are caused by stimulation of the autonomic fibers. It is to be expected, therefore, that atropin would be able to counteract, to a certain degree, the effects produced by pilocarpine, muscarine, and Physostigmin. Experimentally this may be shown to be the case,

"The parallelism between physiological stimulation and the pharmacological action of those selectively acting drugs seems to be broken by the peculiar behaviour of the sweat glands. While the results of anatomical and physiological investigations make it seem probable that these glands arc innervated by the sympathetic, yet they react to autonomic poisons, whereas the sympathetic tonic adrenalin unable to abolish the secretion of the sweat glands.

"Since pharmacological tests seem to be the most decisive, the innervation of the sweat glands must he regarded as of autonomic (parasympathetic) origin.

"Before proceeding further, a tabular resume of the antagonism of the action between adrenalin on the one hand, and atropin and pilocarpine on the other, is here presented.

"A detailed review of the literature cannot be given here owing to the great abundance of facts. This table has been partly taken from the works of Froehlich and Loewi, in part from the work on *Internal Secretions* by Arthur Biedl.

"These tables are chiefly of service in showing that pharmacological investigations particularly have confirmed the idea that the two nervous systems, sympathetic and autonomic, are antagonistic in their action. While adrenalin exerts equal action upon nearly all organs with sympathetic innervation, it may be seen, however, that pilocarpine has more action on some parts of the autonomic system than on others. From this it may be seen that its effects cannot be contrasted with the universal effects of the action of adrenalin. Atropine also shows a gradual differentiation in its action, since it has practically no action upon the pelvic nerve, while it exerts a powerful influence upon the cranial portion of the autonomic system. Other drugs arc known which also have a powerful action upon the autonomic, more in some of its branches than in others. Pilocarpine itself acts particularly upon secretory autonomic fibres, while its action upon the heart is much less potent. This gradual differentiation is very evident if one compares the action of pilocarpine upon the heart with that of muscarine. What is emphasized in considering these two autonomic stimulants, muscarine and pilocarpine is that their selectivity differs. In the case of the heart, for example, muscarine may cause cessation of its action, while pilocarpine and Physostigmin, with the exception of a transitory slowing of the pulse, have no noteworthy effect. That those drugs do influence the cardiac branches of the vagus, however, is shown by stimulating that nerve. Thus the effect of a stimulus applied to the heart is enormously increased after the administration of Physostigmin, so much so that even a mild stimulation may cause the heart to stop beating.

"These few examples serve to show that the various autonomic stimulants do not have precisely similar effects, but have greater affinities for certain branches than for others, and furthermore, it is worth noting that some autonomic poisons affect the central more, than the peripheral endings. Pierotoxin is an example. Finally a differentiation must be made between drugs which act as direct stimulants and those which act by increasing the irritability, i.e., the reactibility to other stimuli. Of the latter Physostigmin is an example. ' '

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