THE CIBA COLLECTION OF MEDICAL ILLUSTRATIONS

VOLUME 1

NERVOUS SYSTEM

FRANK H. NETTER, M.D.

THE CIBA COLLECTION OF MEDICAL ILLUSTRATIONS

VOLUME I

A Compilation of Paintings on the
Normal and Pathologic Anatomy of the

NERVOUS SYSTEM

With a Supplement on

THE HYPOTHALAMUS

Prepared by

FRANK H. NETTER, M. D.

With a foreword by

JOHN F. FULTON, M. D.

Sterling Professor of the History of Medicine
Yale University School of Medicine

Commissioned and published by

C I B A

OTHER PUBLISHED VOLUMES OF
THE CIBA COLLECTION OF MEDICAL ILLUSTRATIONS

By

FRANK H. NETTER, M.D.

REPRODUCTIVE SYSTEM

UPPER DIGESTIVE TRACT

LOWER DIGESTIVE TRACT

LIVER, BILIARY TRACT AND PANCREAS

ENDOCRINE SYSTEM AND
SELECTED METABOLIC DISEASES

HEART

(See page 168 for additional information)

Color transparencies of all the illustrations contained in this book are available. These are often useful as teaching aids. The slides are 35 mm, 2" x 2", mounted in cardboard. More detailed information is available from *CIBA Publications Department, 556 Morris Avenue, Summit, N.J. 07901.*

First Printing, 1953
Second Printing, 1955
Third Printing, 1957
Fourth Printing, 1958
Fifth Printing, 1962
Sixth Printing, 1964
Seventh Printing, 1967
Eighth Printing, 1968
Ninth Printing, 1972

Library of Congress Catalog No.: 53-2151

Printed in U.S.A.

Printing by Colorpress
Color Engravings by Embassy Photo Engraving Co., Inc.
New York, N.Y.

FOREWORD

In the early texts of anatomy the central nervous system of human beings was seldom adequately depicted because, although the art of embalming was known, this procedure was rarely used for the preservation of the brain and spinal cord. The result was that by the time the anatomist or the pathologist came to expose the brain, it was generally soft and disintegrated and not well suited for anatomical study. The first adequate illustrations of cerebral structure are those found in the *Fabrica* of Andreas Vesalius, published in 1543. His plates representing the nervous system show many of the major structures, but the sulci are flattened and the hemispheres themselves have the appearance of being more or less collapsed. However, Vesalius had depicted the major gross structures of the human brain, including the cerebellum, the cerebral ventricles, and the majority of the cranial nerves.

It was discovered later that the cerebral ventricles had been much more clearly portrayed some years earlier in the manuscript notebooks of Leonardo. He injected the ventricular system with wax and, on macerating the surrounding cortical tissue, he emerged with an accurate cast of the ventricles which he had drawn in his notebook; but unfortunately these excellent drawings did not become public property for nearly four centuries.

There were many other anatomists in the sixteenth century who made anatomical illustrations of various parts of the central nervous system — Eustachio, whose plates of the cranial nerves, including the vagus, represent a conspicuous advance over the Vesalian portrayal of corresponding structures. And then the Florentine Guidi, better known as Vidius (the Latin form of his name), grandson of Ghirlandajo, made good use of the artistic talent which he inherited and published an illustrated anatomical and also a surgical text. Vidius' contemporary, Costanzo Varolio, in 1573, issued a monograph on the optic nerves which contains a plate illustrating the base of the brain that was more accurate than anything before him and was only matched by the celebrated plate which Thomas Willis issued in 1674 in his *Cerebri anatome*. The latter plate, showing the vascular circle which still bears Willis' name, was designed by the young Christopher Wren, who had learned the art of injection of blood vessels in London while working as an assistant in the anatomical theatre of Sir Charles Scarborough. Wren introduced the new technique at Oxford, and I have always suspected that it was Wren rather than Willis who discovered the arterial circle.

In the seventeenth and eighteenth centuries there were a number of other notable illustrations of the brain and spinal cord in monographs such as those of Vieussens (1685) and Ridley (1695). In the eighteenth century the most remarkable plates of the nervous system were the colored portrayals of Jan Ladmiral and Jacques Fabian Gautier d'Agoty. The color process employed by these artists, although they claimed it as their own invention, was probably that of the German Le Blon, since they had both worked with him as assistants.

There was little progress in anatomical illustration of the nervous system during the nineteenth century, although note should be made of the plates published by Charles Bell who was as much artist as he was anatomist and of whom it is generally said that he colored his anatomical plates by hand. Those of Cruveilhier should also be mentioned. His plates depicting tumors of the central nervous system are as fine as anything that had appeared before or has been published since.

With the advent of the modern period, hand coloring has largely disappeared and in its place we have the three-color process employed by the German anatomists such as Spalteholtz. The present volume, composed of the beautiful plates of Dr. Frank H. Netter, makes use of every modern device to present the structural relations of the nervous system with care and precision. At a time when a high value is placed on visual aids as an accompaniment to the written word in the educational process, these exquisite and highly accurate illustrations commend themselves to all who are either teaching or learning the functions of the nervous system. Although there have been a number of artists throughout medical history who have achieved lasting acclaim for the excellence of their work even though they were not themselves physicians, this collection of drawings well illustrates the happy result of artist and physician being combined in one person. Dr. Netter's knowledge of function cannot but lend clarity to his plates.

The legends and descriptions to the illustrations as provided by Doctors Kaplan, Kuntz and von Bonin of course do not substitute for a textbook but are comprehensive and yet masterpieces of conciseness. Both illustrations and text together are quite obviously the result of a most cheerful and successful cooperation. The consultant experts have left their imprint also on the pictures and in the method of demonstrating a variety of details, since one may readily recognize traces of their own scientific contributions in their respective fields.

One common source of confusion to students — the position of the Island of Reil — is beautifully resolved in one of Dr. Netter's diagrams to be found in Plate 17. His portrayal of the Circle of Willis in Plate 16 is probably the clearest that one will find in any modern anatomical text. His diagram of the relations of the cerebellum in Plate 44 is also highly illuminating and the diagram in Plate 72 of the innervation of the female genital system is excellent.

These are but a few selections from a work of consistently high quality. Ciba Pharmaceutical Company, in offering this new volume in their series of anatomical illustrations, adds another to their enviable list of contributions to the progress and the history of medicine.

JOHN F. FULTON, M.D.

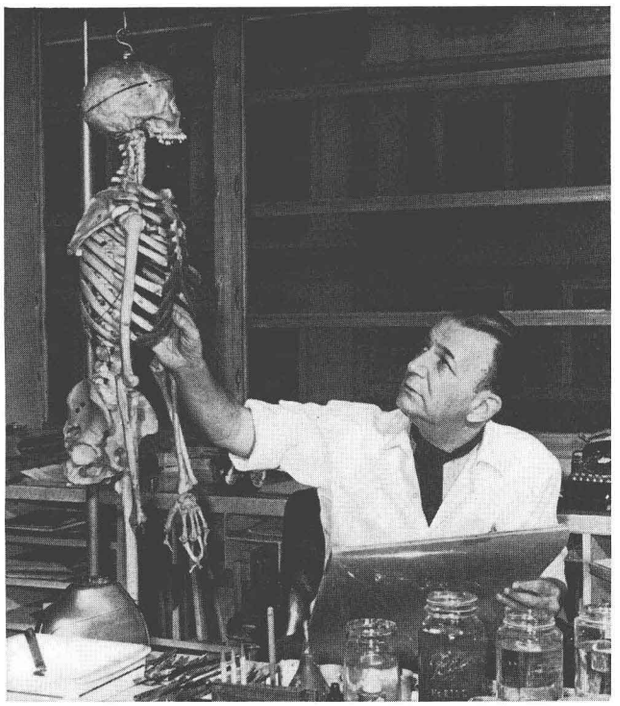
New Haven, March, 1953

PREFACE TO THE NINTH PRINTING

For the eighth time since 1953, because of a continuous demand, it becomes necessary to reprint this volume. The combined supply from the first and second printings lasted only 2 years. Because of the popularity of this book, consideration was seriously given to the issuance of a completely revised and broadened second edition, including those topics under the peripheral nervous system that have been proposed in the many suggestions received from readers of the book. The over-all program and the importance of completing new volumes with as little delay as possible do not permit Dr. Netter to devote his activities to a new version of Volume 1 at this time.

However, it seemed feasible to add to the third and subsequent printings of the first edition a supplement concerned with the hypothalamus, which will be found, following the Index, on pages 145 to 168. This series of illustrations, prepared with the collaboration of Dr. W. R. Ingram, appeared in the July-August, 1956, number of the CIBA CLINICAL SYMPOSIA and received such an immediate response that 3 months later our large stock of this issue was exhausted. The incorporation of this series into Volume 1, distributing the pictures among the various sections according to the anatomic or functional aspects and calling the book a revised edition, was felt to be unwarranted, essentially because of the rather one-sided type of revision that would have resulted. The best solution, thus, appeared to be to add this series as a supplement to this volume.

In order to avoid confusion, it seems appropriate to draw attention to the fact that the color scheme for the hypothalamic nuclei in the supplement (pages 147 to 151) is different from the one used in the earlier illustrations on pages 76 and 77. The difference is obvious, and the legends in both the pictures in Volume 1 proper and in those of the supplement (with far more details) are clear, so that no further explanations are necessary.



THE ARTIST

Many readers of the CIBA COLLECTION have expressed a desire to know more about Dr. Netter. In response to these requests this summary of Dr. Netter's career has been prepared.

Frank Henry Netter, born in 1906 in Brooklyn, New York, received his M.D. degree from New York University in 1931. To help pay his way through medical school and internship at Bellevue, he worked as a commercial artist and as an illustrator of medical books and articles for his professors and other physicians, perfecting his natural talent by studying at the National Academy of Design and attending courses at the Art Students' League.

In 1933 Dr. Netter entered the private practice of surgery in New York City. But it was the depth of the depression, and the recently married physician continued to accept art assignments to supplement his income. Soon he was spending more and more time at the drawing board and finally, realizing that his career lay in medical illustration, he decided to give up practicing and become a full-time artist.

Soon, Dr. Netter was receiving requests to develop many unusual projects. One of the most arduous of these was building the "transparent woman" for the San Francisco Golden Gate Exposition. This 7-foot-high transparent figure depicted the menstrual process, the development and birth of a baby, and the physical and sexual development of a woman, while a synchronized voice told the story of the female endocrine system. Dr. Netter labored on this project night and day for 7 months. Another interesting assignment involved a series of paintings of incidents in the life of a physician. Among others, the pictures showed a medical student sitting up the night before the osteology examination, studying away to the point of exhaustion; an emergency ward; an ambulance call; a class reunion; and a night call made by a country doctor.

During World War II, Dr. Netter was an officer in the Army, stationed first at the Army Institute of Pathology, later at the Surgeon General's Office, in charge of graphic training aids for the Medical Department. Numerous manuals were produced under his direction, among them first aid for combat troops, roentgenology for technicians, sanitation in the field, and survival in the tropics.

After the war, Dr. Netter began work on several major projects for CIBA Pharmaceutical Company, culminating in THE CIBA COLLECTION OF MEDICAL ILLUSTRATIONS. To date, five volumes have been published and work is in progress on the sixth, dealing with the urinary tract.

Dr. Netter goes about planning and executing his illustrations in a very exacting way. First comes the study, unquestionably the most important and most difficult part of the entire undertaking. No drawing is ever started until Dr. Netter has acquired a complete understanding of the subject matter, either through reading or by consultation with leading authorities in the field. Often he visits hospitals to observe clinical cases, pathologic or surgical specimens, or operative procedures. Sometimes an original dissection is necessary.

When all his questions have been answered and the problem is thoroughly understood, Dr. Netter makes a pencil sketch on a tissue or tracing pad. Always, the subject must be visualized from the standpoint of the physician; is it to be viewed from above or below, from the side, the rear, or the front? What area is to be covered, the entire body or just certain segments? What plane provides the clearest understanding? In some pictures two, three, or four planes of dissection may be necessary.

When the sketch is at last satisfactory, Dr. Netter transfers it to a piece of illustration board for the finished drawing. This is done by blocking the back of the picture with a soft pencil, taping the tissue down on the board with Scotch tape, then going over the lines with a hard pencil. Over the years, our physician-artist has used many media to finish his illustrations, but now he works almost exclusively in transparent water colors mixed with white paint.

In spite of the tremendously productive life Dr. Netter has led, he has been able to enjoy his family, first in a handsome country home in East Norwich, Long Island, and, after the five children had grown up, in a penthouse overlooking the East River in Manhattan.

ALFRED W. CUSTER

ACKNOWLEDGMENTS

Ciba Pharmaceutical Company expresses its most sincere appreciation to Ernst Oppenheimer, M.D., Richard H. Roberts, M.D., William T. Strauss, M.D., J. Harold Walton, M.D., Miss Ruth S. Godwyn, Messrs. James R. Beattie, George L. Cantzlaar, Alfred W. Custer, John N. Kolen, and Paul W. Roder, who participated in the development of this volume.

INTRODUCTION

For many years the teaching of the anatomy, physiology, and pathology of the nervous system was conducted in an atmosphere of academic discipline. It was the custom to capture the imagination of the medical student with the more striking natural phenomena and the more dramatic pathologic manifestations, even though their clinical incidence lagged far behind the importance that was accorded them in the lecture hall. Such stress on minutiae tended to lend to this field a character of remoteness in the mind of the student. By the same token the general practitioner and the nonneurologic specialist, pressed for time while meeting the demands of a busy practice, have been relatively impatient with the labyrinthine complications of neurology and have, as a consequence, left the full command of this body of information to specialists in neurology and neurosurgery.

Allowing for recent advances in medical education and for the increasing recognition of neurologic factors in all kinds of illness, the present group of illustrations is offered as a leavening agent. To the end that the intricacies of the nervous system may be more easily comprehended, the most important and clinically useful facts are herein "compressed" and so arranged that one can readily refer to the plates and their accompanying text when confronted by a neurologic problem. The index is designed to further this aim and to anticipate the needs and reference habits of any reader.

The backbone of this collection is, of course, generally accepted information. While minute details and controversial theories have been avoided, this was not done at the expense of accuracy or completeness. Clinical significance has been the guiding principle. In many instances certain anatomic structures are either deliberately omitted or deemphasized in order to stress points that have broader clinical application.

A section on the anatomy of the spine is included instead of being reserved for another volume covering bones and ligaments in general, because an understanding of spinal anatomy is fundamental to a proper appreciation of spinal cord injuries, the compression effects of spinal tumors, the significance of intervertebral herniations, and numerous other clinical conditions. It is for this same reason that a practicing neurosurgeon was chosen as collaborator in selecting and discussing the illustrations concerned with anatomy of the spine. The descriptive text by Dr. Abraham Kaplan in three sections — "Anatomy of the Spine," "The Central Nervous System," and "Pathology of the Brain and Spinal Cord" — exemplifies again the principal aim of this atlas, to serve the practicing physician and the student in their efforts to understand the underlying reasons and conditions of diseases and clinical syndromes.

In view of the considerable individual variations of the spine, the prominence of the tubercles and processes, etc., efforts have been made to portray an average form and to illustrate all the processes so that they might be easily recognized and remembered. The plates show not only the detailed configuration of the individual vertebrae but also the manner in which these articulate. The principal ligaments were also included in such a way as to illustrate their functions, the structures which they bind together, and the motility permitted by them. Different viewing angles are used to foster complete understanding.

In the plates illustrating the basic anatomy of the brain and the spinal cord, the physician will doubtless recognize that a great many details have been omitted. This was done deliberately. The complexity of the central nervous system is such that one must be guided by the fundamental requirements of simplicity if effectiveness in presentation is to be achieved. Only as much of the gross anatomy has been selected as was thought necessary to provide a clear apprehension of the principles developed in the sections dealing with functional neuro-anatomy and, to a degree, the autonomic nervous system.

(continued)

The task of pictorializing functional neuro-anatomy was undertaken with a great deal of trepidation. The complexity of the subject certainly is unsurpassed by any other topic from the standpoint of both the teacher in the field as well as the graphic medical artist. Of necessity, the illustrations in this section are almost entirely schematic. In general, controversial points are by-passed, but it would be vain to hope that differences of opinion would not arise on some details.

In the preparation of the chapter illustrating functional neuro-anatomy, I was fortunate to have had the most valuable and enjoyable cooperation of Dr. Gerhardt von Bonin. His profound knowledge and proficiency in teaching continuously aroused my admiration.

The next section, "The Autonomic Nervous System," presented difficulties, particularly from the graphic point of view, because of the enormous and diverse ramifications. Controlling at least to some extent the function of nearly every organ of the body, this system has a significant interest for every physician, may he be an obstetrician, a gastroenterologist, an endocrinologist, cardiologist, or pharmacologist.

The literature that has accumulated relative to the autonomic system is so voluminous that the practicing physician or student generally cannot afford the time to read even in cursory fashion this tremendous mass of information. The material in this atlas tries to fulfill a need for a simplified, but fairly comprehensive presentation of the subject.

This task, with all its inherent problems, was facilitated through the devoted efforts of Dr. Albert Kuntz. He has for many years been active in this field, and has added a great deal to the knowledge of the autonomic nervous system by his own scientific contributions. His concise explanatory text should guarantee that this chapter will serve fully its intended purposes.

The first ten plates portray the overall morphology of the autonomic nervous system; its functional relation and its manner of distribution to the various body systems. The illustration which analyzes the autonomic nervous system from the point of view of adrenergic and cholinergic nerve endings, should be of particular interest because this field of study is presently receiving ever-increasing attention.

The second group of ten plates in the section deals with the autonomic innervation of specific organs. In these, schematic treatment was resorted to almost exclusively, since this seemed to be the most practical way to sort out the widely disseminated and detailed neuronal ramifications.

The illustrations comprising the last section, "Pathology of the Brain and Spinal Cord," are exemplary rather than specific. Admittedly, it would have been relatively easy to pad the section with pictures of the many varieties of meningiomas, spinal fractures, and cerebral hemorrhages. Instead, a trial has been made to portray, insofar as possible, the *typical* appearance of each condition along with its more important modifications, to achieve overall coverage of a subject rather than a detailed study of any of its aspects. These presentations are intended to serve as "visual definitions" of meningocele, meningomyelocele, syringomyelocele, and the other conditions. The text which accompanies the plates compresses into a few words the generally recognized etiology, symptomatology, diagnostic findings, and therapeutic indications.

Every artist thrives on appreciation, understanding and encouragement. In this respect I have been doubly fortunate. First, the warm reception which the medical profession has accorded my pictures has been a wonderful source of satisfaction to me. Second, more personal and close at hand, has been the inspiring personality of Dr. Ernst Oppenheimer. His understanding of the things I was trying to do, his appreciation of what I had done, and his encouragement to do more were a constant assurance that I was not alone. In addition, his vision of the scope and value of this atlas and his many co-ordinating activities in its behalf have been vital factors in the project.

FRANK H. NETTER, M.D.

CONTENTS

Section I

ANATOMY OF THE SPINE

Section II

THE CENTRAL NERVOUS SYSTEM

Section III

FUNCTIONAL NEURO-ANATOMY

Section IV

THE AUTONOMIC NERVOUS SYSTEM

Section V

PATHOLOGY OF THE BRAIN AND SPINAL CORD

Section I

ANATOMY OF THE SPINE

with descriptive text by

ABRAHAM KAPLAN, M.D., F.A.C.S., D.N.S.
Clinical Professor of Neurosurgery
New York Polyclinic Medical School and Hospital
New York, N. Y.

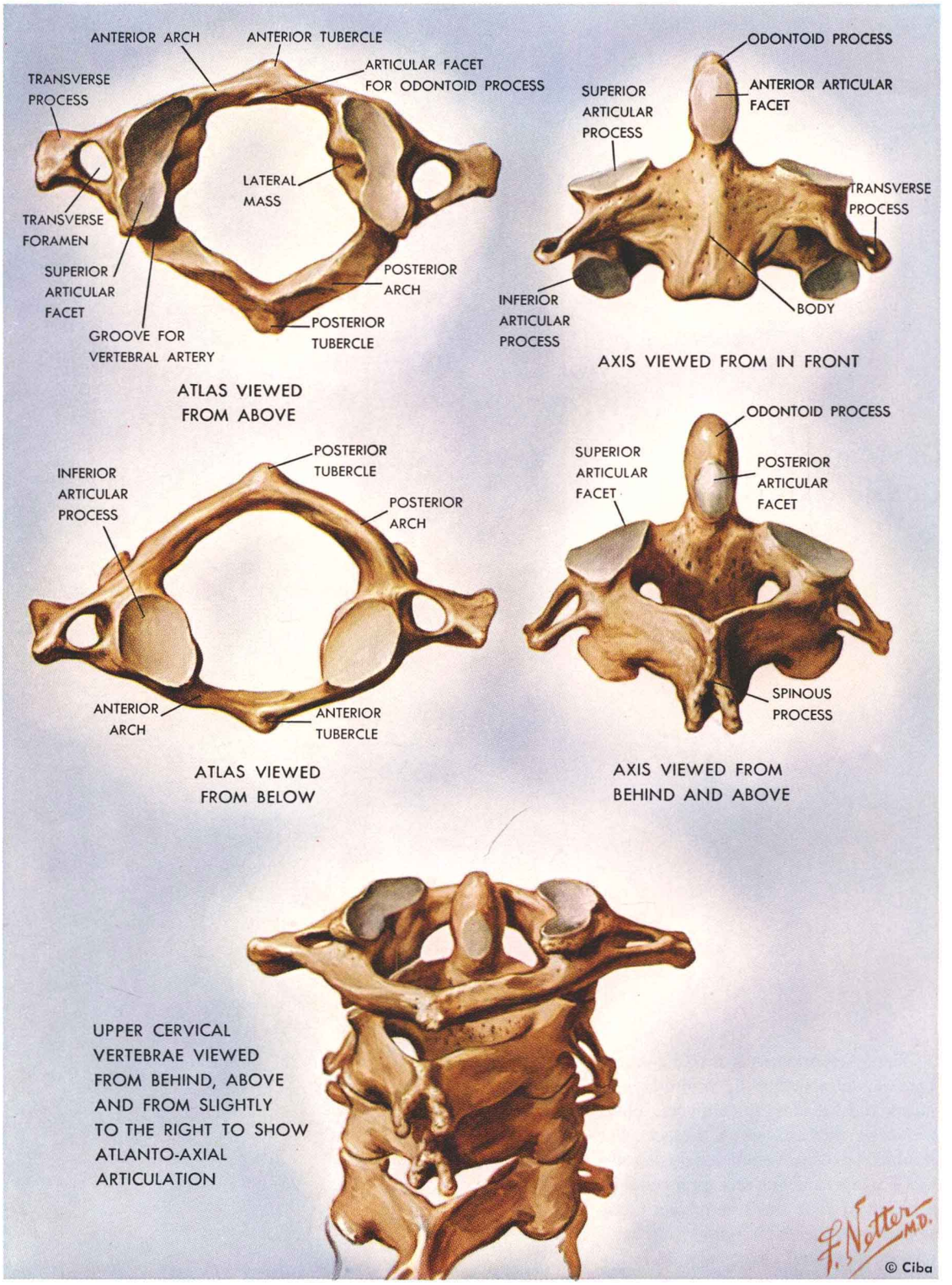
General Configuration

The spinal column consists of 33 vertebrae joined together by multiple ligaments and intervening cartilages. There are seven cervical, twelve thoracic, five lumbar, five sacral vertebrae (the last five fused as one) and one coccygeal vertebra, a fusion of four small vertebrae. Occasionally when an extra lumbar vertebra is present it is usually compensated for by one vertebra less in the thoracic region. Mobility of the vertebrae in the cervical, thoracic and lumbar region is relatively free as compared with those in the sacrum and coccyx which are usually fixed. As a rule, the spinal column in the female is four or five inches shorter than in the male.

Viewed from the side, the cervical curve is concave forward, the thoracic curve convex backward, most prominent at the level of the seventh thoracic vertebra and the lumbar curve, most accentuated in the female, is convex forward, ending at the lumbosacral angle. The pelvic curve is concave downward from the lumbosacral angle to the tip of the coccyx. Viewed from the rear, a slight lateral curvature of the trunk to the right can be observed because most people are right-handed. From the second cervical vertebra to the first thoracic the bodies of the vertebrae gradually increase in width. They decrease in width with the next two or three vertebrae and then again their width steadily increases as far down as the lumbosacral angle. The oval-shaped intervertebral foramina are smallest in the cervical region and gradually increase in size as they approach the lowest lumbar vertebrae. Through these foramina pass the spinal nerves. Viewed from the rear, the spinal column shows the spinous processes in the midline. They are bifid from the second to the sixth cervical vertebrae and these run almost in a horizontal direction. The spines in the thoracic region are described in Plate 6, page 26. In the lumbar region, the spines are practically horizontal. On either side of each spinous process are the laminae which form shallow grooves for muscle layers, and lateral to these laminae are the articular facets. More laterally and somewhat anterior are the transverse processes. In the thoracic region, the transverse processes have a tendency to take a backward direction.

The vertebral canal which extends through the entire length of the spinal column conforms to the various spinal curvatures and to the variations in size of the spinal cord. It is triangular and large in the cervical region, somewhat small and circular in the thoracic region and then again becomes triangular in the lumbar region. The spinal column serves as an excellent protection for the spinal cord with its adjacent spinal nerves and various coverings.

Atlas and Axis



Atlas

The skull rests on the atlas, which is the first cervical vertebra. It has no body and no spinous process, but consists mainly of two lateral masses and two arches. The anterior arch is convex and carries at its midpoint a tubercle which serves as an attachment to the longus coli muscle. At the middle of the posterior surface of this arch is a smooth oval facet for articulation with the odontoid process. The posterior arch is concave backward with the posterior tubercle, a rudimentary spinous process, at the midpoint.

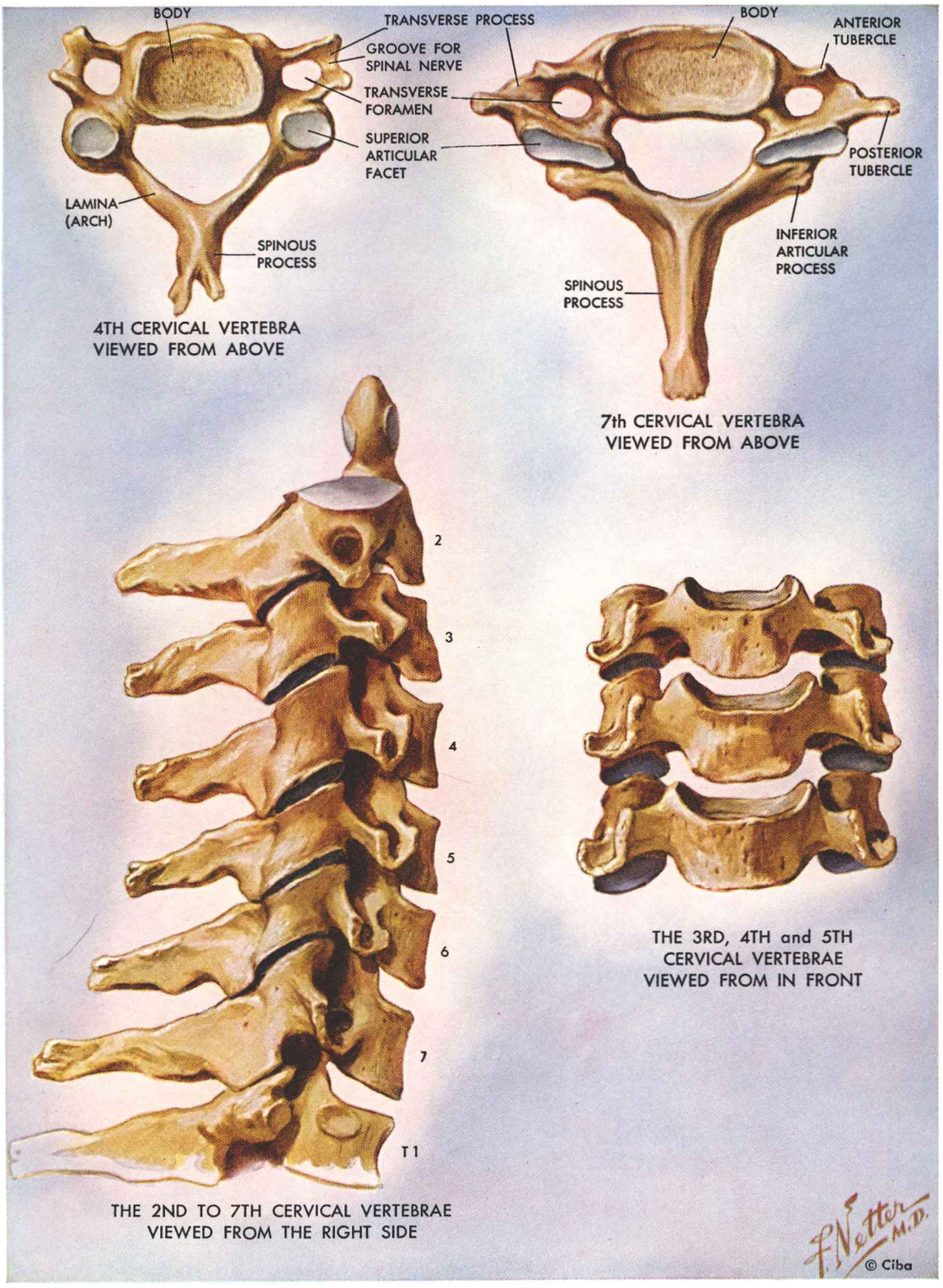
The two lateral masses have a superior and inferior facet. The superior facet is large, oval and concave and is shaped to form a cup for the condyles of the occipital bone. The inferior facet is circular, convex, facing downward and somewhat medially, and articulates with the axis below. Just posterior to the superior facet are small grooves through which the vertebral artery and first spinal nerve enter the skull. Lateral to each lateral mass are the transverse processes with an oval foramen through which run the vertebral artery with its accompanying vein and nerve.

Axis

The second cervical vertebra, also called the epistropheus, is most striking because of the odontoid process. This rises perpendicularly from the midportion of the upper surface of the body of the axis. A slight constriction at its base is called the neck where a small groove may be found for the attachment of the transverse atlantal ligament. On the anterior surface of the odontoid process is an oval facet for articulation with the atlas. At each side of the body of this vertebra is a superior and an inferior facet. The superior articular facet faces upward and outward articulating with the atlas, the inferior articular facet faces downward and inward and articulates with the cervical vertebrae below.

The spinous process is large, strong, and bifid, and is the meeting point of the adjacent thick laminae. The transverse processes are small and end in a single tubercle. They are perforated by a foramen through which run the vertebral artery and its accompanying vein and nerve.

Cervical Vertebrae



The seven cervical vertebrae have in common a foramen through their transverse processes for the vertebral artery. The first and second cervical vertebrae have already been described (Plate 2, page 22).

The seventh cervical vertebra is distinctive because of its prominent spinous process. This process runs practically in a horizontal direction and at its lowest point serves as the lowermost attachment of the ligamentum nuchae.

The other four cervical vertebrae in common show a rather smooth body broader from side to side than in an antero-posterior diameter.

The anterior surface of the body of the vertebra overlaps the upper portion of the vertebra below. The upper surface of the body of the vertebra is concave with somewhat raised edges along its margins. The lower surface of the cervical body is concave from before backward but slightly convex from side to side.

The pedicles arise from the lateral posterior aspect midway between the upper and lower margins of the vertebral bodies.

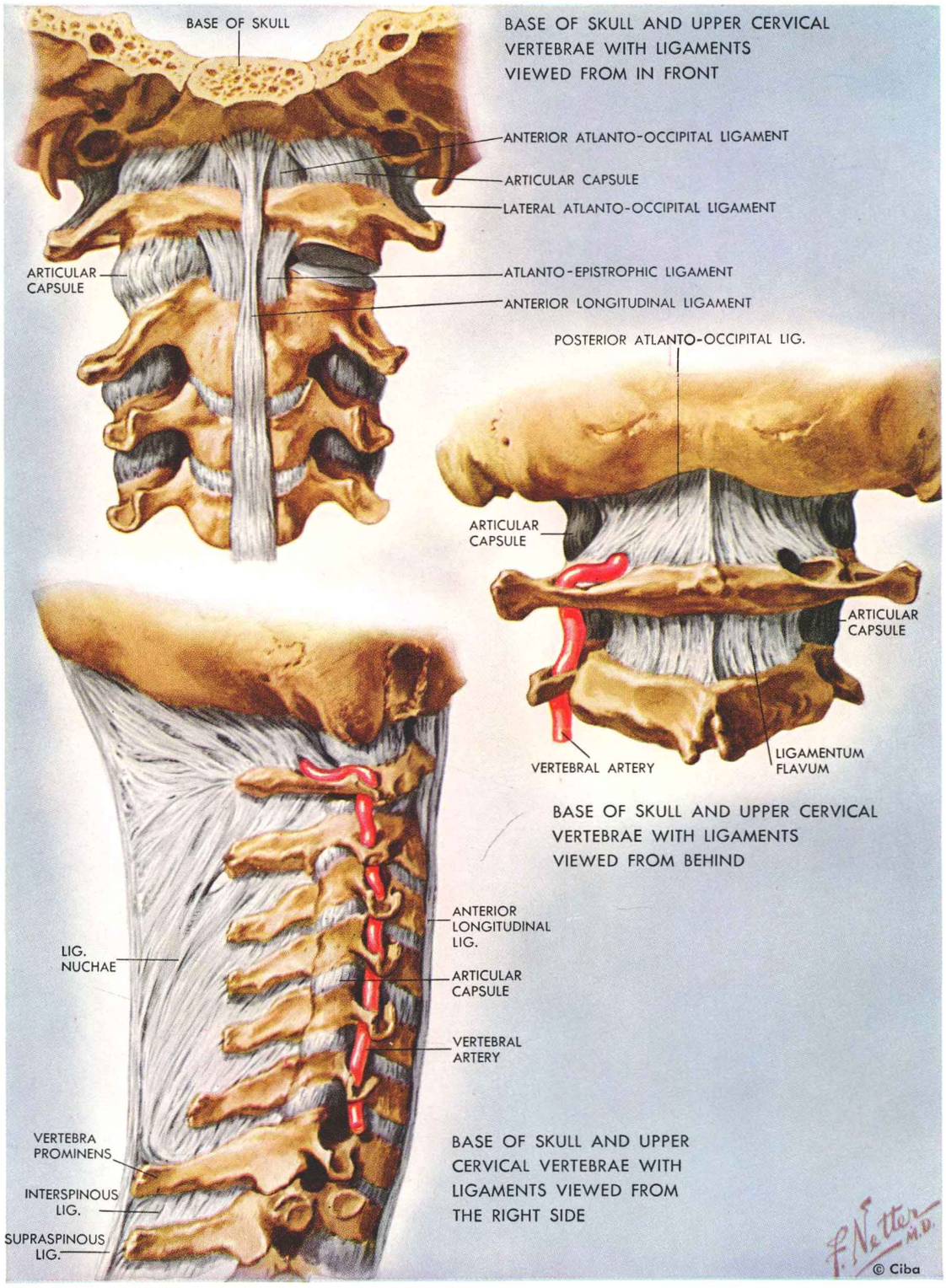
The laminae are narrow and thin and meet in the posterior midline to form short bifid spinous processes. Projecting laterally from the junction of the pedicles and laminae are the articulating facets which have a superior and an inferior surface.

The superior articulating facet is directed upward and backward and somewhat medially while the inferior facet is directed forward, downward, and laterally.

Just anterior to the facets are the transverse processes through which runs an oval foramen, a passageway for the vertebral artery, vein, and sympathetic nerves.

On the extreme outer portion of the anterior transverse process is the anterior tubercle and on the extreme posterior process is the posterior tubercle. Between these tubercles is the groove for the outgoing spinal nerve.

External Cranio-cervical Ligaments



These ligaments connect the cervical vertebrae with each other and with the cranium and are so constructed and arranged as to allow for gross and fine movements of the head and neck with freedom and security.

1. Ligamentum nuchae — is a strong, tense, fan-shaped structure stretching from the external occipital protuberance and median nuchal line down to, and in between, all the seven cervical vertebrae, giving off fibrous bands to the posterior tubercle of the atlas and the bifid spines. Joining the spinous processes of the cervical vertebrae from root to apex, it forms a septum in the midline between the muscles of the neck.

2. Anterior atlanto-occipital ligament — is a broad, dense band of fibers stretching from the anterior margin of the foramen magnum to the upper border of the anterior arch of the atlas and is continuous laterally with the articular capsule. It is reinforced at its midpoint by a rounded ligament stretching from the basilar portion of the occipital bone to the anterior tubercle of the atlas.

3. Articular capsule — joins the posterior articular surfaces of the axis with the margins of the lateral masses of the atlas. The accessory ligament is a reinforcement of the posterior medial margin. These surround the condyles of the occipital bone and connect them with the articular processes of the atlas.

4. Lateral atlanto-occipital ligament — is a thickened portion of the articular capsule stretching from the jugular process of the occipital bone to the transverse process of the atlas.

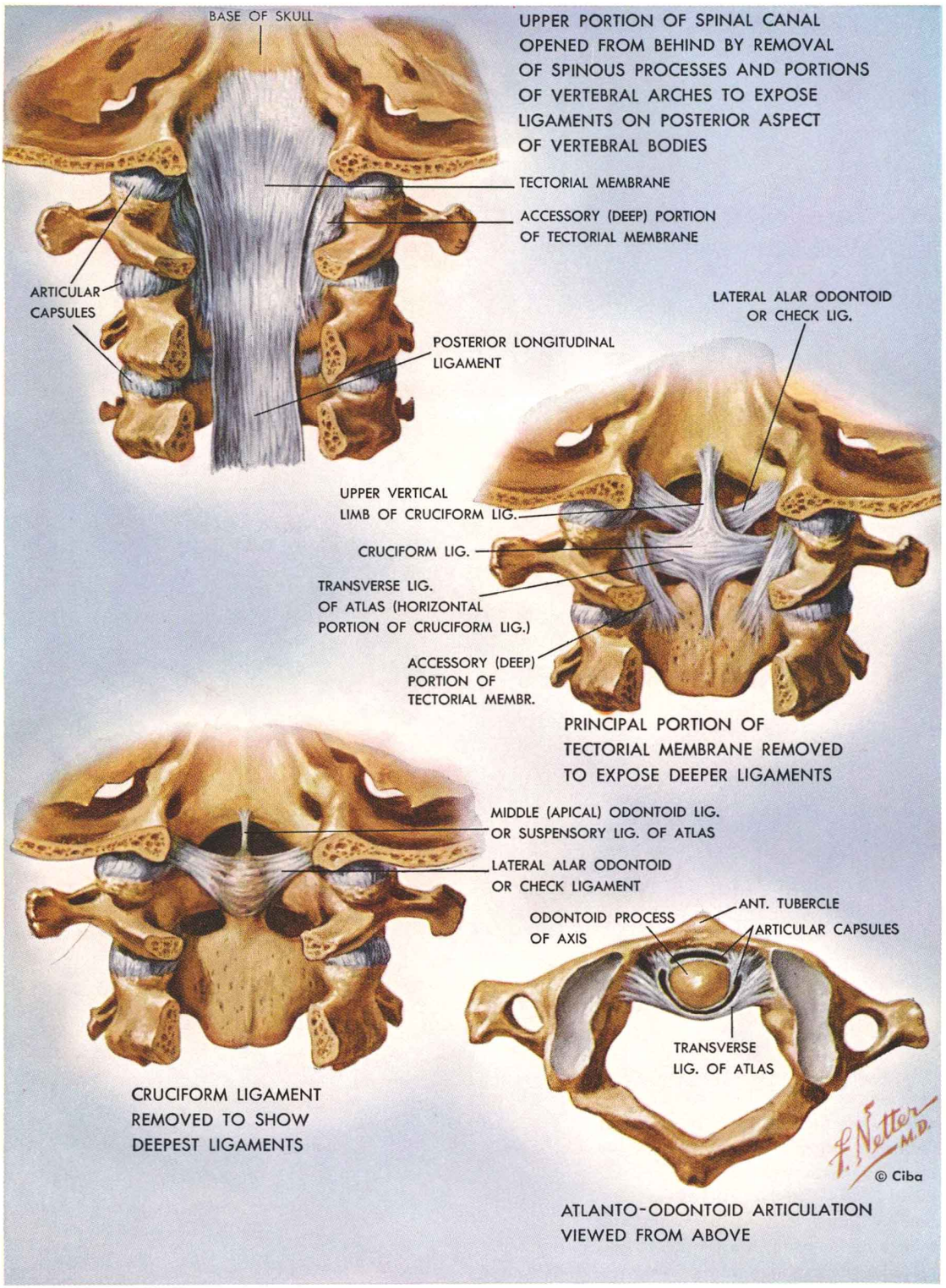
5. Atlanto (axial)-epistrophic ligament — is a strong fibrous band extending from the anterior arch of the atlas to the front of the body of the axis. It is reinforced at its midpoint by a portion of the anterior longitudinal ligament.

6. Anterior longitudinal ligament — is a strong narrow band of fibrous tissue extending from the base of the skull down to the anterior midportion of the vertebral bodies to the sacrum. At each intervertebral space it is reinforced by fibers from the margins of the vertebral bodies and intervertebral discs.

7. Posterior atlanto-occipital ligament — is rather thin but broad and connects the margins of the foramen magnum with the upper margin of the posterior arch of the atlas. The vertebral artery and first cervical nerve pierce the lower lateral portion of this ligament to gain entry into the skull.

8. Ligamentum flavum — is also thin and broad and extends from the inner posterior margins of the vertebra above to the outer superior posterior margin of the vertebra below.

Internal Cranio-cervical Ligaments



These ligaments also serve to permit safe and smooth movement of the head upon the neck, but in addition prevent and check trauma to the medulla oblongata and upper cervical cord.

1. Tectorial (ligament) membrane — is the upper portion of the posterior longitudinal ligament. It is fan-shaped, broad and strong and stretches from the basilar groove of the occipital bone downward over the posterior surfaces of the vertebral bodies. It covers the odontoid process, giving added strength to the transverse ligament of the atlas. This ligament has also an accessory (deep) portion with fibers more laterally placed and stretches from the lateral margins of the anterior foramen magnum to the upper postero-lateral portions of the body of the axis.

2. Posterior longitudinal ligament — is a downward continuation of the tectorial ligament forming the midportion of the posterior aspects of the vertebral bodies and receiving reinforcing fibers from the margins of the vertebral bodies and intervertebral discs.

3. Lateral alar odontoid (check) ligaments — are very strong fibrous bands which stretch from the medial aspects of the condyles of the occipital bone obliquely downward and inward to the upper lateral portions of the odontoid process. They limit rotation of the skull.

4. Cruciform ligament — has an upper vertical portion called the apical (suspensory) odontoid ligament which extends from the tip of the odontoid to midpoint of the anterior margin of the foramen magnum.

5. The transverse ligament of the atlas arises from a small tubercle on either side of the anterior arch of the atlas and stretches across and forms a sling across the posterior aspect of the odontoid holding it firmly to the facet of the mid-anterior arch. In fractures of the odontoid, this ligament usually prevents encroachment upon the cervical spinal cord and medulla.