ANATOMY FOR SURGEONS: VOLUME 2

The Thorax, Abdomen, and Pelvis

SECOND EDITION

Henry Hollinshead, Ph.D

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W. Henry Hollinshead, Ph.D.

PROFESSOR OF ANATOMY, MAYO GRADUATE SCHOOL OF MEDICINE
(UNIVERSITY OF MINNESOTA)
CHAIRMAN, DEPARTMENT OF ANATOMY, MAYO CLINIC AND MAYO FOUNDATION,
ROCHESTER, MINNESOTA

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SURGICAL CONSULTANTS

The following men read and criticized for the author the material indicated.

OLIVER H. BEAHRS, M.D.

Professor of Surgery*
Head of the Section of Head & Neck & General Surgery,
Department of Surgery†

CHAPTER 5—THE ABDOMINAL WALL AND INGUINAL REGION

•

PHILIP E. BERNATZ, M.D.

Associate Professor of Clinical Surgery*
Consultant, Section of Thoracic, Cardiovascular & General Surgery,
Department of Surgery†

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•

B. MARDEN BLACK, M.D.

Professor of Surgery*
Consultant, Section of Head & Neck & General Surgery,
Department of Surgery†

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•

O. THERON CLAGETT, M.D.

Professor of Surgery*
Consultant, Section of Thoracic, Cardiovascular & General Surgery,
Department of Surgery†

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•

ORMOND S. CULP, M.D.

Professor of Urology*
Chairman, Department of Urology†

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*Mayo Graduate School of Medicine (University of Minnesota), Rochester, Minn.
† Mayo Clinic and Mayo Foundation

SURGICAL CONSULTANTS

JAMES H. DEWEERD, M.D.

Professor of Urology*
Consultant, Department of Urology†

CHAPTER 10—THE KIDNEYS, URETERS, AND SUPRARENAL GLANDS

•

DEWARD O. FERRIS, M.D.

Professor of Clinical Surgery*
Consultant, Section of Gastroenterologic & General Surgery,
Department of Surgery†

CHAPTER 7—THE LIVER AND GALLBLADDER

•

RAYMOND J. JACKMAN, M.D.

Professor of Proctology*
Senior Consultant, Section of Proctologic Surgery,
Department of Surgery†

CHAPTER 13—THE RECTUM AND ANAL CANAL

CHAPTER 16—ANAL REGION

•

EDWARD S. JUDD, M.D.

Professor of Surgery*
Consultant, Section of Head & Neck & General Surgery,
Department of Surgery†

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•

HUGH B. LYNN, M.D.

Associate Professor of Clinical Surgery*
Head of the Section of Pediatric Surgery, Department of Surgery†

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•

DWIGHT C. MCGOON, M.D.

Associate Professor of Surgery*
Head of the Section of Thoracic, Cardiovascular & General Surgery,
Department of Surgery†

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DONALD C. MCILRATH, M.D.

Assistant Professor of Surgery*
Head of the Section of Gastroenterologic & General Surgery,
Department of Surgery†

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* Mayo Graduate School of Medicine (University of Minnesota), Rochester, Minn.
† Mayo Clinic and Mayo Foundation

W. SPENCER PAYNE, M.D.

Assistant Professor of Surgery*
Consultant, Section of Thoracic, Cardiovascular & General Surgery, Department of Surgery†

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•

JOSEPH H. PRATT, M.D.

Professor of Clinical Surgery*
Head of the Section of Gynecologic Surgery, Department of Surgery†

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RICHARD E. SYMMONDS, M.D.

Associate Professor of Clinical Obstetrics and Gynecology*
Consultant, Section of Gynecologic Surgery, Department of Surgery†

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•

DAVID C. UTZ, M.D.

Associate Professor of Urology*
Consultant in Urology†

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*Mayo Graduate School of Medicine (University of Minnesota), Rochester, Minn.
† Mayo Clinic and Mayo Foundation

PREFACE TO VOLUME 2

The Second Edition of Volume 2 of *Anatomy for Surgeons* attempts to present, as did the First Edition, anatomical facts and concepts concerning the thorax, abdomen, and pelvis that are of particular interest to the surgeon. It is not intended to detail the complete descriptive anatomy of these parts, but is designed to serve both as a ready reference in which the surgeon can find general descriptions of the basic anatomy and as a review of numerous, sometimes minute, anatomical details that have proved useful to others but are not readily available without wide reading both within and outside his own special field. While no attempt has been made to describe the indications for, or detailed technics of, specific operations—for these are matters that belong to surgery and not to anatomy—particular care has been taken throughout this volume to relate the anatomical and physiological details and concepts to underlying surgical procedures.

Most of the anatomy described in the First Edition is still both valid and pertinent. However, additions, improvements, and refinements in our understanding of anatomical details and their functional importance have contributed to, and, in turn, have been contributed to by similar additions, improvements, and refinements in diagnostic and operative procedures on the thoracic, abdominal, and pelvic viscera to such an extent as to make a thorough rewriting of this book necessary. The basic descriptions have been carefully scrutinized for minor errors and reworded, re-arranged, or partly rewritten as those seemed to serve the interests of greater clarity or accuracy; discussions of material that now seems largely of historical value have been shortened or eliminated; and in all of the chapters numerous minor revisions have been made to incorporate appropriate up-to-date clinical findings and applications.

In Chapters 1 through 4, the thorax, there is new material on the lymphatics of the breast and of the lungs, and new discussions of hiatal hernia, the phrenoesophageal ligament, the gastroesophageal or lower esophageal sphincter, innervation of the esophagus, achalasia, and reconstruction of the esophagus; new material on the vessels of the bronchopulmonary segments; and, necessarily, so much new material on the heart, coronary circulation, and great vessels that much of the text concerning these had to be completely rewritten.

In Chapters 5 through 11, the abdomen, parts of the description of the anterolateral abdominal wall have been rewritten, as have the discussions of the peritoneal recesses about the liver, the

effects of occlusion of the blood supply to the liver, treatment of portal hypertension, the lymphatic drainage of the stomach, small intestine, and colon, and the lymph nodes of the posterior abdominal wall, with the introduction of varying amounts of new material into all of these. Other new material concerns the structure of the common bile duct, the innervation and function of its sphincter, innervation of the pancreas and control of pancreatic secretion, selective vagotomy, the blood supply to the small intestine, colon, and rectum, persistent vitelline vessels, renal segmentation, supernumerary renal vessels, and the innervation of the ureter.

In Chapters 12 through 16, the pelvis and perineum, there is new material on, and new discussions of, the pelvic and perineal fascias, the ligaments of the female pelvis, the anatomy of the anal canal and the external anal sphincter, neuromuscular mechanisms of anal continence and of defecation, imperforate anus, vesico-ureteral reflux, the structure of the urinary bladder and of the urethra, the nerve supply of the bladder, control of micturition, the blood supply and lymphatics of the prostate, and the lymphatics of the testis.

More than 750 new references have been added, in an effort to make the Reference lists up-to-date guides to the literature when further details are required. As in the First Edition, priority was not a consideration in the choice of new references; nor does the necessary elimination of various older references reflect upon their quality.

The first edition of this book was completed before the Nomina Anatomica or Paris Nomina Anatomica of 1955 became available and replaced the B.N.A. and its numerous variations formerly in use. In this present volume, the terminology of the Third (1966) Edition of the N.A., mostly in anglicized form, is used in both text and figures. However, for the benefit of those readers who have had no reason to become familiar with the N.A., as well as for those who are familiar with it but will hear and see B.N.A. and other terms, many of the more common synonyms are also given, and listed in the index, when they differ appreciably from those of the N.A.

The figures have been reviewed, and revised and added to as seemed desirable. A new feature is the index listing of the pages on which the more important structures are illustrated.

I am, as before, much indebted to my Surgical Consultants, listed on the preceding pages. They have, among them, read and criticized for me the entire volume, and I have drawn freely on their knowledge and experience. I am also particularly indebted to the Section of Medical Illustration and Medical Graphics, under the direction of Mr. Vincent Destro; to Dr. Carl Gambill, of the Section of Publications; and to my Secretary, Miss Esther Peters. To these, and to my publishers for their cooperation, my thanks.

W. HENRY HOLLINSHEAD
Rochester, Minnesota

CONTENTS

CHAPTER 1

The Thorax in General

THE detailed anatomy of the thorax has become of interest to the surgeon only within relatively recent years. When it is realized that the first successful pneumonectomy was carried out as recently as 1931 (Nissen), and that since that time the dread of entering the thoracic cavity for surgical intervention has been so minimized that operations upon the nervous system here, the lungs, the esophagus, the great vessels and even the heart have become almost routine, the enormous and rapid strides in thoracic surgery become literally astounding.

As usual, this increased accessibility to the surgeon has resulted in the need for more accurate and detailed knowledge of the anatomy here: this is particularly well illustrated by the numerous investigations of the anatomy of the lungs, of the normal heart, and of abnormalities of the heart and great vessels.

THE THORACIC WALL

The wall of the thoracic cavity is composed of the thoracic vertebral column, the sternum, the ribs, and the intervening musculature. These parts are in turn largely covered by the musculature of the vertebral column and that of the upper limb, respectively, while in the female the surgically important breast in turn covers much of the pectoral muscle. The thoracic vertebral column and its musculature are discussed in another volume, in connection with the vertebral column as a whole; the muscles and related nerves and vessels of the upper limb are discussed in connection with this part of the body, and the breast is discussed in a following section of this chapter.

The superior thoracic aperture, bounded by the upper border of the sternum and by the first ribs, is open, and through it the great vessels and the visceral tubes ascend or descend between the thorax and the neck; through the connective tissue around these structures, cervical infections or tumors may descend into the mediastinum. Similarly, air from a ruptured bleb of the lung, having attained the mediastinum by passing along the perivascular sheaths of the pulmonary vessels, may work its way upward through the mediastinal connective tissue to produce emphysema of the head and neck and adjacent subcutaneous areas. In contrast to the superior aperture, the inferior aperture of the thorax is normally completely closed by the diaphragm, which closely invests those structures passing between the thorax and abdomen.

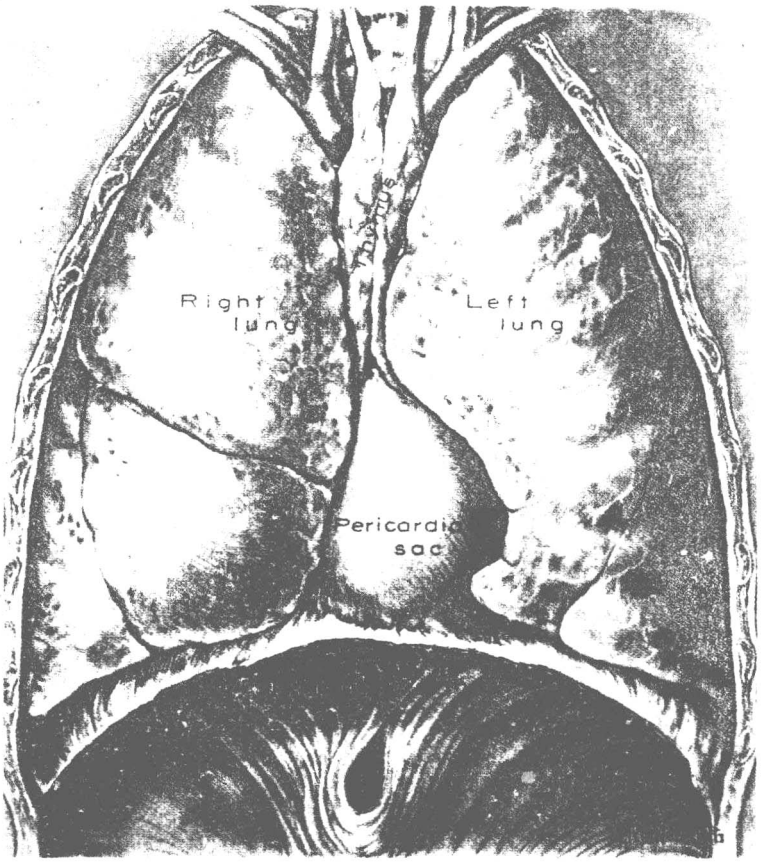

Fig. 1-1. Contents of the thorax after removal of the thoracic wall. The brachiocephalic vessels can be seen at the apices of the lungs, and the esophageal hiatus appears in the diaphragm.

It might be pointed out here that in consequence of the curvature of the diaphragm the lower ribs actually afford much protection to the upper abdominal organs, and are also, therefore, functionally a part of the abdominal wall. It is, of course, because of the relationships of the lower ribs to the upper abdominal viscera that the combined thoracoabdominal approach, apparently increasingly favored in seeking surgical access to some of these viscera, offers advantages in certain operations.

THE RIBS AND STERNUM

SURGICAL APPROACHES

Approaches to the thoracic contents were at one time almost universally through the intercostal spaces or the beds of the ribs, but sternum-splitting operations are now widely used for many purposes, especially for an approach to the heart, the thymus, or other structures in the more anterior portion of the superior mediastinum. In such an approach, the entire sternum may be split throughout its length, or only an upper, middle or lower portion, as desired, may be split in the midline and separated from the remainder by appropriate transverse incisions.

Posterolateral approaches to the thoracic contents are often achieved by resecting the fifth or sixth rib and opening the thorax through its periosteal bed or, more often, the thorax is opened through the periosteal bed of an intact fifth or sixth rib after stripping

the periosteum from its superior and medial aspects. A consequence of the slant of the ribs is that anterolateral and posterolateral approaches to the same intrathoracic structure are necessarily made in relation to different ribs. Thus, for instance, the anterolateral approach for closure of a patent ductus arteriosus is in the region of the second or third rib, the posterolateral approach in that of the fifth.

In gaining access to an intercostal space, the muscles of the shoulder which overlie it must be divided or reflected. Posteriorly and above, these are the trapezius and the rhomboids; posteriorly and below, the latissimus dorsi; laterally, the serratus anterior; and anteriorly, the pectoralis major and minor. The incision may also extend inferiorly into the external oblique. Lateral incisions over the ribs, necessitating dividing the serratus anterior muscle, involve the danger of sectioning the nerve (long thoracic) to the serratus anterior and even that to the latissimus dorsi, since these run longitudinally on the thoracic wall. They lie in approximately the posterior axillary line, and are especially liable to damage in an approach to the upper ribs. Some of the general anatomy of the anterolateral surface of the thorax is shown in Figure 1-2. More posterior ap-

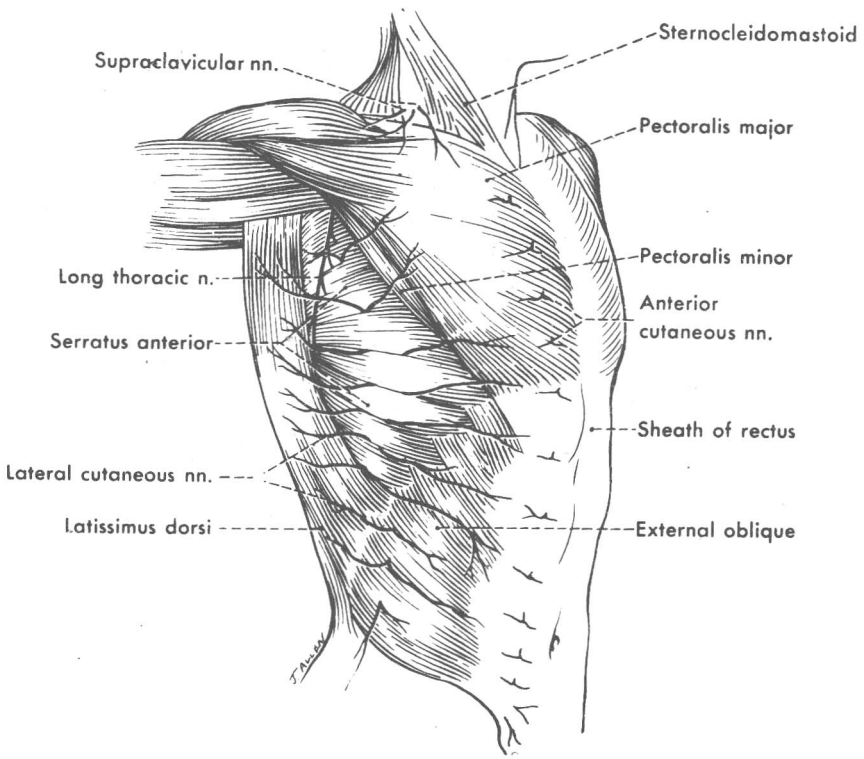

Fig. 1-2. The anterolateral thoracic wall.

proaches to these ribs can be made between the vertebral spinous processes and the vertebral border of the scapula and thence deep to this bone and the serratus anterior muscle; in this way the integrity of the nerve supply to this muscle is not threatened.

RIBS

Typically, the first seven (the true) ribs attach to the sternum (Fig. 1-3), and of the succeeding false ribs three attach to the cartilage of the seventh or to the cartilage of

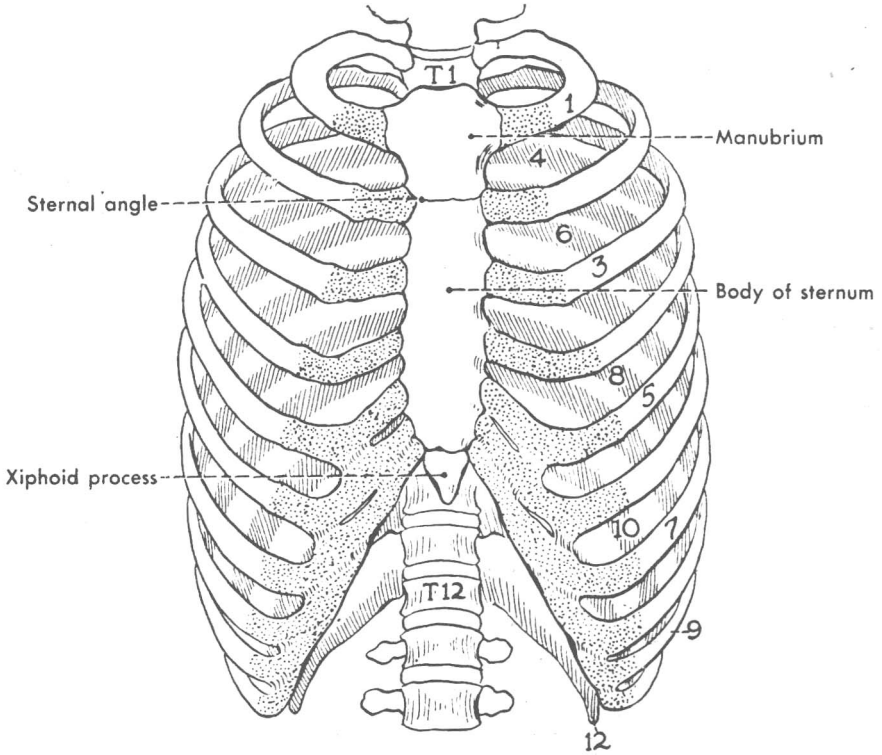

Fig. 1-3. The costal cage, anterior view.

the rib preceding the one under consideration, while the last two end freely in the abdominal musculature and are hence termed "floating" ribs. Occasionally, as reported for instance by Tredgold, an eighth sternal (true) rib occurs. The articulations between the costal cartilages also vary somewhat.

Variations in the total number of ribs may occur. Mention has already been made of cervical and rudimentary first thoracic ribs, and their apparent relation to symptoms of compression at the brachial plexus, in Volume 1; a thirteenth, lumbar, or "gorilla" rib occurs also occasionally, but is of clinical importance only as it may confuse matters if the ribs are counted from below upward, in attempting to identify the proper rib for resection.

In a posterolateral approach the first rib may be felt deep to the scapula, and the count begun with it; or the second rib can be identified by the insertion of the serratus posterior superior into it. Anteriorly, however, the first rib is normally rather well covered by the clavicle and not easily palpable, therefore if the ribs are to be counted at their sternal ends one should start with the second, which normally articulates at the sternal angle; it might be pointed out that occasionally the manubrium sterni has developed in a faulty fashion and is unusually long, and it is then the third rib which articulates at the sternal angle. Similarly, in counting the ribs from below upward by palpation, it must be recognized that the twelfth rib may be so short as not to be palpable, or a thirteenth rib may be present, and counts from below are therefore particularly liable to error.

Marked congenital *deformities* of the ribs are apparently rare; Colman and Bisgard reported a case of absence of the left third, fourth, and fifth costal cartilages, but stated

that such defects unassociated with other congenital defects of the thorax are uncommon. They found congenital absence of ribs and cartilages combined more common than absence of cartilages alone, and said such defects are usually unilateral, on the left side, and involve one or more of the sixth to the tenth ribs. Etter reported that any of the first seven ribs may be bifid, and that there may be synostoses between any two ribs from the first to the tenth.

The Costal Articulations

The costovertebral articulations consist of those of the head of the rib, and the costotransverse joints. The heads of the first, eleventh, and twelfth ribs usually articulate with the upper ends of the bodies of the corresponding vertebrae by complete facets (foveae), while the heads of the remaining ones are in demifacets associated with the adjacent surfaces of two contiguous vertebrae. The costotransverse articulations, lacking for the last three ribs, are between the tubercle of the rib and the transverse process of the corresponding vertebra. Both costovertebral articulations are synovial joints or diarthroses, with an articular capsule and supporting ligaments. Those of most heads of the ribs include an intraarticular ligament that separates the joint cavity into two parts, one for each of the vertebral bodies. The mobility provided by this arrangement is undoubtedly somewhat diminished by the attachment of the upper ten ribs to the sternum or to each other, and would be even more seriously restricted were it not for the elasticity of the costal cartilages. In contrast to the costovertebral articulations, the costochondral joints are fibrous joints or synarthroses, in which the bone and cartilage are closely bound together by connective tissue.

STERNOCOSTAL JOINTS

While the sternocostal articulations are usually described as diarthroses, they actually vary considerably (Fig. 1-4). Apparently there is never a synovial joint cavity present in connection with the union of the first rib to the sternum, and the articulations from the second through the seventh vary between having a single joint cavity, none at all, and double joint cavities. Gray and Gardner ('48) stated that all the sternocostal joints are covered by fibrocartilage, and when a synovial cavity occurs it therefore lies within this fibrocartilage; the intraarticular (interarticular) ligament, which occurs in some sternochondral joints to divide them into upper and lower cavities, is also composed of fibrocartilage.

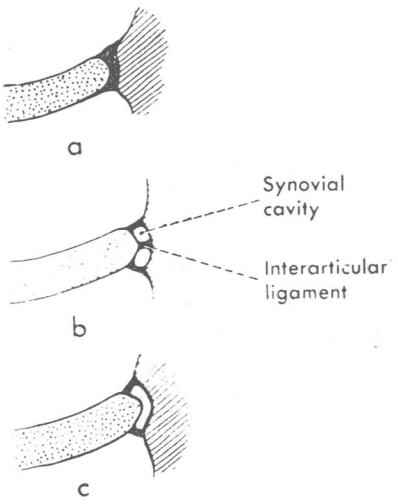

Fig. 1-4. Types of sternocostal junctions. The hyaline cartilage of the rib is indicated by stippling, the bony sternum by shading, and fibrocartilage by black. **a** shows a synchondrosis, **b** two synovial cavities, **c** a single cavity.

Musgrove examined the sternochondral joints in 18 individuals, and found that the number of synovial cavities associated with a sternocostal articulation decreases from above downward (except, of course, for the first), a fact also observed by Gray and Gardner ('43); thus, for instance, in 36 second sternocostal joints Musgrove found two synovial cavities in 21, none in 2, and a single joint, representing the lower one, in the remaining cases, while among the same number of seventh sternocostal joints there were none with double cavities, 17 with single cavities, and 19 with no cavity. Gray

and Gardner ('43), in their study of fetuses, found a considerable variation in the time of appearance of the joint cavities, but in their adult specimens were able to find no correlation between age and the number of joint cavities observed.

INTERCHONDRAL JOINTS

Those costal cartilages which articulate with each other may do so by means of synovial cavities, by ligamentous union without a joint cavity, or by direct cartilaginous union. In 200 sides Briscoe ('25) found an articulation between the fourth and fifth cartilages in only 1 case, between the fifth and sixth in 96, between the sixth and seventh in 198. In a lesser number of specimens, articulations between the seventh and eighth and the eighth and ninth cartilages were also found, but the ninth and tenth were never truly articulated, being united only by loose connective tissue or by muscle. The articulations between the sixth and seventh cartilages showed the highest percentage of synovial cavities (92 per cent), those between the eighth and ninth the lowest (about 24 per cent).

Sternal Defects

The sternum, consisting of manubrium, body, and xiphoid process (xiphisternum), is formed by the fusion of paired bars which originate in connection with the ventral ends of the ribs, and by the appearance within this fused tissue of longitudinally arranged centers of ossification (typically a single center for the manubrium, one single and three paired centers for the body, and of course none for the xiphoid). Because of this origin, the sternum may show segmental defects of ossification or, if the defect develops earlier, midline defects due to failure of fusion of the paired elements. An example of the former is the sternum with an elongated manubrium, already mentioned, in which the sternal angle lies at the level of the third rib instead of the second; or the manubrium may be normal, but the body of the sternum may retain traces of its longitudinal segmentation (for instance, Buchanan).

Failure of fusion of the sternal bands is more serious, as it usually involves a considerable length of the sternum, or all of it, giving rise to a grave defect. Partial failure of fusion may occur in any portion of the sternum: in the case reported by Buchanan, not only was the body of the sternum segmented longitudinally, but the lower two segments were paired, while in a case reported by Knight and Morley the defect involved the manubrium and body of the sternum as far down as the xiphoid process. Still greater defects of the sternum, involving a wide gap in the thoracic bony wall in the anterior midline, are often incompatible with life; in these cases, for instance, the heart may lie subcutaneously, entirely outside the thoracic wall. Maier and Bortone reported a rare case in which, although there was complete failure of the sternal bands to fuse, only the thymus and pericardium protruded through the defect, and it was possible to close this surgically.

Synostosis between the manubrium and the body of the sternum is said to occur in approximately 10 per cent of adults (Trotter), replacing the usual cartilaginous union of these elements. It is apparently more common in females than in males, and approximately twice as common in white females as in Negro females.

FUNNEL CHEST

A deformity shared by the sternum and the ribs is that of "funnel chest" or pectus excavatum, in which a variable lower part of the sternum and the ribs attaching to it are drawn more or less deeply backward, thus leaving a depression on the anterior thoracic wall. Funnel chest is said to be due not to abnormal development of the ribs and sternum per se, but rather to a fibrous instead of muscular attachment of the diaphragm to the xiphoid and sternum (Sutherland), resulting in retraction of the anterior part of the thoracic wall. Thus, the deformity is not particularly marked at birth but

increases with growth of the individual. While it has sometimes been regarded as of no particular consequence, Sutherland found it to be a common cause of progressive postural defects in children and said that, although cutting the xiphoid and the fibrous attachment of the diaphragm away from the sternum is effective in young children, the sternum must be cut transversely and costal cartilages removed in older children. Ravitch ('51) said that the depressed ribs and sternum may seriously interfere with the action of the heart and ('65) described the technic (subperichondrial removal of the ribs, separation of the xiphoid and of the intercostal muscles from the sternum) used in a large series of cases. For correction of the defect in adults, usually done for cosmetic reasons only, Masson and co-workers have inserted a preformed Silastic prosthesis.

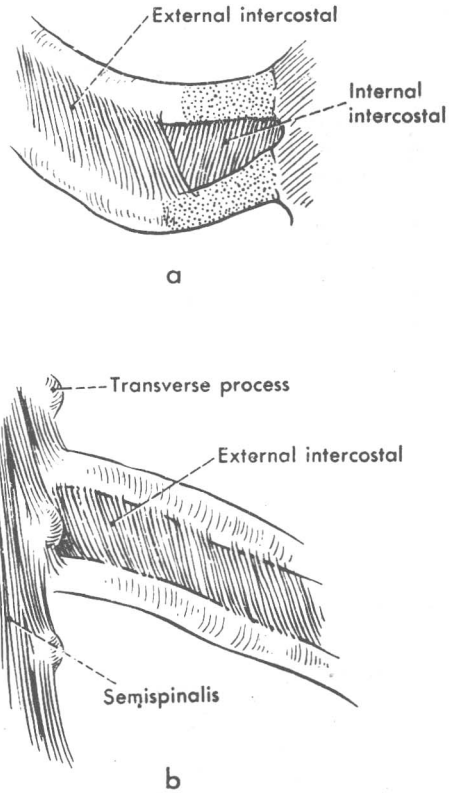

Fig. 1-5. Anterior **(a)** and posterior **(b)** ends of an intercostal space, external view. In **a** the anterior intercostal membrane is represented as perfectly transparent. In **b** the overlying iliocostal and longissimus muscles have been cut away.

THE INTERCOSTAL SPACES

MUSCLES

The intercostal muscles (Figs. 1-5, 1-6, and 1-7) occupy the spaces between the ribs; the external intercostal runs downward and forward from one rib to the next, in the same direction as the external abdominal oblique muscle. The external intercostal muscle fails to reach the sternum anteriorly, being replaced here by an anterior intercostal membrane. Similarly, the internal intercostal muscle, which runs upward and forward from one rib to the next, reaches posteriorly only about to the angles of the ribs, behind which it is replaced by a posterior intercostal membrane.

The intercostal nerves and vessels have been described as running between external and internal intercostal muscles; a large muscular branch of the nerve may so run to supply both muscles, but the main branches of these structures lie between the internal intercostal muscle and another layer whose fibers parallel the internal, the innermost intercostal or intercostalis intimus (Figs. 1-6 and 1-7), which has also been called the intracostal, and another lamina of the internal intercostal.

The innermost intercostal is better developed in the more lateral aspect of the thorax (and, according to Cave, usually lacking in the first or first and second intercostal spaces). There are also fibers in the region of the costal angle which pass over more than one intercostal space, and are known as the subcostal muscle (Fig. 1-6); anteriorly is the transversus thoracis muscle, which radiates outward from the posterior surface of the sternum to the inner surfaces of the ribs. These three muscles are often regarded as the thoracic equivalent of the transversus abdominis.