The GUT tube and Body Cavities

During the third and fourth weeks the top layer (ectoderm) of the trilaminar embryonic disc forms the neural plate that rolls up into a tube to form the brain and spinal cord by the process called neurulation. Almost simultaneously, the ventral layer (endoderm) rolls down to form the gut tube, such that the embryo consists of a tube on top of a tube: the neural tube dorsally and the gut tube ventrally. The middle layer (mesoderm) holds the two tubes together and the lateral plate component of this mesoderm layer also splits into visceral (splanchnic) and parietal (somatic) layers. The visceral layer rolls ventrally and is intimately connected to the gut tube; the parietal layer, together with the overlying ectoderm, forms the lateral body wall folds (one on each side of the embryo), which move ventrally and meet in the midline to close the ventral body wall. The space between visceral and parietal layers of lateral plate mesoderm is the primitive body cavity, which at this early stage is a continuous cavity, since it has not yet been subdivided into the pericardial, pleural, and abdominopelvic regions.

Formation of the Intraembryonic Cavity

At the end of the third week, intraembryonic mesoderm on each side of the midline differentiates into a paraxial portion, an intermediate portion, and a lateral plate. When intercellular clefts appear in the lateral mesoderm, the plates are divided into two layers: the somatic mesoderm layer and the splanchnic mesoderm layer. The latter is continuous with mesoderm of the wall of the yolk sac. The space bordered by these layers forms the intraembryonic cavity (body cavity). At first the right and left sides of the intraembryonic cavity are in open connection with the extraembryonic cavity, but when the body of the embryo folds cephalocaudally and laterally, this connection is lost. In this manner a large intraembryonic cavity extending from the thoracic to the pelvic region forms.

Serous Membranes

Cells of the somatic mesoderm lining the intraembryonic cavity become mesothelial and form the parietal layer of the serous membranes lining the outside of the peritoneal, pleural, and pericardial cavities. In a similar manner, cells of the splanchnic mesoderm layer form the visceral layer of the serous membranes covering the abdominal organs, lungs, and heart. Visceral and parietal layers are continuous with each other as the dorsal mesentery, which suspends the gut tube in the peritoneal cavity. Initially this dorsal mesentery is a thick band of mesoderm running continuously from the caudal limit of the foregut to the end of the hindgut. Ventral mesentery exists only from the caudal foregut to the upper portion of the duodenum and results from thinning of mesoderm of the septum transversum. These mesenteries are double layers of peritoneum that provide a pathway for blood vessels, nerves, and lymphatics to the organs.

Diaphragm and Thoracic Cavity

The septum transversum is a thick plate of mesodermal tissue occupying the space between the thoracic cavity and the stalk of the yolk sac. This septum does not separate the thoracic and abdominal cavities completely but leaves large openings, the pericardioperitoneal canals, on each side of the foregut. When lung buds begin to grow, they expand caudolaterally within the pericardioperitoneal canals. As a result of the rapid growth of the lungs, the pericardioperitoneal canals become too small, and the lungs begin to expand into the mesenchyme of the body wall dorsally, laterally, and ventrally. Ventral and lateral expansion is posterior to the pleuropericardial folds. At first these folds appear as small ridges projecting into the primitive undivided thoracic cavity. With expansion of the lungs, mesoderm of the body wall splits into two components:

(*a*) the definitive wall of the thorax and

(*b*) the pleuropericardial membranes,

which are extensions of the pleuropericardial folds that contain the common cardinal veins and phrenic nerves. Subsequently, descent of the heart and positional changes of the sinus venosus shift the common cardinal veins toward the midline, and the pleuropericardial membranes are drawn out in mesentery-like fashion. Finally, they fuse with each other and with the root of the lungs, and the thoracic cavity is divided into the definitive pericardial cavity and two pleural cavities. In the adult, the pleuropericardial membranes form the fibrous pericardium.

Formation of the Diaphragm

Although the pleural cavities are separate from the pericardial cavity, they remain in open communication with the abdominal (peritoneal) cavity, since the diaphragm is incomplete. During further development, the opening between the prospective pleural and peritoneal cavities is closed by crescent-shaped folds, the pleuroperitoneal folds, which project into the caudal end of the pericardioperitoneal canals. Gradually the folds extend medially and ventrally so that by the seventh week they fuse with the mesentery of the esophagus and with the septum transversum. Hence the connection between the pleural and peritoneal portions of the body cavity is closed by the pleuroperitoneal membranes. Further expansion of the pleural cavities relative to mesenchyme of the body wall adds a peripheral rim to the pleuroperitoneal membranes. Once this rim is established, myoblasts originating in the body wall penetrate the membranes to form the muscular part of the diaphragm. Thus the diaphragm is derived from the following structures:

(*a*) the septum transversum, which forms the central tendon of the diaphragm;
(*b*) the two pleuroperitoneal membranes;
(*c*) muscular components from the lateral and dorsal body walls; and
(*d*) the mesentery of the esophagus, in which the crura of the diaphragm develop.

Initially the septum transversum lies opposite cervical somites, and nerve components of the third, fourth, and fifth cervical segments of the spinal cord grow into the septum. At first the nerves, known as phrenic nerves, pass
into the septum through the pleuropericardial folds. This explains why further expansion of the lungs and descent of the septum shift the phrenic nerves that innervate the diaphragm into the fibrous pericardium. Although the septum transversum lies opposite cervical segments during the fourth week, by the sixth week the developing diaphragm is at the level of thoracic somites. The repositioning of the diaphragm is caused by rapid growth of the dorsal part of the embryo (vertebral column), compared with that of the ventral part. By the beginning of the third month some of the dorsal bands of the diaphragm originate at the level of the first lumbar vertebra. The phrenic nerves supply the diaphragm with its motor and sensory innervation. Since the most peripheral part of the diaphragm is derived from mesenchyme of the thoracic wall, it is generally accepted that some of the lower intercostal (thoracic) nerves contribute sensory fibers to the peripheral part of the diaphragm.

Diaphragmatic Hernias

A congenital diaphragmatic hernia, one of the more common malformations in the newborn (1/2000), is most frequently caused by failure of one or both of the pleuroperitoneal membranes to close the pericardioperitoneal canals. In that case the peritoneal and pleural cavities are continuous with one another along the posterior body wall. This hernia allows abdominal viscera to enter the pleural cavity. In 85 to 90% of cases the hernia is on the left side, and intestinal loops, stomach, spleen, and part of the liver may enter the thoracic cavity. The abdominal viscera in the chest push the heart anteriorly and compress the lungs, which are commonly hypoplastic. A large defect is associated with a high rate of mortality (75%) from pulmonary hypoplasia and dysfunction. Occasionally a small part of the muscular fibers of the diaphragm fails to develop, and a herniamay remain undiscovered until the child is several years old. Such a defect, frequently seen in the anterior portion of the diaphragm, is a ***parasternal hernia***. A small peritoneal sac containing intestinal loops may enter the chest between the sternal and costal portions of the diaphragm. Another type of diaphragmatic hernia, ***esophageal hernia***, is thought to be due to congenital shortness of the esophagus. Upper portions of the stomach are retained in the thorax, and the stomach is constricted at the level of the diaphragm.