Digestive System

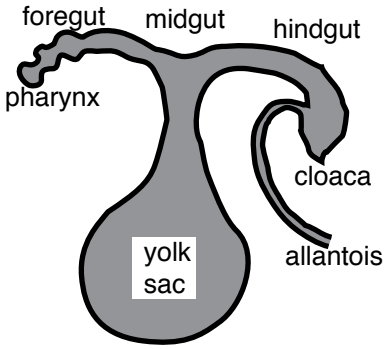
NOTE: The digestive system consists of the: mouth (oral cavity); pharynx; esophagus; stomach; small intestine; colon and cecum; rectum; anal canal; and the liver, pancreas, and salivary glands.

• Development of head and tail processes, and the merger ventrally of lateral body folds, transforms splanchnopleure into: *foregut*, *hindgut*, & *midgut* (the latter is continuous with the yolk sac).

• *Endoderm* becomes epithelium lining of the digestive tract; *splanchnic mesoderm* forms connective tissue and smooth muscle components (except that *ectoderm* forms epithelium lining the proctodeum (caudal end of anal canal) and stomadeum (mouth & some salivary glands — parotid, zygomatic, labial & buccal).

Foregut becomes pharynx, esophagus, stomach, cranial duodenum, and liver and pancreas.
Midgut becomes the remaining small intestines, cecum, ascending colon, and part of the transverse colon.
Hindgut becomes transverse and descending colon and a cloaca which forms the rectum and most of the anal canal.

In the adult abdomen, derivatives of the *foregut*, *midgut*, and *hindgut* are those structures supplied by the ***celiac***, ***cranial mesenteric***, and ***caudal mesenteric arteries***, respectively.



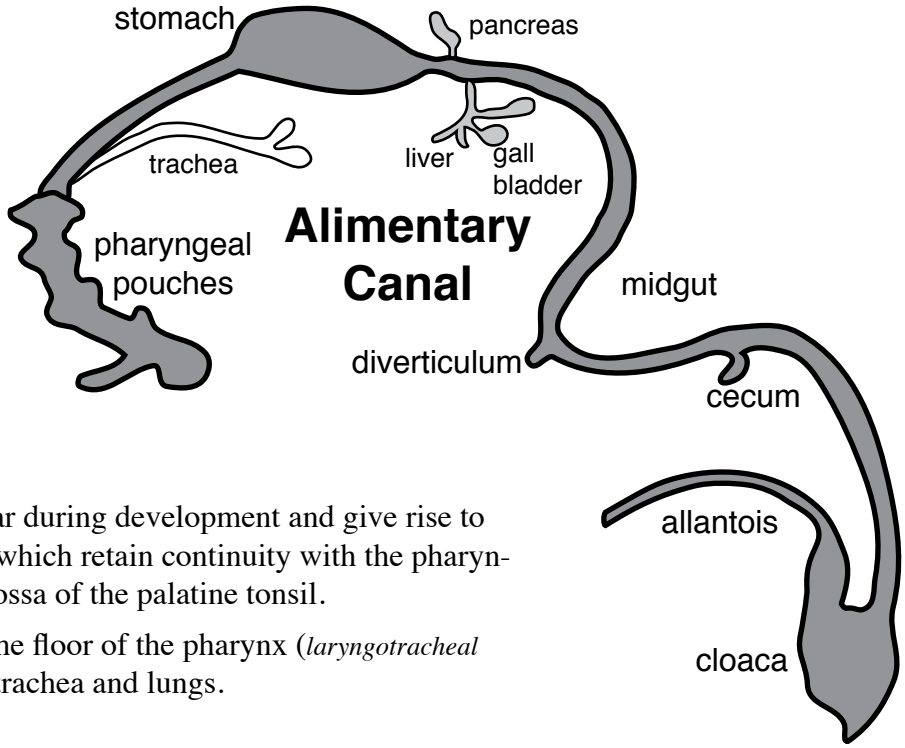
Pharynx...

• The adult pharynx is a common respiratory-digestive chamber.

• Initially, the pharynx is closed cranially by an *oropharyngeal membrane* that must degenerate to allow:

— the pharynx to communicate with oral and nasal cavity outgrowths;

— migration of tongue muscle from the pharynx into the oral cavity.



• *Pharyngeal pouches* appear during development and give rise to several adult structures, two of which retain continuity with the pharyngeal cavity: auditory tube and fossa of the palatine tonsil.

• A midline evagination of the floor of the pharynx (*laryngotracheal groove*) gives rise to the larynx, trachea and lungs.

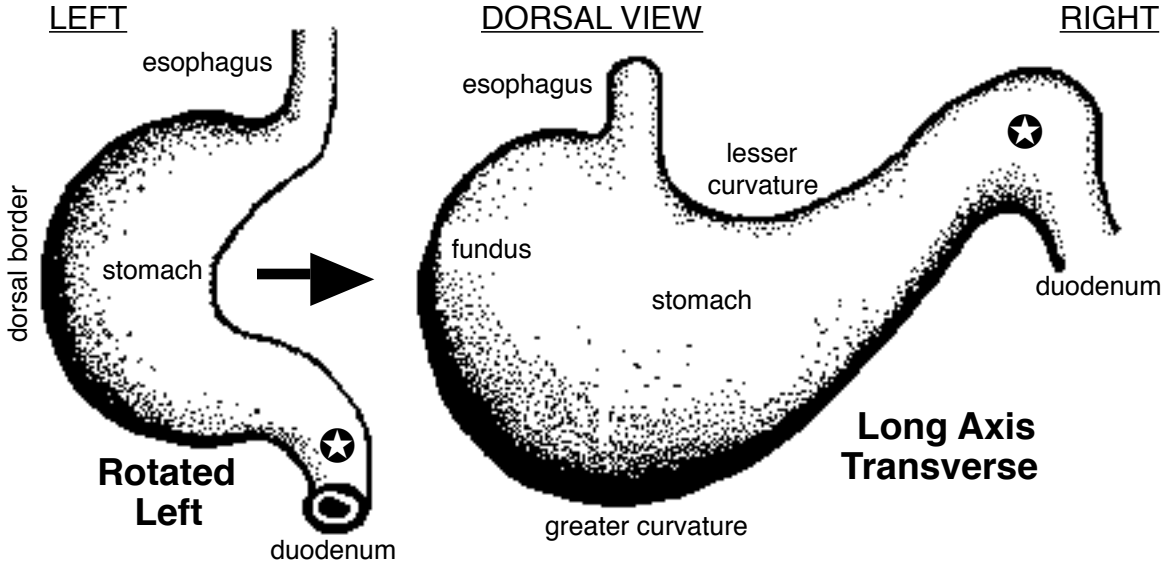
Esophagus...

• The esophagus develops from *foregut*, caudal to the pharynx. Its principal morphogenic development is elongation.

• Skeletal muscle associated with both the esophagus & pharynx is derived from somites that migrate to the pharyngeal arches IV & VI (innervation is from ***vagus nerve***).

NOTE: Esophagus may be coated by skeletal muscle: throughout its length (dog, ruminants), to the level of the diaphragm (pig), to the mid-thorax (cat, horse, human), or not at all (avian).

SIMPLE STOMACH DEVELOPMENT

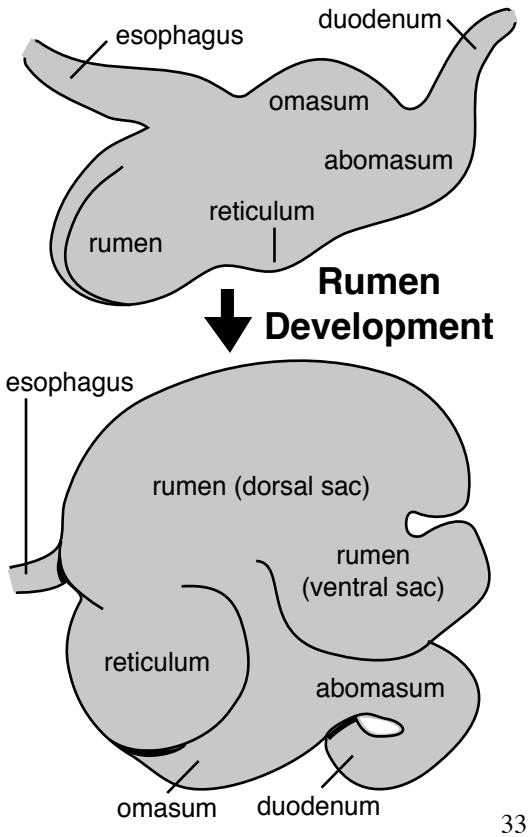


Stomach (simple stomach)...

Most domestic mammals have a simple stomach; in contrast, ruminants have a complex stomach with multiple compartments.

The simple stomach develops from a tubular segment of *foregut* that undergoes the following morphogenic changes:

- the tube becomes convex dorsally (future ***greater curvature***) and concave ventrally (future ***lesser curvature***), because growth is more rapid dorsally than it is ventrally
- the tube rotates 90° to the left (dorsal faces left & ventral faces right);
- the long axis becomes transverse as liver growth pushes the cranial end of the stomach to the left side (the greater curvature faces caudally and drops ventrally when the stomach is filled);
- increased growth along the left cranial margin of the future greater curvature produces a ***fundus*** region;
- endoderm forms the epithelium lining the stomach and differentiates into different cells types that vary regionally among species.

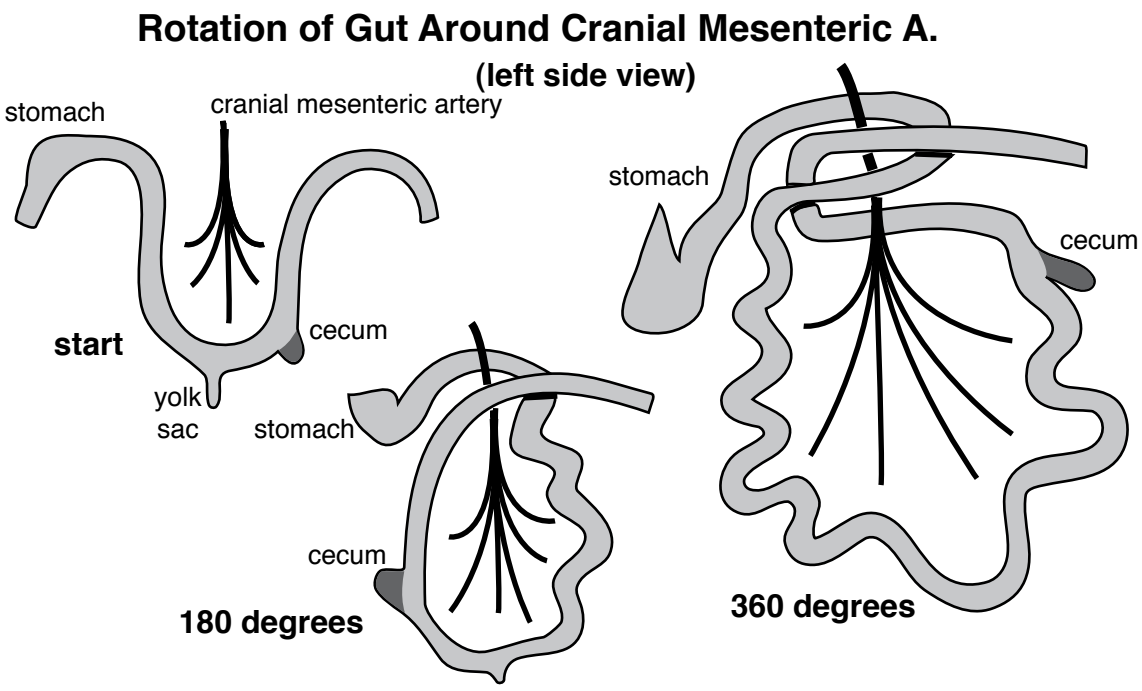


Ruminant stomach...

The adult ruminant stomach consists of three compartments lined by stratified squamous epithelium (***rumen***, ***reticulum***, and ***omasum***) and one glandular compartment (***abomasum***).

- The early development of the ruminant stomach is the same as the simple stomach; subsequently:
- the *rumen* develops as an expansion of the fundus
- the *reticulum* arises as a caudoventral pocket of the developing rumen
- the *omasum* develops as a bulge along the lesser curvature.
- the *abomasum* develops from rest of the stomach

Later in development the rumen "flips" caudally so it lays on top of the abomasum and the reticulum is cranial.



Intestinal tract...

NOTE. The intestinal tract consists of: duodenum (descending & ascending), jejunum, ileum, colon (ascending, transverse, & descending). cecum (diverticulum at the beginning of the colon), rectum, and anal canal.

Along with general tubular elongation, the following morphogenic events occur:

— where the *yolk sac* is attached, the *midgut* to form an elongate loop that herniates through the *umbilicus* (out of the embryo and into the coelom of the umbilical stalk); as the embryo grows, the loop returns into the embryonic coelom (abdominal cavity).

— the elongating loop rotates 360° around the right vitelline a. (adult ***cranial mesenteric artery***), the rotation is clockwise as viewed dorsally (freedom to rotate is the result of the reduced yolk sac attachment and elongation of the cranial limb of the midgut loop).

— the caudal limb of the loop develops a diverticulum, the future cecum.

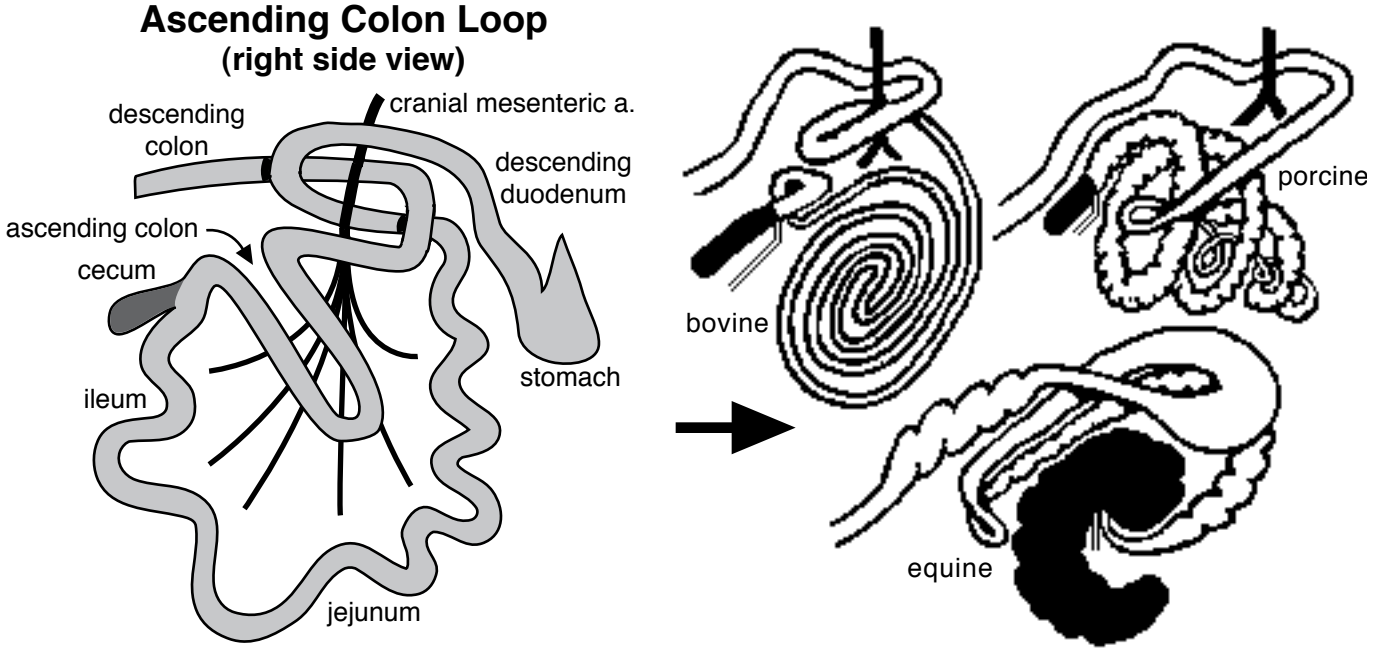
Additional intestinal events in ungulates...

- a loop of colon forms just distal to the cecum (loop of adult ascending colon)
- in pig and ruminant—the loop coils (forming a spiral or coiled colon);
- in horse—the loop enlarges and bends on itself; also, the cecum enlarges so that the proximal colon is incorporated within the cecum.

Anomalies...

• The intestinal tract and esophagus normally undergo temporary atresia (occluded lumen) during development as a result of epithelial proliferation. Re-canalization occurs by formation of vacuoles that coalesce to form the ultimate lumen. Persistent **atresia** (failure to re-canalize) or **stenosis** (narrow lumen) is a congenital anomaly that can occur at localized sites anywhere along the esophagus or intestines.

• Failure of the *yolk sac* to be absorbed by the *midgut* (**jejunum**) can result in: a diverticulum of the jejunum, a fistulous (hollow) cord to the umbilicus, or a fibrous connection between the jejunum and umbilicus. Each of these can become a source of colic



Cloaca...

The *hindgut* terminates in a *cloaca*, i.e., a chamber that communicates with digestive, urinary and genital systems:

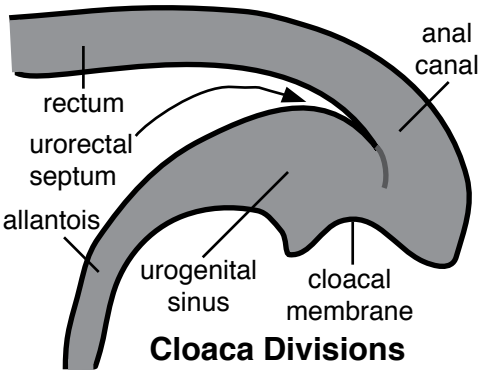
- — the caudal wall of the cloaca (*cloacal membrane*) is endoderm apposed to surface ectoderm
- — the allantois evaginates from the hindgut at the cranial end of the cloaca
- — the cloaca persists in adult birds, reptiles, & amphibians

Rectum:

The rectum is formed when a mesenchyme partition (*urorectal septum*) divides the cloaca into dorsal and ventral chambers:

• The dorsal chamber, which is continuous with the hindgut, becomes the ***rectum*** and most of the ***anal canal***, including a temporary anal membrane.

• The ventral chamber, the *urogenital sinus*, is continuous with the allantois. The urinary bladder and urethra develop from the proximal allantois and urogenital sinus.



Anal canal:

The cranial part of the anal canal (most of the canal) is formed along with the rectum; this part of the anal canal is lined by a mucosal epithelium derived from endoderm.

The caudal part of the anal canal (caudal to the adult ***anocutaneous line***) is lined by stratified squamous epithelium. It forms as follows:

- — external tissue surrounding the anal membrane grows caudally creating a *ectoderm* lined depression called the *proctodeum*
- — the proctodeum becomes incorporated into the anal canal when the anal membrane degenerates (atresia ani or intact anal membrane is a congenital anomaly);
- — in carnivores, lateral diverticula of proctodeum ectoderm become anal sacs.

Liver...

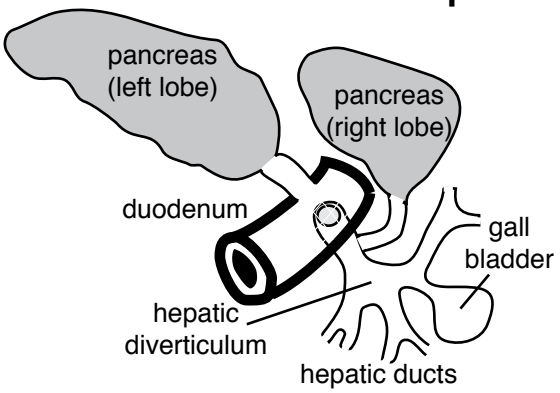
- the liver originates from endoderm as an *hepatic diverticulum* that arises from the region of foregut that will become adult ***descending duodenum***
- the diverticulum gives rise to multiple branches that, in the adult, become: ***hepatic ducts***, ***cystic duct*** and the ***pancreatic duct***
- **lobes** of the **liver** are formed during continued growth & branching of hepatic duct primordia
- a ***gall bladder*** develops at the end of the cystic duct
- the ***bile duct*** is derived from the initial part of the hepatic diverticulum
- the hepatic diverticulum originates ventrally but differential growth of the duodenal wall results in the bile duct entering the duodenum dorsally, with the pancreatic duct on the ***major duodenal papilla***.

Pancreas...

- The pancreas originates from two separate endoderm diverticula, each of which elongates, branches, and then forms acini in typical glandular fashion
  - — one diverticulum arises ventrally as a bud of the hepatic diverticulum, it forms the ***pancreatic duct*** and ***right lobe of the pancreas***
  - — the other diverticulum arises dorsally from the duodenum (***minor duodenal papilla***) and forms the ***accessory pancreatic duct*** and the ***left lobe of the pancreas***
- As the right and left lobes cross one another during development, they fuse to from the ***body*** of the ***pancreas***; also, the duct systems anastomose to form a common drainage system
- The endocrine (islet) cells of the pancreas also develop from the endoderm of the diverticula.

NOTE: One of the two pancreatic ducts will be smaller than the other and may even disappear. Which one is destined to become smaller or absent depends on the species. In the dog, the accessory pancreatic duct is the larger one, but only about 20% of cats have an accessory pancreatic duct and the associated minor duodenal papilla.

Pancreas & Liver Development



Avian...

The avian digestive tract features:

- — a crop, which develops as a diverticulum of the esophagus;
- — a two-compartment stomach:
  - 1] proventriculus (glandular stomach) and
  - 2] ventriculus or gizzard (stratified squamous epithelium and heavy muscles for grinding);
- — a pair of ceca;
- — a cloaca which opens externally by means of a vent.

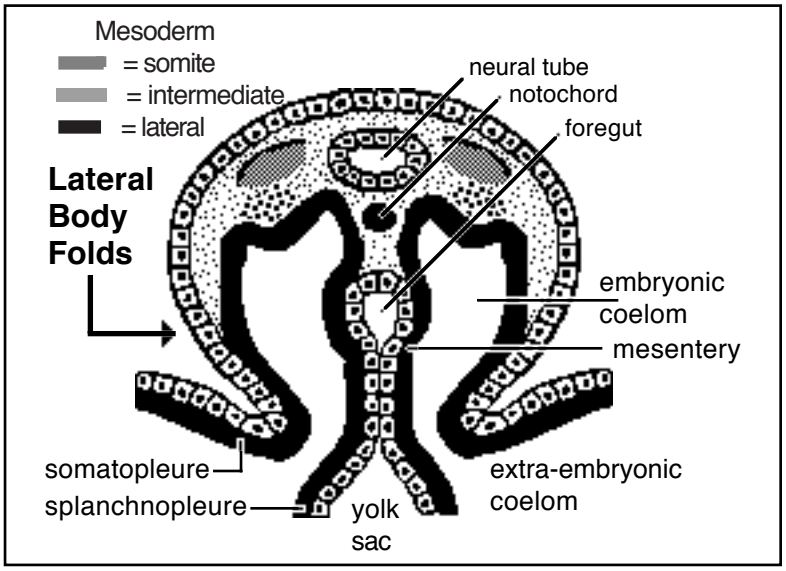
Mesenteries...

• The embryonic *coelom* separates splanchnic mesoderm from somatic mesoderm. The mesoderm lining the coelom transforms into serous membrane, making the coelom a serous cavity.

• Mesenteries are formed by *splanchnic mesoderm* at the same time that the embryonic gut is created as the embryo assumes a tubular shape.

• Caudal to the pharynx, dorsal and ventral "mesenteries" of the esophagus persist as ***mediastinum*** in the thorax.

• In the abdomen, a dorsal mesentery persists, but a ventral mesentery is absent in the midgut region.



Abdomen:

The *dorsal mesentery* becomes: greater omentum, mesoduodenum, mesentery (mesojejunum and mesoileum), mesocolon, and mesorectum.

The original dorsal mesogastrium elongates greatly as it forms ***greater omentum***. The left lobe of the pancreas develops within the dorsal portion of the greater omentum. The spleen develops within the greater omentum from blood vessels that accumulate in the vicinity of the greater curvature of the stomach.

As the *midgut* elongates and rotates around the cranial mesenteric artery, portions of the mesojejunum and mesoileum come into contact near the dorsal body wall and fuse, forming the ***root of the mesentery***. Parts of the mesoduodenum and mesocolon also fuse to the root the mesentery.

The *ventral mesentery*, in which the liver develops, becomes the ***lesser omentum*** and coronary and falciform ligaments of the liver. Caudally, ventral mesentery becomes ***median ligament of the urinary bladder***.