DIGESTIVE SYSTEM - 4

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LEARNING OBJECTIVES

1. Describe the anatomy of the smooth muscle layers in the outer walls of the gastrointestinal tract.
2. Explain gastrointestinal motility and pacemaker function
3. Explain the patterns of motility in the fed and fasted states.

GENERAL ANATOMY

The outside wall of the GI tract has **two layers of smooth muscle** which are oriented perpendicular to each other (Fig 1). Constriction of the **innermost layer of muscle changes the diameter** of the tube. Constriction of the **outermost layer of muscle shortens the tube**.

The smooth muscles of the GI tract behave like an electrical syncytium (single unit smooth muscle fibers). Each muscle cell is connected to its neighbor by gap junctions that provide low resistance fiber-to-fiber coupling.

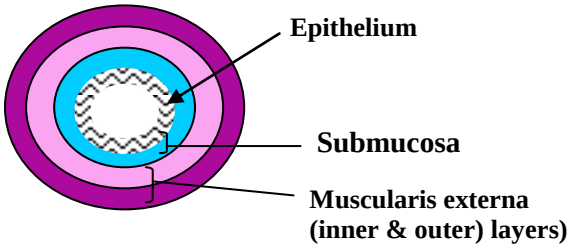

Figure 1. Inner and outer layers of muscle in the walls of the gastrointestinal tract are oriented perpendicular to one another.

MOTILITY

The motility in the different regions of the GI tract reflects coordinated contraction and relaxation of the two muscle layers located within the wall of the tube. Contractions are organized to propel the chyme along the tract and to mix ingested food with digestive enzymes and to bring nutrients into contact with the epithelial cells for efficient absorption.

Movement along the GI tract is regulated mostly by the local **enteric nervous system** which is modulated by inputs from the CNS. These two nervous systems organize motility under conditions of fasting and feeding, as well during times of abnormal behavior (GI distress).

The smooth muscle of the GI tract has pacemaker cells. The pacemaker activity is called the electrical slow waves. These electrical slow waves occur **spontaneously** in the stomach, small and large intestines as cycles of depolarization and repolarization. Like all pacemakers, the electrical slow wave brings the membrane potential of the smooth muscle fiber close to the threshold. If threshold is reached then the voltage gated calcium channels open and an action potential is triggered. **Electrical slow waves are always present but action potentials are not.** Action potentials are triggered at the crest of depolarization (Fig 2). If an action potential occurs, then the muscle contracts (Fig 2).

The electrical slow waves determine the direction and velocity of the contractions along the tube.

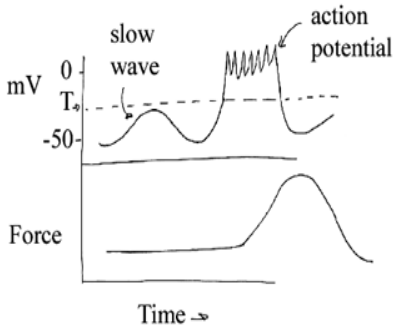

Figure 2. Electrical slow waves are rhythmic changes in electrical potential (top tracing). If an action potential is fired from the crest of the slow wave then contraction follows (bottom tracing).

Enteric neurons work in concert with the electrical slow waves. The inhibitory neurons of the enteric nervous system determine the initiation of the action potentials, their propagation, distance and direction. **The inhibitory neurons are continuously active.** Muscle contraction can occur only when they are **turned off.** The inhibitory neurons are coordinately on or off to allow movement of material from one segment to the next along the tube.

Recall that contraction of the inner circular muscle layer decreases the diameter of the tube. This propels the food bolus from the contracted region into a neighboring relaxed region. Each contraction is discrete and transient. But tonic, prolonged contractions can occur if the action potentials summate with increased rate of firing.

PATTERNS OF MOTILITY

When food is present, all patterns of gastrointestinal motility are based on three fundamental motor events programmed by the enteric nervous system: **peristalsis** (propulsion), **mixing movements** (called segmentation), and **tonic contraction** at the sphincters.

SEGMENTATION (mixing movement) are cyclic contractions of the muscle in local segments which force the chyme (food bolus) to slosh back and forth for short distances (Fig 3). This ensures maximal absorption of nutrients by the epithelial cells. Segmentation occurs in the fed state.

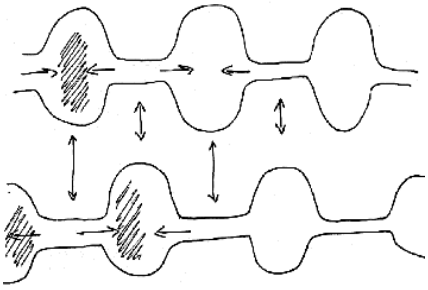

Figure34. Mixing movements occurs when propulsive segments are bordered by relaxed segments. The chyme "sloshes" forward and backward.

PERISTALSIS is the unidirectional movement of chyme over variable distances within the intestinal lumen. This involves coordinated contraction and relaxation within adjacent regions (Fig 4). Peristalsis involves the contraction of the longitudinal muscle layer to shorten the tube while the inner muscle layer in an adjacent region is relaxed (Fig 4). The normal direction of flow is from mouth to anus.

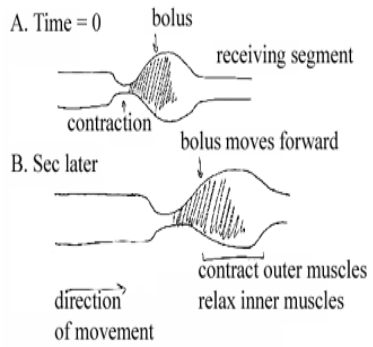

Figure 4. Peristaltic propulsion moves the food bolus along the tube. This occurs in the fed state.

TONIC CONTRACTIONS occur when the tract is quiescent and there is no motility. The state of tonic contraction is lost when enteric innervation is ablated. Under these conditions, disorganized and non-propulsive contractile behavior will occur continuously. Tonic contractions occur at the sphincters to separate one region from another. To open the sphincter the muscle must relax. Controlled relaxation of the sphincters occur in both the fed and fasted states.

MIGRATING MOTOR COMPLEX (MMC) sweeps the GI tract clean during periods of fasting. The MMC performs a "housekeeping" function in that it prevents bacterial overgrowth due to stagnant food contents. The MMC usually originates in the stomach but can begin in either the duodenum or the jejunum. It occurs at a different frequency than the peristalsis associated with fed states. The hormone, motilin, is thought to be responsible for the initiation of the MMC. Motilin is secreted by an empty stomach.

MASS MOVEMENTS are waves of contraction that propel semi-solid feces into the distal colon (large intestine) and then into the rectum and anal canal. These occur one to three times daily. Defecation is the voiding of fecal material from the body. Defecation is controlled by the parasympathetic nervous system and can be modulated by higher CNS centers. The anal sphincter is under voluntary control.

VOMITING is the expulsion of gastric chyme (and sometimes duodenal chyme) from the mouth. Vomiting occurs as a protective response to ingestion of toxins and in response to either too rapid emptying of stomach contents (dumping syndrome) or delayed emptying of stomach contents. Vomiting is controlled by the **Vomiting Center located in the medulla of the brain stem**. Respiratory and abdominal muscles are used in vomiting, not the smooth muscle lining the walls of the gastrointestinal tract.

KEY CONCEPTS

1. Movement involves the coordinated activities of the two outer muscle masses in the wall of the gastrointestinal tract.
2. Movement and activities are coordinated by the enteric nervous system with modulation from the CNS.
3. Pacemakers cells are found throughout the gastrointestinal tract. These cells generate spontaneous electrical activity called electrical slow waves. An action potential can fire at the peak of a slow wave. Contractions follow an action potential.
4. In the fed state two types of motility occur, segmentation (or mixing) and peristalsis. In the fasted state, the migrating motor complex sweeps the tract clean.
5. Tonic contractions occur at the sphincters and when there is no motility within the tract.

QUESTIONS

1. In the fed state, segmentation depends on:
    A. an intact enteric nervous system
    B. an intact parasympathetic nervous system
    C. an intact sympathetic nervous system
    D. occurs only in the stomach

2. If an electrical slow wave passes through a region of the ileum that is stretched due to the presence of food, then:
    A. the resting membrane potential is hyperpolarized
    B. an action potential is generated
    C. a graded potential is generated
    D. the slow wave is inhibited

3. In the fasting state, between meals,
    A. slow waves are inhibited
    B. migrating motor complexes occur
    C. all sphincters are open
    D. B and C

ANSWERS

1. A
2. B
3. B