Gastrointestinal Motility 2: Intestinal and Colonic Motility
Jack Grider, Ph.D.

OBJECTIVES:

1. Contrast the types of motility in the small intestine.
2. Describe the neural circuits that mediate peristalsis.
3. Differentiate the migrating motor complex from the peristaltic type of motility.
4. Compare colonic motility with that of the small intestine.
5. Describe the process of defecation.

Suggested Reading: Berne & Levy pp. 543- 563

1. MOTILITY OF THE SMALL INTESTINE
   A. Motility Patterns.

   1. There are three normal motility patterns that occur in the small intestine (Figure 1):

      a. Propagating contractions or Peristalsis. These are spatially and temporally coordinated
      b. Stationary contractions or Segmentation. These occur at random in a region and do not propagate.
      c. Clustered contractions. These are groups of contractions that may be stationary or may propagate.

Figure 1.
2. There are two abnormal motility patterns (Figure 2)

   a. **Antiperistaltic contractions.** These move in the anal to oral direction and may be indicative of pathology.
   b. **Aboral Power Contractions.** The are high amplitude contractions that move in the normal oral to anal direction.

   ![Peristalsis - antiperistasis](image1)

   ![Aboral power contraction](image2)

   **Figure 2.**

B. **Postprandial (after eating)** motility consists mainly of two types of motility, **peristalsis** (dashed lines in Figure 3) and **segmentation** (arrow heads in Figure 3)

![Postprandial motility](image3)

**Figure 3.**
C. Peristalsis (Figure 4A&4B)

1. As described earlier peristalsis is a traveling wave of contraction preceded by a traveling wave of relaxation. The process is mediated through neurons of myenteric plexus and is therefore a Short Arc Reflex.

2. A sensory stimulus initiates the peristaltic reflex, a dual reflex consisting of the "ascending excitatory reflex and descending inhibitory reflex". Different stimuli may activate the reflex via different mechanisms described below although once activated, the efferent limb of the reflex is identical for all stimuli and is mediated wholly by intrinsic or enteric neurons. The reflex results in contraction of circular muscle and relaxation of longitudinal muscle orad or above the site of stimulation (ascending excitatory reflex) and a relaxation of circular muscle and contraction of longitudinal muscle caudad or below the site of stimulation (descending inhibitory reflex). (the Law of the Intestine). Contraction of both muscle layers is mediated by acetylcholine/tachykinin excitatory motor neurons. Relaxation of circular muscle is mediated by VIP/NOS inhibitory motor neurons. Relaxation of longitudinal muscle is mediated by inhibition of cholinergic/tachykinin motor neurons. The reflex arc likely involves several interneurons that release a variety of neurotransmitters such as enkephalins, somatostatin, Neuropeptide Y, and acetylcholine/tachykinin.

3. Sensory (Afferent) limb: Short chain fatty acids, HCl, Bile acids, and mechanical distortion of the villi of the mucosa activate an intrinsic primary afferent neuron (IPAN) indirectly. These stimuli cause the release of serotonin (5-hydroxytryptamine) from enterochromaffin cells of the mucosa. These are a subtype of enteroendocrine cell. Local paracrine release of serotonin activates a 5-HT4 receptor on the IPAN. The IPAN then releases the sensory transmitter calcitonin gene-related peptide (CGRP) and substance P to activated the interneurons in the reflex arc. This mucosal reflex is the most likely physiological stimulus for intestinal peristalsis. Physical distention of the gut wall activates an extrinsic afferent CGRP neuron originating in the dorsal root ganglion. An axon collateral of this extrinsic neuron has a branch that activates the same interneurons and motor neurons of the peristaltic reflex pathway activated by mucosal stimulation. This is called an Axon Collateral or Distension Reflex and probably is activated in pathological conditions. It may also be activated when there is a need for more powerful peristalsis since the mucosal reflex and the distension reflex potentiate each other.

4. Peristalsis becomes a moving wave of the peristaltic reflex (contraction preceded by a moving wave of relaxation) that pushes chyme caudad (anally). It is the primary propulsive type of contraction in the small intestine.
5. Normally, these peristaltic contractions only travel a few centimeters before dying out because of dissipation of the stimulus.

![Diagram showing ascending excitatory reflex (AER) and descending inhibitory reflex (DIR)](image)

Figure 4A.

D. Segmentation
1. As described earlier this is a local cycle of relaxation and contraction.

   a. This type of motility is non-propagating and is non-propulsive by itself.

2. Segmental contractions are the main mixing movements of the small intestine. Chyme is pushed orad and caudad to expose more of it to the mucosa of the gut where it is absorbed. This movement also mixes chyme with digestive enzymes and secretions to increase digestion.

3. The maximal rate of contraction is set by rate of the electrical slow waves because in the intestine the contraction is determined by the spike potential that occur on the plateau of the slow wave. This is determined by local pacemaker cells (Interstitial cells of Cajal) and is characteristic of the region of the intestine. The slow wave rate is about 12/min in the duodenum and decreases anally to about 8/min in the ileum so that there is a net frequency gradient which slowly moves chyme anally towards the ileocecal sphincter (Figure 5).

![Slow Wave Frequency Decreases Stepwise From Duodenum to Ileum](image)

Figure 5.

E. Migrating Myoelectric (or Motor) Complex (MMC)

1. During the interdigestive period, a distinct pattern of electrical and contractile activity spreads through the gut. This pattern is called the migrating myoelectric complex (MMC), migrating motor complex (MMC) or the interdigestive housekeeper.

2. The pattern consists of three phases: a period of quiescence (Phase I) lasting 45-60min, followed by a phase of increasing contractile activity where slow waves have increasingly more action potentials (Phase II), followed by a short period (about 10 min) during which almost every slow wave has action potentials and the muscle is contracting intensely (Phase III) (Figure 6).
3. This cycle originates in the stomach and migrates anally throughout the small intestine. A new MMC begins in the stomach every 75-90 min (Figure 7). This type of motility allows large particle to leave the stomach and enter the small intestine.

4. The function of the MMC seems to be to continually sweep through the small intestine and keep it clear of secretions and chime between meals.

5. The mechanism is not fully understood however neural reflexes are involved. The hormone motilin cycles in the same manner as the MMC and may also have a role in initiating or regulation the MMC. Opioid peptides and somatostatin have also been implicated.

6. On ingestion of a meal, the MMC is interrupted by continuous contractile activity throughout the small intestine. This continuous activity is of the segmental, non-propulsive type (Figure 7).

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F. **Intestinal reflexes**

1. The activity of the intestine is coordinated over long distances and between other digestive organs by long arc reflexes.
2. The **intestino-intestinal reflex** coordinates regions of the intestine such that distension of one area results in inhibition of motility in other area. This ensures adequate digestion in all regions and prevents blockage of movement.

3. The **gastro-ileal reflex** coordinates activity in the stomach and ileum so that increase activity in the stomach causes increased activity in the ileum to clear it of contents.

4. Even though these are long arc reflexes, remember that they act finally through the enteric nervous system.

**G. Ileocecal sphincter**

1. The sphincter at the ileocecal junction ensures the continued movement of chyme in the anal direction. The sphincter extends several cm orally in the distal ileum and extends into the cecum where it has a fold or flap that prevents movement from cecum into ileum. In addition, neural reflexes exist such that an increase in intracecal pressure results in an increase in the sphincteric pressure.

**II. COLONIC MOTILITY**

A. Functional anatomy (Figure 8)

1. Longitudinal muscle gathered into three bands called **tenia coli**.
2. Circular muscle forms pouches called **haustra**.

![Figure 8](image-url)
B. Motility patterns

1. **Mixing movements or local contractions:**
   
a. These mix lumenal contents and are analogous to segmentation in the small intestine. Often those of the ascending colon are **antiperistaltic** (anal to oral direction) and function to delay movement of feces into the transverse colon.

   b. These push feces towards the cecum, which is a storage site somewhat analogous to the stomach, and also aid in the removal of water and electrolyte.

2. **Mass movements:** Major propulsive contraction which usually is initiated in transverse colon and propels feces long distances into sigmoid colon and rectum. Usually occurs 1-2 times per day.

C. Colonic reflexes

1. Colonic long arc reflexes are similar to those of the intestine.

2. The **colono-colonic** reflex insures that distension of one region of the colon causes relaxation of other regions. This is mediated by the sympathetic nervous system.

3. The **gastrocolonic** reflex: distension of the stomach caused increased motility in the colon and increases the frequency of the mass movements in order to prepare the way for material to arrive in the colon.

D. Defecation Reflex (Figure 9)

1. Mass movement pushed feces distally, filling and distending the rectum and activating stretch receptors in muscle wall.

2. A reflex is initiated through enteric and pelvic nerves to smooth muscle and through the pudendal nerve to the skeletal muscle (external anal sphincter).

3. The rectum contracts pushing feces towards the anus.

4. At the same time, the internal anal sphincter relaxes and the external anal sphincter contracts.

5. Neural inputs from the central nervous system then either reinforce or inhibit these signals. If reinforced, defecation is aborted; if inhibited, defecation proceeds. Thus, defecation is under voluntary control.
6. Defecation requires additionally regulation of muscles of the pelvic floor in coordination with the internal and external anal sphincter. The **Puborectalis muscle** normally is contracted thereby pulling the anal canal at a 90-degree angle. This hinders the passage of feces. Defecation includes relaxation of the puborectalis and elevation of the **levator ani muscle** to increase the anal canal angle to about 110-degrees. In addition contraction of the diaphragm increases intra-abdominal pressure that adds to pressure generated by contraction of the rectum.
III. STUDY QUESTIONS

1. The rate of intestinal segmentation
   A. Is dependent of the concentration of gut hormones.
   B. Decreases from duodenum to ileum.
   C. Is set by the number of smooth muscle cells contracting.
   D. Depends on the density of innervation of a region by the vagus nerve.
   E. Is highest in the Sphincter of Oddi.

2. The peristaltic reflex following mucosal stimulation is initiated as a result of the release of
   A. Substance P.
   B. Acetylcholine.
   C. Serotonin (5-HT).
   D. Nitric Oxide.
   E. Vasoactive Intestinal Peptide.

3. Distension of the rectum
   A. Always leads to a defecation reflex.
   B. Causes only a passive contraction of the rectal circular muscle.
   C. Causes contraction of both the internal and external anal sphincters.
   D. Causes a mass movement of the transverse colon.
   E. Causes relaxation of the internal anal sphincter and contractions of the external anal sphincter.

Answers: 1=B, 2=C, 3=E.