Introduction to Gastrointestinal Diseases Vol. 1

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Editor

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Preface

“We are what we eat” is a common saying, yet not always understood and applied, and not many of us know that the delivery of proper nutrients is necessary for maintenance of homeostasis and functioning of the entire body. On the other hand, only recently the gastrointestinal (GI) tract has emerged as a crucial system, intertwining structurally and functionally with the central and peripheral nervous as well as immune systems, and several others. Therefore, not only diet, but also lifestyle and surrounding environment may influence the GI tract and related systems.

In the recent years, functional and inflammatory diseases of the GI tract have been taking their toll and the number of their cases is significantly increasing, what triggers the need for extensive medical care. In case of irritable bowel syndrome (IBS), its management constitutes 25–50 % of the entire gastroenterology outpatients workload. As for inflammatory bowel disease (IBD), the incidence of Crohn’s disease (CD) is estimated at 5 per 100,000 people per year and the prevalence is 40–50 per 100,000 people in the Western and Northern Europe. The incidence and prevalence of CD are maintained at a stable level in developed countries, whereas in developing areas these rates are constantly growing. The incidence rate of ulcerative colitis (UC) is about 10 per 100,000 people.

Furthermore, the average age of onset of the GI tract diseases becomes a serious concern. Approximately 25 % of IBD cases are diagnosed in the first two decades of patient’s life, especially in childhood (age 13–18). The highest incidence of UC occurs already between the ages of 20 and 40.

Alarmingly, only the minority of patients (e.g., one-third in the case of IBS) seek advice from a general practitioner; many do not consider their symptoms serious enough to consult the doctor and usually seek different treatment modalities, not always acceptable from the medical point of view or efficient. Moreover, only 20 % of patients—when they do not respond to conventional treatment—are referred to see a gastroenterologist. Finally, IBS and IBD patients often look for medical information from the Internet, which does not necessarily provide the same quality of knowledge as official brochures, books, or medical professionals.

Through this book, we hope to change the current situation for the patient and for the doctor. The book has been prepared by professionals in basic and clinical gastroenterology, therefore the information provided is up to date and of highest quality. Moreover, we focus on both, the patient and the doctor. We hope that through this book we will encourage a new approach to the management of the GI tract diseases not only by educating the patient and the doctor, but also showing that the collaboration between them is beneficial for better diagnosis and cure.

Lodz, Poland Jakub Fichna

In collaboration with Natalia Fabisiak, Paula Mosińska and Maciej Sałaga.

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Introduction

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Abstract The chapter focuses on composition and function of the gastrointestinal tract, primarily in physiological conditions. The information provided in the chapter will give basis for understanding the malfunction of the digestive system that leads to diseases described further in the book.

Keywords Gastrointestinal tract • Small and large bowel • Digestion • Gastrointestinal motility • Water and electrolyte transport

The gastrointestinal (GI) tract (or *alimentary canal*) is often regarded as a simple tube that allows us turning meals into body muscle (or fat) and that—from time to time—may cause some trouble, whether before a stressful interview or once we eat too many sour cherries. In fact, there is much more "magic" in the functioning of the GI tract and the digestive system plays a much more important role than expected.

Five basic functions of the GI tract that refer to food and nutrient processing are ingestion, propulsion, digestion (chemical and mechanical), absorption and elimination. However, the GI tract cross talks with several other systems, thus its role in immune defense, water and electrolyte homeostasis or—at the time of disease—delivery of therapeutics cannot be forgotten. The GI tract is sometimes, and not necessarily wrongfully, compared to skin that separates us from the outside environment, yet allows communication with external stimuli and translation of this signaling so that it can be understood by the body.

Food goes first to the mouth, where accessory digestive organs (teeth, tongue, salivary glands along with palatal surfaces) start the process of ingestion and digestion, first through mechanical processing and breaking down (through tearing, chewing, mashing, and crushing) and then mixing with saliva (for detailed information on food digestion in the GI tract please see Table 1). Saliva not only moistens the food matter, but also contains amylase, an enzyme that helps digest

Table 1 Food digestion in the gastrointestinal tract

Nutrient	Organ	Enzyme	End product
Carbohydrates (Polysaccharides)	Mouth	Salivary amylase	Oligosaccharides
	Duodenum and small intestine	Pancreatic amylase	Disaccharides and monosaccharides
	Small intestine	Brush border enzymes	Monosaccharides
Proteins	Stomach	Pepsin in presence of HCl	Polypeptides and oligopeptides and amino acids
	Duodenum and small intestine	Trypsin and chymotrypsin	Oligopeptides and dipeptides and amino acids
	Duodenum and small intestine	Carboxypeptidase	Oligopeptides and dipeptides and amino acids
	Small intestine	Aminopeptidase and dipeptidase	Amino acids
Lipids	Duodenum and small intestine	Pancreatic lipase in presence of bile salts	

carbohydrates, as well as immunoglobulins, lysozyme and other bacteriostatics and antibiotics. Last but not least, let's not forget the tongue and its role in taste sensing through taste buds.

The processed food (or *bolus*) may now proceed to esophagus, a 20–25 cm long tube (all measures for an average adult male) that transports it rapidly to the stomach. The passage through esophagus is facilitated by mucus secretion and peristaltic movement of its walls due to visceral muscles located within. A small flap called epiglottis is unequivocally important at this stage—located in the pharynx, it prevents from food entering the trachea by covering and closing its entrance.

Stomach (1 L when empty, 2–4 L when full) is the first organ of the digestive tract where the food can be stored for some time, allowing further mixing and digestion. The chemicals excreted by gastric glands in the stomach wall (for GI tract histology please see Box 1; for GI tract control please see Box 2) are hydrochloric acid (HCl, an inorganic acid) and pepsinogen (a precursor molecule to an enzyme pepsin) that allow digestion of proteins. Of note, enteroendocrine cells in the stomach wall secrete specific hormones that influence the GI tract functioning, like gastrin, histamine, endorphins, serotonin, cholecystokinin, and somatostatin. Further processing of carbohydrates under the influence of salivary amylase may also be possible in the stomach, yet harsh acidic conditions do not promote high activity of the enzyme.

Box 1. Histology of the Gastrointestinal Tract
The gastrointestinal tract wall has four layers

1. Mucosa (secretes mucus, digestive enzymes, and hormones; absorbs nutrients; protects deeper parts of the wall from damaging conditions and the entire system against ingested infectious and toxic factors)
   - Epithelium
   - Lamina propria
   - Muscularis mucosae
2. Submucosa (connective tissue with large blood vessels, lymphatics, and nerves branching into the mucosa and muscularis externa; contains an enteric nervous plexus called the submucosal plexus)
3. Muscularis Externa (responsible for peristaltic contractions and segmentation movements; forms sphincters; contains myenteric plexus between two muscle layers)
   - Longitudinal muscle
   - Circular muscle
4. Serosa (for intraperitoneal and retroperitoneal organs) or Adventitia (for esophagus and retroperitoneal organs)
   - Epithelium
   - Connective tissue.

Box 2. Neuronal Control of the Gastrointestinal Tract
Local (involves enteric nervous system):

- Submucosal plexus (controls glands and mucosal muscle)
- Myenteric plexus (controls GI motility)

General (involves central nervous system):

- Parasympathetic (enhances GI motility and secretion)
- Sympathetic (decreases GI motility and secretion).

Food (in a form of chyme) now propagates to the small intestine, composed of the duodenum, the jejunum, and the ileum. The duodenum, measuring 20–25 cm plays multiple roles in food processing: it receives chyme from the stomach, due to higher pH (=alkaline conditions) it neutralizes gastric acid before it enters further into the small intestine, and receives "juices" (digestive secretions) from the pancreas and the liver. The pancreas, which is regarded as an accessory digestive organ, secretes (1) into the pancreatic juice (by exocrine cells)—enzymes necessary for food digestion, such as amylase (breaks down carbohydrates), lipase (breaks down lipids), proteases (break proteins), and peptidases (break peptides into amino acids); (2) into the bloodstream (by endocrine cells of the pancreatic islets)—insulin and glucagon, which participate in glucose homeostasis. Pancreatic secretion may be regulated neuronally (through parasympathetic nerves) and hormonally (through gut hormones cholecystokinin and secretin). Liver on the other hand is like a large laboratory in our body, involved in (1) direct or indirect regulation of hundreds of biochemical and hematological processes and (2) bile production, which is an important emulsifier indispensable for dispersing lipids into smaller droplets, whose surface is available for pancreatic lipase. It needs to be mentioned that bile, before it gets to the duodenum, is stored by the gallbladder and released upon a specific gut hormone, cholecystokinin. Secretin, another gut hormone, stimulates bile secretion.

From the duodenum, the chyme passes to the jejunum (2.5 m long) and the ileum (3.5 m long), where further mixing, chemical digestion and nutrient absorption to lymph and blood occurs. Lining of the small intestine wall has finger-like projections called villi, covered in microvilli which further increase surface area for absorption. The chyme in the small intestine is kept moist by intestinal secretions, what allows action of digestive enzymes which require aqueous environment, and it propagates through peristaltic contractions and segmentation movements, which are independent of the brain control. It has been estimated that it takes on average 5 h for the chyme to pass from the duodenum to the distal part of the ileum.

Next step is the large intestine (or large bowel, 1.5 m), which divides into the cecum (receives material from the ileum which is then stored and compacted), the colon (ascending—transverse—descending—sigmoid) and the rectum. In the large intestine, the undigested contents is formed into and temporarily stored as feces (later expelled through defecation through the anus), and reabsorption of excess of water and bile salts (which are transported with blood back to the liver) occurs. Similarly to the small intestine, the movement of the contents is due to peristaltic waves ("along the length") and segmentation movements ("churning"), yet much slower up to transverse colon, what allows water absorption. Defecation is triggered by distension of rectal wall, which is detected through specific stretch receptors. In physiological conditions, feces (on average 80–220 g/day) contain unused or indigestible food, mucus, and dead cells that used to line the GI tract.

Importantly, the large intestine is colonized by several bacterial strains, which produce vitamins (K, B_5, biotin) that are also absorbed within the colon. They also process bilirubin (end product of red blood cell breakdown) to yellow-to-brown colorants of the fecal matter, as well as peptides and carbohydrates to intestinal gases.