Digestion, Absorption, Transport, and Excretion of Nutrients

(Session 5)

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The Large Intestine
The large intestine is approximately 1.5 m long and consists of the cecum, colon, and rectum.

Mucus secreted by its mucosa protects the intestinal wall and provides the medium for binding the feces together.

Bicarbonate ions secreted in exchange for absorbed chloride ions help to neutralize the acidic end products produced from bacterial action.
Approximately 2 L of fluids are taken in food and beverages during the day, and 7 to 9 L of fluid is secreted along the GIT.

**Under normal circumstances,** most of that fluid is absorbed in the small intestine and **approximately 1 to 1.5 L of fluid enters the large intestine.**

Only approximately 100 mL remain to be excreted in the feces.
Ingest 2000 mL/day of water

Saliva 1500 mL/day

Gastric secretions 2000 mL/day

Bile 500 mL/day

Pancreatic juices 1500 mL/day

Intestinal secretions 1500 mL/day

Small intestine absorbs 8500 mL/day

Colon absorbs 400 mL/day

≡ 100 mL/day water excreted
The large intestine is also the site of bacterial fermentation of remaining carbohydrates and amino acids, synthesis of a small amount of vitamins, and storage and excretion of fecal residues.

Colonic contents move forward slowly at a rate of 5 cm/h.

Defecation, occurs with varying frequency, ranging from three times daily to once every 3 or more days.
Humans have squatted for millennia – until the advent of the modern toilet.

The colon moves waste to the rectum for elimination. It has a natural kink that maintains continence.

The puborectalis muscle partially relaxes, keeping the colon kinked and blocking the flow of waste.

The puborectalis muscle fully relaxes allowing the colon to empty quickly and completely.
Average stool weight is in the range of 100 to 200 g, and mouth-to-anus transit time may vary from 18 to 72 hours.

The feces generally consist of 75% water and 25% solids.

Approximately two thirds of the contents of the wet weight of the stool is bacteria, with the remainder coming from GI secretions, mucus, sloughed cells, and undigested foods.

A diet abundant in fruits, vegetables, legumes, and whole grains results in a shorter overall GI transit time, more frequent defecation, and larger and softer stools.
Mouth 1 minute
Esophagus 4-8 seconds
Stomach 2-4 hours
Small Intestine 3-5 hours
Colon 10 hours to several days
Bacterial Action
At birth, the GIT is sterile, but Lactobacillus organisms soon become the chief component of the GIT flora until an infant begins to eat solid foods, which in turn leads to the predominance of Escherichia coli in the distal ileum.

The primary colonic flora are anaerobic, with species of the genus Bacteroides occurring most frequently.

Lactobacilli are also present in the stools of most people who consume an ordinary mixed diet; but differences in the host's genome, dietary intake, hygiene, and medical and surgical history affect the kind of flora in the GIT.
<table>
<thead>
<tr>
<th>Bacteria</th>
<th>Lactobacilli</th>
<th>Fungi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acinetobacter</td>
<td>Peptostreptococcus</td>
<td>Candida</td>
</tr>
<tr>
<td>Bacteroides</td>
<td>Porphyromonas</td>
<td>Parasites</td>
</tr>
<tr>
<td>Bifidobacterium</td>
<td>Prevotella</td>
<td>Blastocystis</td>
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<tr>
<td>Clostridium</td>
<td>Propionibacterium</td>
<td>Endolimax</td>
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<tr>
<td>Corynebacterium</td>
<td>Pseudomonas</td>
<td>Entamoeba coli</td>
</tr>
<tr>
<td>Eubacterium</td>
<td>Staphylococcus</td>
<td>E. hartmanni</td>
</tr>
<tr>
<td>Enterobacteriaceae</td>
<td>Streptococcus A, B, C, F, G</td>
<td>E. polecki</td>
</tr>
<tr>
<td>Enterococcus</td>
<td>Streptococcus bovis</td>
<td>Iodamoeba</td>
</tr>
<tr>
<td>Fusobacterium</td>
<td>Streptococcus</td>
<td>Trichomonas hominis</td>
</tr>
<tr>
<td>Helicobacter</td>
<td>Veillonella</td>
<td></td>
</tr>
</tbody>
</table>
**INTESTINAL MICROFLORA**

$10^{14}$ micro-organisms, >500 different species

- Lactobacilli
- Streptococci
- Lactobacilli
- Enterobacteria
- Enterococcus Faecalis
- Bacteroides
- Bifidobacteria
- Peptococcus
- Peptostreptococcus
- Ruminococcus
- Clostridia
- Lactobacilli

- Stomach $10^2$ to $10^3$
- Duodenum $<10^{4-5}$
- Jejunum
- Ileum $10^3$ to $10^7$
- Colon with appendix $10^9$ to $10^{12}$

and....
Normally, few bacteria remain in the stomach or small intestine after meals because bile, hydrochloric acid (HCl), and pepsin work as germicides.

However, decreased gastric secretions can increase the risk of inflammation of the gastric mucosa (gastritis), increase the risk of bacterial overgrowth in the small intestine, or increase the numbers of microbes reaching the colon.

Interestingly, an acid-tolerant bacterium is known to infect the stomach (Helicobacter pylori) and may cause gastritis and ulceration in the host.
Bacterial action is most intense in the large intestine.

Following a meal, dietary fiber, resistant starches, remaining bits of amino acids, and mucus sloughed from the intestine are fermented in the colon.

Colonic bacteria contribute to the formation of gases (e.g. hydrogen, carbon dioxide, nitrogen, and in some individuals methane) and SCFAs (e.g. acetic, propionic, butyric, and some lactic acids).
Dietary Fiber

Intestinal Microflora

Fermented
- Gas Production
  - Short-Chain Fatty Acid Production
- Microbial Growth
  - Increased Bulk in the Colon
  - Increased Bulk of Feces
- Poorly Fermented
  - Physical Properties Maintained (Water holding properties)
  - Mechanical Effects
  - Shorter Intestinal Transit Time
  - Energy Lost in Feces

Absorbed to the Host
Colonic bacteria continue the digestion of some materials that have resisted digestion, and during this process several nutrients (e.g. vitamin K, vitamin $B_{12}$, thiamin, and riboflavin) are formed by bacterial synthesis.

These nutrients usually contribute little to meeting the nutrient requirements of the human host.
Increased consumption of prebiotic material leads to an increase in SCFAs and in the microbial mass of beneficial indigenous bacterial species such as Bifidobacteria and Lactobacilli.

Prebiotic carbohydrates typically refer to oligosaccharides from vegetables, grains, and legumes.

Chicory, Jerusalem artichokes, soybeans, and wheat bran are the best dietary sources of prebiotics.
Foods Naturally High in Prebiotics

tomatoes
artichokes
onions
garlic
chicory
dandelion greens
asparagus
leeks
berries
bananas
flax seed
legumes
Bacterial action also may result in the formation of potentially toxic substances such as ammonia, indoles, amines, and phenolic compounds such as indolacetate, tyramine, histamine, and cresol.

Some of the gases and organic acids produced by bacterial action contribute to the odor of feces.
Interactions among the host immune system, host genome, diet, and GI microflora may be linked with several infectious and inflammatory bowel diseases, allergies, immune disorders, metabolic disorders, and neoplasms.

This fact has led to the increasing attention being given to the therapeutic potential of probiotic, prebiotic, and synbiotic products as antibiotics and antiinflammatory or immunosuppressive agents.
Probiotics are foods or concentrates of live organisms that contribute to a healthy microbial environment and suppress potential harmful microbes.

Prebiotics are oligosaccharide components of the diet (e.g. fructo-oligosaccharides, inulin) that are the preferred energy substrates of "friendly" microbes in the GIT.

Synbiotics are a combination of probiotics and prebiotics.
<table>
<thead>
<tr>
<th></th>
<th><strong>Probiotics</strong></th>
<th><strong>Prebiotics</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Beneficial effect when consumed</td>
<td>Resistance to gastric acidity and hydrolysis by mammalian enzymes and gastrointestinal absorption</td>
</tr>
<tr>
<td></td>
<td>Lack of pathogenicity and toxicity</td>
<td>Ability to be fermented by intestinal microflora</td>
</tr>
<tr>
<td></td>
<td>Large numbers of viable cells</td>
<td>Selective stimulation of growth and/or activity of intestinal bacteria associated with health and well-being</td>
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<tr>
<td></td>
<td>Ability to survive and metabolize in the gut</td>
<td></td>
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<tr>
<td></td>
<td>Retained viability during storage and use</td>
<td></td>
</tr>
<tr>
<td></td>
<td>If incorporated into a food, good sensory qualities</td>
<td></td>
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</tbody>
</table>
- Synbiotics are made of long-chain, inulin-type fructans as compared with short-chain derivatives.

- These fructans, extracted from chicory roots, are prebiotic food ingredients that are fermented to lactic acid and SCFAs in the gut lumen.

- Synbiotics may be useful for early prevention or treatment of allergic disease.
Colonic Salvage of Malabsorbed Energy Sources and Short-Chain Fatty Acids
Normally, varying amounts of small-molecular-weight carbohydrates and amino acids reach the colon.

Accumulation of these molecules could become osmotically important if it was not for the action of colonic bacteria.

The disposal of residual substrates through production of SCFAs is called colonic salvage.
Colonic production of short-chain fatty acids (i.e. colonic salvage)
SCFAs produced in fermentation are rapidly absorbed and serve as fuel for the colonocytes and gut microbes, stimulate colonocyte proliferation and differentiation, enhance the absorption of electrolytes and water, and reduce the osmotic load of malabsorbed sugars.

SCFAs also help slow the movement of GI contents and participate in several other regulatory functions.
SITUATIONS OF INCREASED CARBOHYDRATE MALABSORPTION WITH COLONIC FERMENTATION

In normal individuals, after consumption of:
- lactose when lactase deficiency is present
- dietary fiber
- resistant starch, olestra (sucrose polyester), acarbose (amylace inhibitor)
- small amounts of sorbitol, mannitol, xylitol, or lactulose
- significant amounts of fructose
- fairly large amounts of sucrose

In patients with malabsorption secondary to:
- gastric resection and modest ingestion of sugars, carbohydrates
- pancreatic insufficiency
- short bowel syndrome
- inflammatory bowel disease
- celiac sprue
- disaccharidase deficiencies

Fermentation of malabsorbed carbohydrate and fiber by colonic microbes leads to:
- short-chain fatty acids (SCFAs [butyrate, propionate, acetate, and lactate])
- gases (H₂, CO₂, N, CH₄)

SCFAs:
serve as fuel and stimulate proliferation and differentiation of cells; reduce osmolality, enhance absorption of Na⁺ and water

COLON

Significant malabsorption leads to bloating, abdominal distention, flatulence, acidification of stool, and, possibly, diarrhea.

FIGURE 1-6 Colonic fermentation of malabsorbed carbohydrates and fiber.
In humans, colonic fermentation only disposes of 20 to 25 g of carbohydrate over 24 hours.

Excess amounts of carbohydrate and fermentable fiber in the colon can cause increased gas production, abdominal distention, bloating, pain, increased flatulence, decreased colonic pH, or even diarrhea.

However, over time, adaptation occurs in individuals consuming diets high in fiber.
Thus, consumption of 24-38 g/d of dietary fiber from fruits, vegetables, legumes, and whole grains is recommended for:

(1) Maintaining the health of the cells lining the colon

(2) Preventing excessive intracolonic pressure

(3) Preventing constipation

(4) Maintaining a stable and healthful microbial population
References:


4- Wikipedia, the free encyclopedia. Available from: URL: http://en.wikipedia.org