HOW YOU DIGEST FOOD
DIGESTION:

Breakdown of food

Small components

WHY?
• Carbohydrates → Sugars

• Protein → Amino Acids

• Fats → Fatty Acids
Absorption:

Taking Substances

Interior of Body

(blood)
Gastrointestinal Tract: 30 feet long

Mouth → Pharynx → Esophagus

Stomach ← Small Intestine ← Large Intestine

Rectum → Anus

Transit time- Food: Mouth → Anus

24-72 hours (small beads + meal)
Digestion Begins: “Mouth Waters”

Stomach → Gastric Juice

- Sight
- Sounds
- Smell
Mouth- Salivary Glands → Saliva

Saliva → Enzyme → Starch (bread)

Enzymes (protein): speed up chemical reaction, reused.

A → enzyme → B

Substrate   Product(s)
• Chemical Digestion

• Mechanical Digestion: Chewing

↑ Surface Area- Digestive Juices
Mouth Food → Pharynx (throat)

Epiglottis (trachea)

Esophagus ← Swallowing
breathing

swallowing

food
Food → Esophagus

Stomach ← Sphincter

Peristalsis
• Vomiting

• Heartburn

• Gastroesophageal Reflux Disease (GERD)

Backwash: stomach acid
The mechanism of heartburn and gastroesophageal reflux disease is the same: acidic gastric juices seep backward through an open or relaxed sphincter into the lower portion of the esophagus, burning its lining. The pain is felt above the sternum, over the heart.
GERD: Possible causes

- Overweight
- Family history
- Hiatal hernia
- Smoking
- Excessive alcohol
- Large or high fat meals

Although the exact causes of gastroesophageal reflux disease (GERD) are unknown, smoking and being overweight may be contributing factors.
Gastric bypass, stapling, banding
Digestion in Stomach
2-6 hours

- **Gastric Juice**: Acid (kills bacteria) + Enzymes
- **Enzyme**: Pepsin → Protein digestion
- **Contractions**: Churning, mixing food
Release of Gastric Juice

• **Nervous system**: thought, smell, taste - food → brain

  impulses

  gastric juice ← stomach
Sphincters control the flow into and out of the stomach.

Esophagus

Accordion-like folds allow the stomach to expand.

Food particle

Stomach lining secretes gastric juice (acid, enzyme molecules, and mucus).

Small intestine
Release of Gastric Juice

- **Hormone**: Gastrin

Response to food in stomach:
- Gastric Juice
- Contractions
Absorption (limited) in stomach

- Water
- Alcohol
- Aspirin, Acetaminophen (Tylenol)
Chyme (partially digested liquid food) → sphincter

small intestine (duodenum)

• Large, solid meal—slower
• Small, liquid meal—faster
Figure 3.11  The brush border. Absorption of nutrients occurs via this specialized lining of the small intestine.
Stomach Emptying

Carbohydrates ➔ Protein ➔ Fat

Sadness/Fear ➔ Emptying

Aggression ↑ Emptying + Contractions
ULCERS

• Stomach lining- **gastric mucosa**

• **Erosions** (open sores) of lining- esophagus, stomach, duodenum: **peptic ulcer**

• 1 in 10 people
ULCERS- Causes

• Bacteria (*Helicobacter pylori*)
• Aleve, Advil, Motrin (not Tylenol)
• Smoking
• Excess alcohol
“An 11 year look inside the living stomach”

• 1822- Fur trapper’s store Michigan.
• Gun accident: St. Martin shot
  Dr. Beaumont dressed wound
• Healing → fistula → gauze (opening)
Dr. Beaumont and St. Martin
Beaumont-St. Martin

- Bread ➔ gastric juice release
- Remove fluid ➔ test tube
digest meat
- Anger: gastric mucosa red
  (blood)
  ↑ contractions  ↑ acid
- Fear: gastric mucosa pale
  ↓ contractions
Most digestion: small intestine 3-5 hours

Intestinal cells (lining)

Intestinal Juice

Enzymes: starch → sugars
          polypeptides → amino acids
Pancreas

Pancreatic Juice:

- Bicarbonates: neutralize acid
- Enzymes:
  - Starch → sugar
  - Protein → polypeptides
  - Fats → fatty acids

Amino acids
Pancreas

- **Exocrine** gland:
  - secretions → ducts (tubes) (enzymes)

- **Endocrine** gland:
  - secretions → blood (insulin)
Gallbladder

Bile produced - liver $\rightarrow$ stored gallbladder

Bile $\rightarrow$ duct $\rightarrow$ small intestine

Emulsification Fats

↑ Surface area (detergent)-helps fat digestive enzymes
ASSIGNMENT

EMULSIFICATION EXPERIMENT
Bile

- Bile acids (made from cholesterol)
- Cholesterol
- Lipids (lecithin)
- Bile pigments (hemoglobin breakdown → feces-color)
Pathology: gallstones

Bile: *supersaturated* with *cholesterol*

cholesterol $\rightarrow$ crystals $\rightarrow$ gallstones

Block ducts $\rightarrow$ bile secretion
Obstructive jaundice

- Backup: bile pigments
- Yellow skin, eyes
- Fat malabsorption
- Surgery: remove stones
Your Liver: what it does for you
Liver unique: can regenerate completely

- After injury
- After partial surgical removal
- Adjusts to body shape
- Liver transplant (living donor-usually close relative)

- Donor & recipient: liver grows to full size: 2 months
Liver Functions

1. Makes **Bile** (digestion)

2. **Glucostat** - regulates blood glucose (homeostasis)

**Fasting:** glycogen $\rightarrow$ glucose $\rightarrow$ blood

**After meal:** Blood glucose $\rightarrow$ liver $\rightarrow$ glycogen
Liver Functions

3. **Urea** formation:

   amino acids breakdown → urea → urine ← kidneys
Liver functions

4. Synthesis & breakdown: lipoproteins, other proteins (albumin, clotting proteins)

5. Detoxification: Drugs, toxins, alcohol
Liver functions

6. Stores **vitamins & iron**

7. Destroys old **red blood cells**
ABSORPTION

Small end products- digestion:

- glucose
- amino acids
- fatty acids
- H20
- minerals
- vitamins
Small Intestine

• 20 feet long
• Major site: absorption “nutrients”
• Huge **surface area:**
  tennis court
**duodenum:**
receives chyme from stomach and secretions from pancreas and liver

**jejunum:**
region of most digestion and nutrient absorption

**ileum:**
absorption continues

**small intestine**

**large intestine**

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The small intestine. (a) The interior of the small intestine, also called the mucosal membrane. (b) The lining of the small intestine has thousands of folds and finger-like projections called villi that increase its surface area over 500 times, significantly increasing the small intestine's absorptive capacity.
Small Intestine

- Inner surface: fingerlike villi
- Each villus- covered- microvilli
- Absorptive surface
- Inside villus:
  1. Capillaries - blood
  2. Lacteal - lymphatic system
Figure 3.11  The brush border. Absorption of nutrients occurs via this specialized lining of the small intestine.
Absorption - small intestine

Nutrients

Intestinal absorptive cells

Blood or Lymph
Glucose absorption

Glucose → small intestine cells
  → villus capillaries
  → liver via vein
Glucose: How it’s used

• Glucose - liver cells: energy

• Glucose - liver ➔ vein ➔ heart

• General circulation: glucose energy ➔ cells/tissues
Glucose: How it's used

• Extra glucose
  - Glycogen (stored- liver)  24 hr supply
  - Fat (stored- adipose tissue)
FASTING

After 24 hours- no new glucose (food)

Brain senses ↓ glucose

Liver: amino acids → glucose (homeostasis) blood
Carbohydrate loading marathoners

• **Muscle glycogen** - used 1st: intense exercise

• **Loading**: restrict carbohydrate - few weeks

• Day before event - carbohydrate loading: replenish stores (muscle/liver)
Amino acid absorption and use

• Amino acid absorption- same as glucose
  Intestine capillaries → vein → liver

• Amino acid use:
  enzymes, hormones, new protein structure
Excess amino acids

In liver: excess amino acids

urea

glucose

glycogen (stored)

fat (stored)
Fasting → Starvation

Example:
anorexia nervosa

BMI: Weight (lbs) / Height (inches)² × 703
NY Times 9/17/06 “As models strut in London, new call to ban the skeletal”
NY Times 9/17/06 & 12/20/06

• 2006/2007: Madrid’s Fashion Week banned models with BMI below 18. Milan bans models BMI \( \leq 18.5 \)

• To achieve BMI of 18: 5’ 9” model would weigh 125 pounds.

• Average 5’9” runway model: 115 pounds
Ana Carolina Reston died 11/14/06- complications-anorexia

- 5’ 8” 88 pounds (BMI : 13)
- Mother: “emotional appeal take better care of children-aspiring young models.”
Body tries to keep blood glucose normal level for the brain.
EARLY ON
Liver glycogen (becomes depleted)

Fat $\rightarrow$ fatty acids
+ glycerol

amino acids

Blood Glucose

“Protein sparing”
Later

- Carbohydrate-depleted
- Fats rapidly broken down *(ketosis)*

- Acetone odor- breath; upsets pH

- Brain adapts → 50% energy- ketones
Finally

• **Protein** (structure)- liver, spleen, muscles **broken down**

• **Break down** heart muscle

• **Death**
Atkins Diet

- Low carbohydrate
- Theory:
  - ↑ Fat breakdown
  - ↑ Ketosis
  - ↓ Appetite

Comparison:
Atkins (2-16% carbs- stage of diet) vs. Control diet (60% carbs)
Comparison: Atkins vs. Control

• Atkins- greater initial weight loss
• Early weight loss- H2O
• At 18 months- no difference
• Long-term safety?
  High % protein (animal) & fat (saturated, cholesterol)
  ↑ urinary calcium loss- kidney stones?
  ↑ uric acid blood?
Vitamins, minerals, H$_2$O absorption

- **Vitamins** (water-soluble B, C), **minerals** (sodium, potassium, chloride), H$_2$O (99%)
Fat Absorption & lymphatic system

- Capillaries “leaky” → fluid, protein tissues → tissue fluid

- Lymphatic system: system of vessels- collect leaked fluid
Lymphatic System

- Tissue fluid inside lymph vessels = lymph

- Lymph → veins in shoulders as muscles contract

- Exercise: **10X** faster return-lymph
Figure 16.21 Lymphatic vessels. The lymphatic vessels drain the interstitial space and lymph vessels. The right lymphatic duct drains these vessels to the right subclavian vein. The thoracic duct drains through the right lymphatic duct and most drains through the left subclavian vein, pushing lymph back into the bloodstream.

The pressure from outside the arteries press against the arterioles, which press against the veins, pushing lymph back into the lymph vessels. Largely due to muscle activity, lymph flows up to 10 liters per day, but during rest.
Lymphatic System

- **Lymph nodes**: filters, white blood cells: bacteria, cancers

- Throat infection—lymph nodes near jaw: sore, swollen
Figure 16.25 Elephantiasis. Roundworms and connective tissue block the flow through lymph nodes in this person, preventing the return of lymph to the blood. Lymph and interstitial fluid accumulate behind the block, causing a tremendous swelling. (From the Armed Forces Institute of Pathology, Negative No. 76-18002.)
Fat Absorption - how you do it

- Digested fatty acids

  intestine cells

  Reform triglyceride
Triglyceride

Glycerol

Fatty acid

Fatty acid

Fatty acid
Triglyceride + Fat soluble vitamins (A, D, E, K) + protein

Chylomicron (lipoprotein)
Chylomicrons

Enter lacteals

Lymph vessels

Vein left shoulder

General circulation
Lacteal

(c) Villi and crypt

(d) Intestinal microvilli
Chylomicron triglyceride

→ muscle

→ adipose tissue

Fat Stored
Colon: 5 feet long

Colon ————> **appendix** (dead end)

Rectum ———> Anus
**large intestine**

- **cecum:** receives material from small intestine
- ileocecal valve
- appendix
- ileum of small intestine

**colon:** reabsorbs water and vitamins

**rectum:** end of digestive tract

anus

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Colon functions (last chance)

- Absorb H2O (dehydrator) ➡ blood
- Convert chyme (liquid) ➡ feces
- Absorb vitamins/minerals ➡ blood
- Home: bacteria: cecum (pouch) + appendix
**Bacteria** (300-500 species)

- Make B vitamins & vitamin K
- You: enzymes digest fiber
- **Bacteria**- guests partially digest fiber (cellulose- plant cell walls)
- Gas production (fermentation)

blood
Feces

• Undigested fiber, dead cells, water, bacteria

• Water in feces:
  - Fiber – attracts H20 feces: softer-easier bowel movements
  - Fiber- hard/dry → constipation
Peristalsis - slower than small intestine

Feces (rectum) → sphincter muscle (relaxes) → defecation
Digestive System:
Problems/Diseases

- **Colonoscopy** – cancer screening-gold standard: everyone $\geq 50$

- Flexible tube → rectum
  - camera
  - large intestine
  - view entire colon
Colon Pathology

- Colonoscopy: polyps (pre-cancerous) removed
- Afterward doctor recommends: exercise + aspirin
Where Colon Cancer Occurs

- Transverse colon 11%
- Ascending colon 17%
- Descending colon 6%
- Cecum 19%
- Rectum 25%
- Sigmoid colon 22%

A view a doctor might see in a colonoscopy, in this case, revealing a polyp.
Probiotics

• Population- good bacteria: essential health/normal functions
• Prevent growth- bad bacteria
• Bad bacteria-take over: diarrhea, infection

Should you eat bacteria?

Probiotics: eat living organisms health benefit
Probiotics: Benefits

- Help immune function - intestine
- Reduce toxins - colon
- Inhibit enzymes → carcinogens
- Relieve constipation, bloating, diarrhea, gas
HELPFUL BACTERIA
Should you take probiotics?

BY DAVID SCHARDT

Activia Yogurt

What’s in it: Bifidobacterium animalis DN-173 010.

Cost: $20-$60 a month for one to three 4-oz. yogurts a day.

Stonyfield Farm Yogurt

What’s in it: L. acidophilus, Bifidus, L. casei, and L. reuteri 55730. Stonyfield Farm says that it sells the only U.S. yogurt with L. reuteri.

Cost: About $30 a month for one 6-oz. tub a day.

Claims: L. reuteri can fight “viruses and bacteria associated with diarrhea and gastrointestinal disease” and “harmful bacteria such as Salmonella, E. coli, Staphylococcus, Candida yeast, and other harmful microorganisms.”
Federal Trade Commission

2010 Ruling: Ads deceptive

• Nestlé stops ads: Kids Essentials
  (probiotics in straw): \( \uparrow \) immune system
  \( \downarrow \) colds, diarrhea, missing school

• Kellogg stops ads:
  Rice Krispies \( \downarrow \) illness children
  Frosted Mini-wheats \( \uparrow \) 20% attentiveness
Diverticulitis

• Small pouches in colon (diverticula) → inflamed/painful (diverticulitis)

• Treatment
  🔺 Soluble fiber (reduces pressure)
  🔺 H₂O
Nuts & Diverticulitis
Older view: People with diverticulitis: *avoid* nuts, small seeds

Intestinal problems?

New study 2008: 47,000 men Ate nuts/ popcorn 2X/week

↓ Risk Diverticulitis

No Complications
Colostomy

• Example: colon cancer
• Diseased colon removed
• Separate opening- abdomen
• Remaining colon opening (stoma)
• Permanent fistula
• Bag-collect feces; anus: non-functional
## Other Digestive Disorders
*(Harkin/Deen 2005)*

<table>
<thead>
<tr>
<th>Disorder</th>
<th>What is it?</th>
<th>What helps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constipation</td>
<td>Infrequent/ difficult passage stools</td>
<td>![fiber]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>![fluids]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>![exercise]</td>
</tr>
<tr>
<td>Disorder</td>
<td>What is it?</td>
<td>What helps</td>
</tr>
<tr>
<td>------------</td>
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</tr>
<tr>
<td>Diarrhea</td>
<td>Frequent, loose, watery stools</td>
<td>Fiber (short-term)</td>
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<td></td>
<td>Soluble Fiber (long-term)</td>
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<td>Sorbitol</td>
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<td>Fluids</td>
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<tr>
<td>Disorder</td>
<td>What is it?</td>
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<tr>
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<tr>
<td>Irritable Bowel Syndrome</td>
<td>Abdominal pain, bloating, excessive gas</td>
<td>Low fat, high fiber diet caffeine</td>
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<tr>
<td>Disorder</td>
<td>What is it?</td>
<td>What helps</td>
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<tr>
<td>Lactose Intolerance</td>
<td>Inability to digest milk sugar (lactose)</td>
<td>Milk/milk products choose: low-lactose, lactose-free drinks; take calcium &amp; vitamin D supplements</td>
</tr>
<tr>
<td>Disorder</td>
<td>What is it?</td>
<td>What helps</td>
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<tr>
<td>Celiac Disease</td>
<td>Small intestine damage due to <strong>gluten</strong> (proteins in cereals, grains <strong>wheat</strong>); result: malabsorption</td>
<td>Exclude gluten from diet; Read labels</td>
</tr>
<tr>
<td>Disorder</td>
<td>What is it?</td>
<td>What helps</td>
</tr>
<tr>
<td>------------------</td>
<td>-----------------------------------------------------------------------------</td>
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</tr>
<tr>
<td>Crohn’s Disease</td>
<td>Inflammatory disorder of ileum &amp; colon; mutant gene-immune response to healthy bacteria</td>
<td>Diet low in fat, fiber, lactose; Take: vitamin &amp; mineral supplement</td>
</tr>
<tr>
<td>Disorder</td>
<td>What is it?</td>
<td>What helps</td>
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</tr>
<tr>
<td>Ulcerative</td>
<td>Inflammation &amp; ulcers- colon, rectum; Mutant gene-response to healthy bacteria</td>
<td># insoluble fiber; Take vitamin &amp; mineral supplements</td>
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</tbody>
</table>