Nutrition, Digestion, Absorption, and Excretion

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What are the key terms?

- Nutrients
- Toxins
- Gastrointestinal system
- Excretory organs
- Osmosis
- Kidney
- Urine
What do animals require from food?

- Animals are heterotrophs:
  - derive energy & molecular building blocks, directly or indirectly, from autotrophs.
- For many animals, food provides essential carbon skeletons that they cannot synthesize themselves.
  - Humans require 8 essential amino acids from food.
What do animals require from food?

- Animals need **mineral elements** for a variety of functions:
  - **Macronutrients**, like Ca for bone growth, blood clotting, nerve and muscle action, enzyme activation (1.2kg in a 70kg body).
  - **Micronutrients**, like Fe for enzymatic reactions, oxygen binding in blood (4g in a 70kg body).
- Animals must obtain **vitamins** from food
  - Carbon compounds functioning as **coenzymes** for growth and metabolism.
  - Humans require **13 vitamins**.
How do animals **digest** food?

- **Animals digest** their food **extracellularly**.
  - Food is ingested into a **body cavity**. Digestive **enzymes** are secreted into that cavity. Enzymes **break down** the food into nutrient molecules that can be **absorbed** by the **cells lining** the cavity.

- **Absorptive areas** of the gut are characterized by a **large surface area** produced by extensive folding and numerous **villi (folds)** and **microvilli (cell projections)**.
How do animals avoid digesting themselves?!

- Most digestive enzymes are produced in inactive forms or zymogens.
- When secreted in the gut, a zymogen becomes activated by an other enzyme.
- Cells lining the gut are protected by mucus.

Tissue layers of the vertebrate gut. **Mucosa** is secretory and absorptive. **Submucosa** contains blood vessels and nerves. Muscle layers are separated by a nerve net that controls gut movements.
How does the **gastrointestinal system** function?

- **Chemical digestion** begins in the **mouth**, where **amylase** is secreted with saliva and starts digestion of **starch**.
- The human **stomach** stores and **breaks down** ingested food.
  - Alcohol, caffeine, aspirin... can be absorbed **through the stomach wall**.
- **Parietal cells** secrete **HCl**, and **chief cells** secrete **pepsinogen** activated into **pepsin** by very low pH.
  - **Pepsin** begins the digestion of **protein**.

![Diagram of stomach cells](image)
How does the **gastrointestinal system** function?

- Entering the **duodenum** from the stomach, the acidic **chyme** is neutralized by **pancreatic** bicarbonate ions. Then **pancreatic enzymes** can operate.

- In the **small intestine** (3 sections), digestion of **proteins** and **carbohydrates** continues; digestion of **lipids** and absorption of nutrients begin.
  - Most digestion occurs in **duodenum** (section 1).
  - 90% nutrient absorption occur in sections 2-3.
  - **Liver** and **pancreas** provide many enzymes and other secretions. **Bile** aids in digesting **lipids**.

- All of the blood leaving the digestive tract flows to the liver. **Liver cells absorb the nutrients** and either **store** them or **convert** them to molecules the body needs.
How is the flow of nutrients **regulated**?

**Hormones control digestion.**

- **Gastrin**, **cholecystokinin**, and **secretin** involved in feedback loops that control the sequential processing of food in the digestive tract.
How is the flow of nutrients regulated?

• When food is present in the gut, nutrients are absorbed: **absorptive period**. During the **postabsorptive period** (stomach and small intestine empty) energy metabolism and biosynthesis must run on **internal reserves**.

• The liver directs the traffic of the molecules that fuel metabolism: **glucose** and **fat**.

• **Pancreatic hormones** insulin and glucagon are key players of glucose homeostasis.
How do animals deal with ingested toxins?

• **Toxins** in food may come from natural sources,
  ✓ but many come from **human activities** such as the use of **pesticides** and the release of **pollutants** into the environment.

• Toxins such as **PCBs** (polychlorinated biphenyls, used as insulating fluid in electrical transformers) accumulate in the bodies of **prey** and are **transferred** and further **concentrated** in the bodies of their **predators**.
  ✓ This is **bioaccumulation**: produces **high concentrations** of toxins in animals **high up the food chain**.
What roles do **excretory organs** play in maintaining homeostasis?

- **Excretory organs** control the **volume**, **concentration**, and **composition** of the extracellular fluids of animals.
- **Water** enters or leaves cells by **osmosis**.
- Excretory organs control extracellular fluid **osmolarity** by **filtration**, **secretion**, and **reabsorption**.
  - ✓ **Osmolarity** = concentration of osmotically active particles.
- The **kidney** is the major **excretory organ** of **vertebrates**.
- **Urine** is the **output** of excretory organs.
How do animals excrete toxic wastes from nitrogen metabolism?

- The end products of metabolism of carbohydrates and fats are water and CO2: not difficult to eliminate.
- Metabolism of proteins and nucleic acids also produces nitrogenous wastes.
  - Most common form: Ammonia. Highly toxic, must be excreted, or detoxified = converted into other molecules: urea or uric acid.
How do mammals maintain salt and water balance?

• The kidney is well adapted for water excretion or conservation.
• Mammals and birds have high body temperatures and high metabolism, hence potential for high rate of water loss.
  ✓ In mammals and birds, kidneys have evolved a unique adaptation: ability to reabsorb water from urine.
  ✓ As a result, mammals and birds can produce urine more concentrated than their extracellular fluids.
• Nephron: functional unit of the vertebrate kidney.
  ✓ Consists of glomerulus, renal tubules, peritubular capillaries.
How does the mammalian kidney produce concentrated urine?

- **Nephrons** have a regular distribution in the kidney.
- Blood is filtered in the *glomerulus*.
- Certain molecules are actively reabsorbed from glomerular filtrate by *tubule cells*.
- Urine concentration is the result of *countercurrent multiplier mechanisms* involving the straight sections of renal tubules called *loops of Henle* and *collecting ducts*. 

*LIFE 8e, Figure 51.10*
What mechanisms **regulate kidney function**?

- Kidney function in mammals is controlled by **autoregulatory** mechanisms.
  - They maintain constant high glomerular filtration rate even if blood pressure varies.
- When blood pressure falls, the kidney releases the enzyme **renin**.
- **Renin** converts a protein into **hormone angiotensin**:
  - Causes **constriction of blood vessels**,
  - Triggers release of **hormone aldosterone**, which **enhances water reabsorption**,
  - Stimulates **thirst**.
What mechanisms **regulate kidney function?**

- Changes in **blood pressure** and **osmolarity** influence the release of **antidiuretic hormone (ADH)**.
- **ADH** stimulates the expression and controls the intracellular location of **aquaporin proteins**.
  - With ADH, **aquaporins** can fuse with membrane of collecting duct cells and **serve as water channels**: the cells become **more permeable** to water.
- **Alcohol** inhibits ADH release...
  - This is why **excessive beer drinking** leads to even more **excessive urination and dehydration**, which contributes to **hangover symptoms**...
Suggested readings


Leutwyler, K. 2000. New gene for Type II Diabetes. Scientific American, September. Individuals such as the Pima people are rendered more susceptible to Type II Diabetes by environmental factors such as diet and by complex sets of genetic influences. This article describes the search for genes that influence Type II Diabetes susceptibility.


Weindruch, R. 1996. Caloric restriction and aging. Scientific American, January. A discussion of whether humans can live longer on a well-balanced, low-calorie diet, as has been shown for many other animals.
