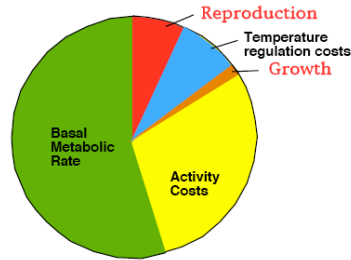


USE of energy and materials: energy budgets

Animals use food for two purposes:

- energy sources (for making ATP: 'maintenance')
- raw materials (for making new tissues: **growth** or **reproduction**)

In most animals, most of the energy and materials in food are used for *maintenance* -- not for *production* (growth, reproduction)



60 kg female human from a temperate climate
800,000 Kcal/year

Acquisition of energy and materials: nutrition and digestion

Animal **nutrients** often classified as:

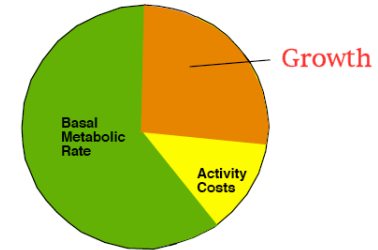
- **macronutrients** (needed in relatively large quantities):
energy sources and building materials
 - **proteins** (essential and non-essential amino acids)
 - **lipids** (some essential fatty acids)
 - **carbohydrates** (none essential in mammals)
- **micronutrients** (needed in relatively small quantities):
often catalytic
 - inorganic **minerals**
 - organic **vitamins**

USE of energy and materials: energy budgets

Animals use food for two purposes:

- energy sources (for making ATP: 'maintenance')
- raw materials (for making new tissues: **growth** or **reproduction**)

In domestic animals selected for food production, growth can be > 25% of energy budget:



Broiler chicken, first (and *only* 40-50) days of life:
36,000 Kcal *total* to make 9,000 Kcal of *flesh*

Acquisition of energy and materials: nutrition and digestion

Macronutrients: proteins, lipids, carbohydrates

- source of chemical potential energy
- building blocks for synthesis of new tissue

Some **essential** (critical for life); others are not

- *No* essential carbohydrates (all can be synthesized from proteins or lipids).
- Of the twenty amino acids used to make protein, 8-10 are essential (same for most animals). The others (nonessential) can be synthesized from the essential amino acids.
- Some lipids (unsaturated fatty acids with >1 double bond) are essential for membrane lipids, some storage fats, certain hormone precursors, etc.

Acquisition of energy and materials: nutrition and digestion

Micronutrients -- Two general categories:

- inorganic **minerals**
- organic **vitamins** (synthesized by plants or other organisms)

Roughly 15-17 **mineral elements** needed by humans (and other animals)

- Some in relatively large quantities (calcium, sodium, potassium, sulfur, phosphorus, chlorine, iron) -- *structural*
- Some in small quantities -- *catalytic* (enzyme cofactors, etc.)
- **All are harmful or toxic if consumed in excessive amounts**

Acquisition of energy and materials: nutrition and digestion

Micronutrients -- Two general categories:

- inorganic **minerals**
- organic **vitamins** (synthesized by plants or other organisms)

About 13 **vitamins** are currently known to be necessary

- used for a wide range of functions, but mainly *catalytic* (enzyme cofactors, etc.)
- two general categories:
 - water soluble** (B, C, niacin, folic acid, etc.)
 - lipid soluble** (A, D, E, K)

Acquisition of energy and materials: nutrition and digestion

Lack of sufficient **caloric intake** (less chemical potential energy obtained than is necessary) is undernourishment (a.k.a. *starvation* if the condition persists)

Lack of essential amino acids, fatty acids, or any other essential nutrient in the diet results in **deficiency diseases** (malnourishment). *Examples:*

- **Kwashiorkor** (insufficient **tryptophan** and **lysine**)
- **Scurvy** (insufficient **vitamin C**)
- **Goiter** (insufficient **iodine**)

Acquisition of energy and materials: nutrition and digestion

Vitamin dosages:

Minimum necessary doses (“RDA”) should keep you healthy; easily obtained in a balanced diet.

Considerable debate about possible health benefits of enhanced vitamin intake:

- *weak* evidence suggests that there may be benefits from intake higher than RDAs for *some* vitamins -- but it’s far from certain -- recent study by FDA shows little effect.
- ‘megavitamin’ intake (very large doses) doesn’t confer major health benefits (you just generate vitamin-rich urine) and can be dangerous with lipid-soluble vitamins

Acquisition of energy and materials: nutrition and digestion

Digestion and absorption are the processes that make the nutrients in food available to an animal's cells.

- Nutrients are used by cells as *simple monomers* (sugars, amino acids, fatty acids, etc.).
- Food is a complex mixture of **large polymers** (proteins, starches, etc.) and various unusable components, often in **BIG** pieces.
- **Digestion** breaks food down into monomers; this takes place in the gut lumen and is *external* to the body.
- These monomers are then **absorbed** across the gut epithelium and into the body.

Basic digestive tract functions

Salivary glands



Salivary functions:

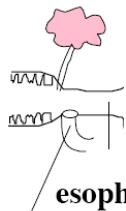
- lubrication
- moistening
- initial carbohydrate digestion (salivary α -**amylase**):
chemical breakdown

Digestive enzymes work by **hydrolysis** of substrates: chemical addition of water to break substrate macromolecule into smaller subunits:

| | | |
|----------------------|---|----------------------|
| Lipids | → | fatty acids |
| Proteins | → | amino acids |
| Carbohydrates | → | simple sugars |

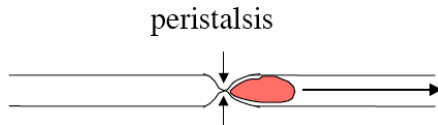
Basic digestive tract functions

moves food from mouth to stomach
by *peristalsis*



esophagus

glottis
(valve between esophagus
and trachea)

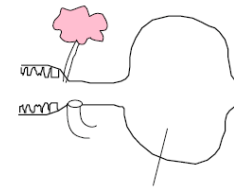


Peristalsis is a wave of circular contraction of muscle lining the gut, moving in one direction to push a bolus of food along.

Basic digestive tract functions

Functions:

- **Storage** (in omnivores, carnivores)
- **mechanical breakdown** (churning)
- **chemical digestion**:
-- high acidity (HCl secretion)
-- **peptidases** (*pepsin*; digests proteins)
- **absorption** (minor in humans)

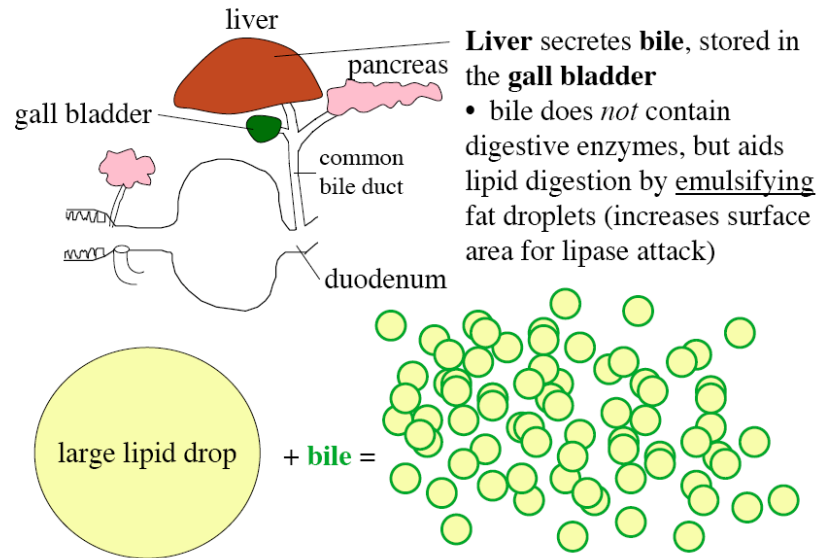


Stomach

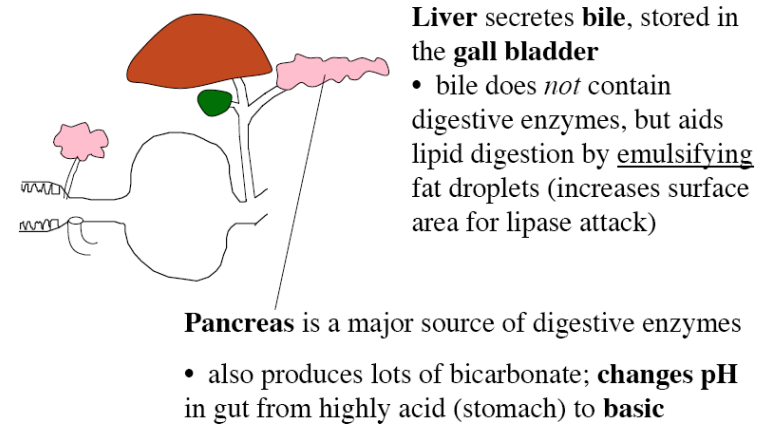
How does digestive tract avoid digesting *itself*?

- secretion of digestive enzymes as inactive **zymogens** (activated in the gut lumen, by low pH, other enzymes, etc.)
- 'armor': thick protective layer of mucus
- rapid replacement of epithelial cells

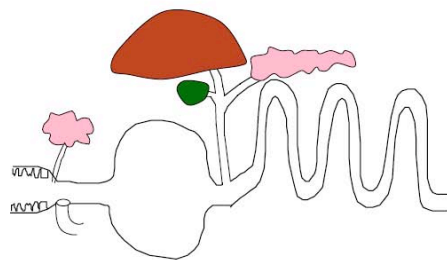
Basic digestive tract functions



Basic digestive tract functions



Basic digestive tract functions

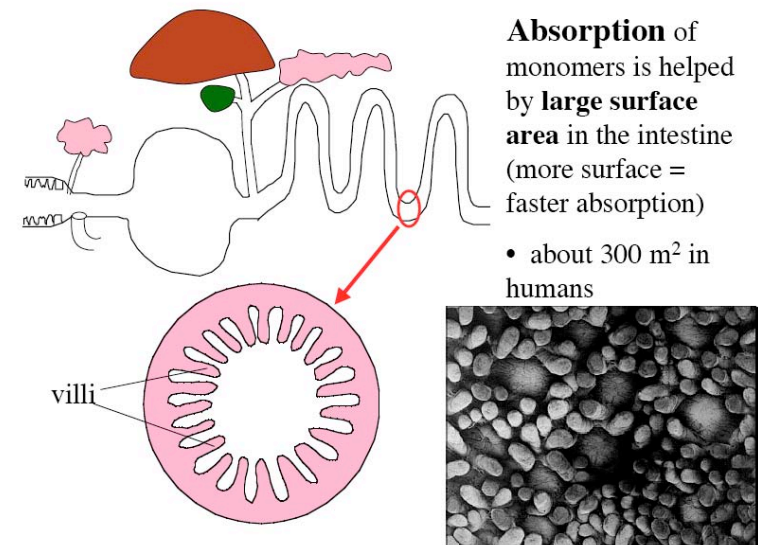


Small intestine:
major site of both **digestion** and **absorption**

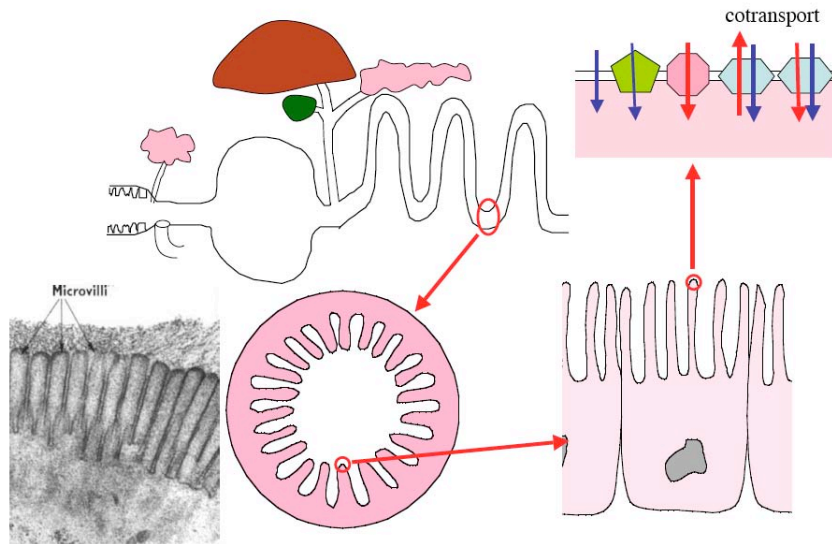
Digestive enzymes: **proteases, amylases, lipases, nucleases**
(from pancreas and from small intestine)

- complete the breakdown of food into absorbable monomers
-- mostly in first half of small intestine

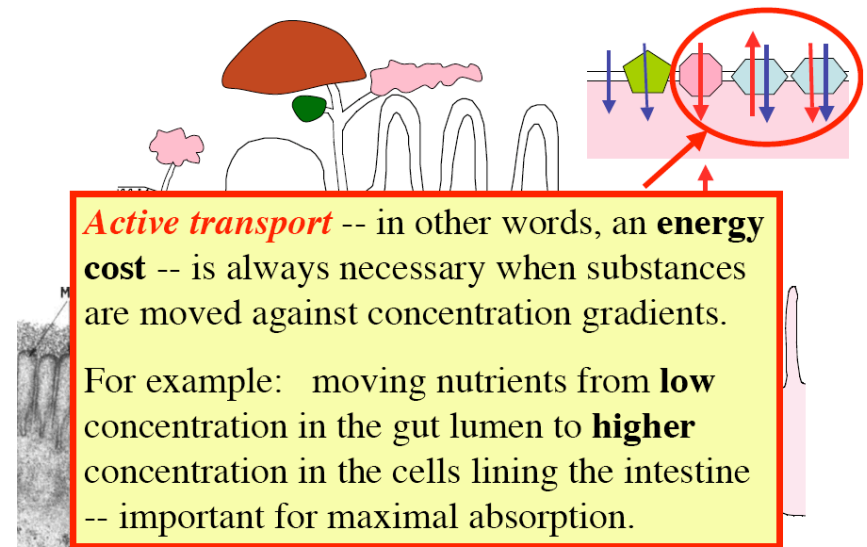
Basic digestive tract functions



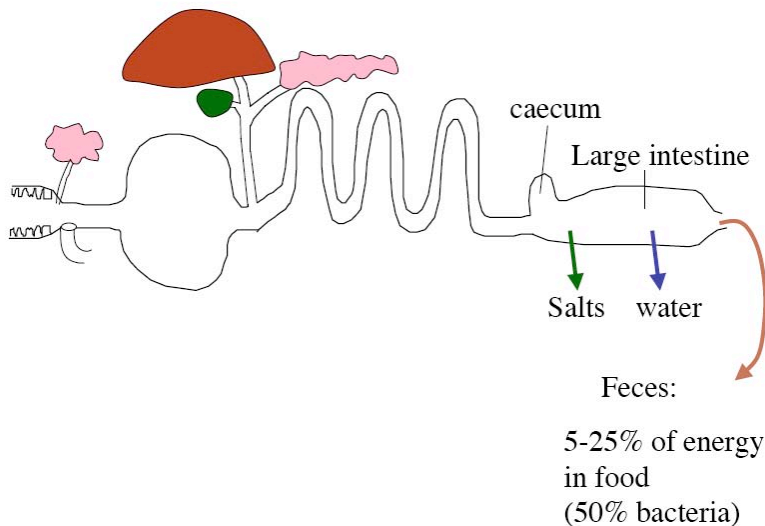
Basic digestive tract functions



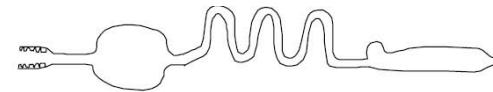
Basic digestive tract functions



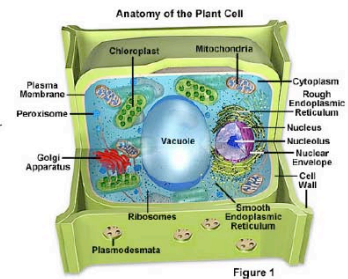
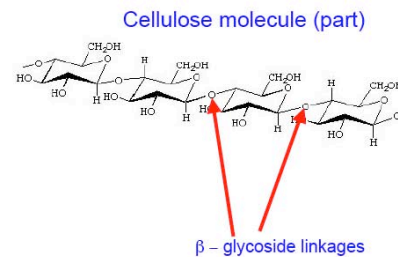
Basic digestive tract functions



Omnivore
(generalist)



Herbivore *Problem:* plant material is abundant but full of cell walls (cellulose) -- and animals don't produce enzymes that break down cellulose.





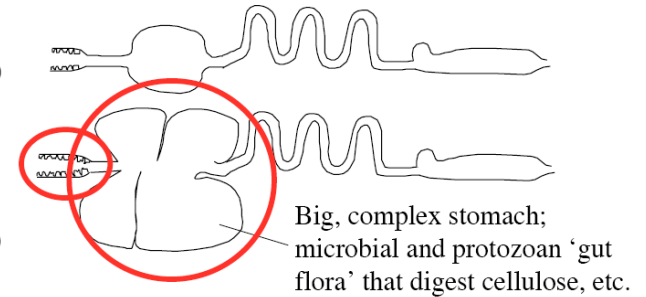
Herbivore *Problem:* plant material is abundant but full of cell walls (cellulose) -- and animals don't produce enzymes that break down cellulose.

Solution: **symbiosis** with other organisms that can digest cellulose: various bacteria and protists.

- 'housed' in modified parts of the gut used as **fermentation chambers**.
- often **very large** populations of symbionts, in big and complex fermentation chambers.
- symbionts primarily use carbohydrates; herbivores absorb fatty acids or other substances released by symbionts, **and** digest the symbionts as well!



Herbivore
(stomach
fermenter:
ruminants)



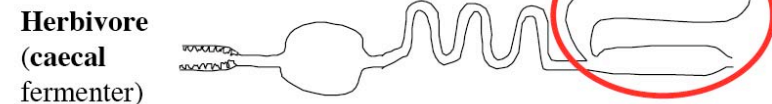
Most herbivores have very elaborate and rapidly-growing teeth and mobile, well-muscled jaws. Extensive chewing **and in many cases, re-chewing** of food: mechanical breakdown to small particles.

- ruminants '**ruminate**' -- they regurgitate small boluses of food for re-chewing ('chewing their cuds').



Alternative to having an enlarged stomach is to perform fermentation in an enlarged **caecum**.

Same basic concept: microbial populations in the caecum break down otherwise undigestible plant material.



Horses and their relatives use caecal fermentation with absorption of symbiont byproducts in the caecum alone.

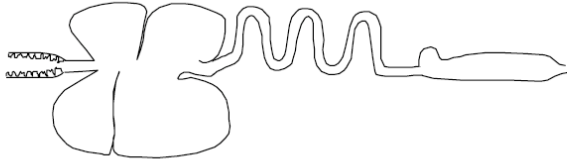
Remaining material is excreted after leaving the caecum.



Omnivore
(generalist)



Herbivore
(stomach
fermenter:
ruminants)



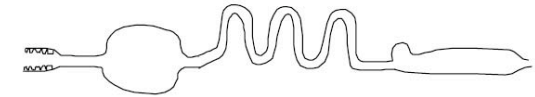
Herbivore
(caecal
fermenter)



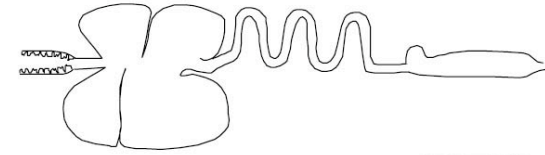
However, absorption through the caecum alone results in the loss of considerable energy and nutrients.

How to compensate? Cannot move caecal material backwards through the small intestine...

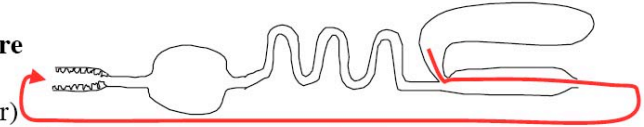
Omnivore
(generalist)



Herbivore
(stomach
fermenter:
ruminants)



Herbivore
(caecal
fermenter)



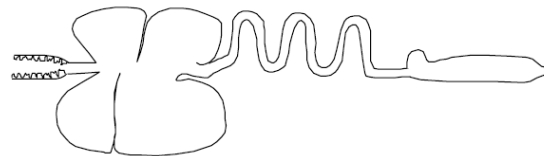
Coprophagy -- rabbits, some rodents

Two kinds of 'pellets' produced: one is consumed, one is not.

Omnivore
(generalist)



Herbivore
(stomach
fermenter:
ruminants)



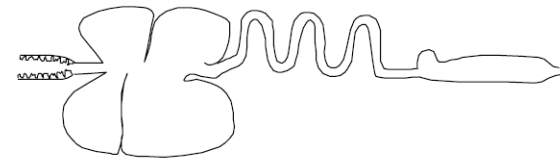
Herbivore
(caecal
fermenter)



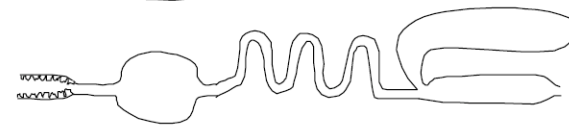
Omnivore
(generalist)



Herbivore
(stomach
fermenter:
ruminants)



Herbivore
(caecal
fermenter)



In general, herbivores:

- can digest **low-quality food** (plant cell walls), *but...*
- they have to 'pay' their symbionts a portion of the food energy
- they have **long transit time**; **low digestive 'efficiency'** (fraction of ingested food that is absorbed)
- so they may be limited by **processing time** (not food availability)

Carnivore

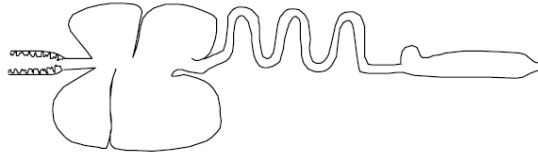
Problem: animal flesh is easy to digest, but often hard to catch (intake limited by **food availability**, not processing time).

Solution: eat a lot when food *is* available.

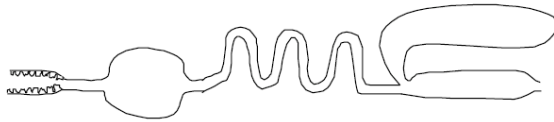
Omnivore
(generalist)



Herbivore
(stomach
fermenter:
ruminants)

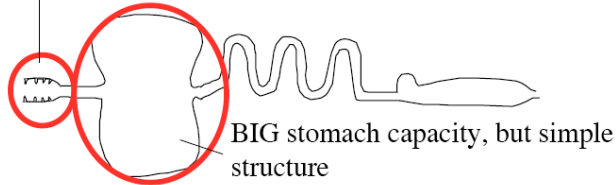


Herbivore
(caecal
fermenter)



Usually, simple dentition (for catching, not chewing)

Carnivore
(large prey)



BIG stomach capacity, but simple structure

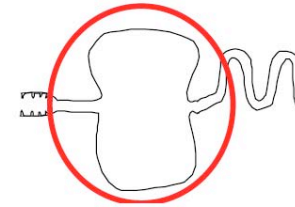
Omnivore
(generalist)



Herbivore
(stomach
fermenter:
ruminants)

Herbivore
(caecal
fermenter)

Carnivore
(large prey)



Carnivores usually have:

- rapid digestion (unless meal is **very** big)
- **high** digestive efficiency (little is wasted)