Keeping the machinery going – eating other life

Every living critter's gotta eat something to stay alive. Even autotrophs like plants, need some nutrients, in spite of being able to make their own sugar; but here we're talking about heterotrophs, and they have to eat a lot!
There are four steps in obtaining and using food.

1) Ingestion – assimilation of food into the digestive tract (feed me!);

2) Digestion – physical (e.g. chewing) and chemical (enzymatic) breakdown of food;

3) Absorption – nutrients cross the cells lining the digestive system and enter the bloodstream (and then go to all of the cells of the body).

4) Elimination – undigested food is egested (this is feces, plus lots of bacteria and archaea).
Ingestion versus external digestion

“The early bird get the worm!” (inside its body)

Fungal hyphae secrete digestive enzymes into the food source such that digestion occurs external to the fungi. Absorption of the soluble products occur by diffusion and active transport.
All of the ‘vores . . .

* Herbivores – eat only plants, and sometimes they specialize even further . . .
* Frugivores – eat only fruit;
* Folivore – eat only leaves;
* Granivores – eat only grains.

* Carnivores – eat only meat; some of them are . . .
* Insectivores – eat only insects.
* Detritivores – eat decomposing organic matter (sometimes called saprovores [death eater]).
* Omnivores – eat both plants and animals (omni is all). Humans are definitely omnivores!
This is not based on size.

For example the giant panda only eats bamboo shoots, and the blue whale mainly eats tiny krill.
Whereas the tiny shrew . . .

* Is sometimes considered the most vicious mammal. It . . .
* Must eat 80-90% of its own body weight in food daily to support its incredibly high metabolic rate. Most of its prey are insects, but it’ll even go after other critters their own size and larger, such as small mice.
Furthermore, the way things eat divides them up . . .

* Bulk feeders – ingest large pieces of food, like us. Some even eat their food whole, like snakes.
* Fluid feeders – drink their food, like blood.
* Substrate feeders – live in their food, and eat it from the inside out (many insect larvae).
* Deposit feeders (a type of substrate feeder) – strain decayed organic material from the soil or sediments they live in (e.g. earthworms).
* Filter feeder – strain their food from the water they live in (e.g. corals, mollusks, and baleen whales).
Digestive tracts...

* Are specialized compartments within an animal's body that keeps these processes separate from the rest of the body; and...
* Does the job of obtaining nutrients;
* Processing and absorbing those nutrients; and of...
* Eliminating the wastes.
* They have different levels of complexity.
The simplest is intracellular digestion.

Take nutrients into the cell by phagocytosis. The loaded food vacuole fuses with a vacuole containing digestive enzymes where the processing occurs; e.g. the Paramecium.

Sponges are the only true animal with this type of digestion.
More complex animals use extracellular digestion. They produce hydrolytic enzymes in a digestive cavity connected with the outside world. The food remains outside the body cells until it is digested.
This can be either an incomplete digestive cavity.

With one opening that both ingests food and egests waste. This ‘two-way traffic’ . . .

Limits the potential for specialized compartments (e.g. digestion vs. absorption) within the system.

Cnidarians (e.g. jellyfish) and flatworms have this.

Not a penis! It’s actually both mouth and anus.
Or it can be a complete digestive system. With two openings, an entrance and exit. This allows for...

- One-way travel of food through the system, and the evolution of specialized compartments for different jobs.
- This is called the alimentary canal or gastrointestinal (GI) tract.
Digestive systems evolve in hand with diet and lifestyle.

- For example, an herbivore diet is rich in hard-to-digest cellulose. Therefore, their . . .
- Longer digestive tract allows extra time for digestion. Furthermore, . . .
- Ruminants have a four-chambered stomach.
- Rumen – the first chamber where Bacteria, Archaea, protists, and Fungi break down grass into a “cud,” which is regurgitated and rechewed.
- It eventually goes on to the cecum – a large pouch, housing more microorganisms that further ferment the plant material. Many of these microbes are also digested.
Here's a diagram.

Take home message – the reindeer doesn't digest the grass, all the microorganisms in its gut do!
Versus an herbivore that doesn’t have the multiple chambered stomach.

b. Nonruminant herbivore

- Esophagus
- Stomach
- Small intestine
- Large intestine
- Cecum
- Anus

*But they still have the big cecum for microbial digestion of cellulose.*
Carnivores have shorter intestines and a small or absent cecum. Because the high protein diet they eat is much easier to digest.
The human digestive tract includes...

The alimentary canal and all the accessory structures: Salivary glands, teeth, tongue, pancreas, liver, and gall bladder.

- **Salivary glands**: Secrete saliva, which contains enzymes that initiate breakdown of carbohydrates.
- **Pharynx**: Connects mouth with esophagus; routes air to trachea.
- **Esophagus**: Peristalsis pushes food to stomach.
- **Liver**: Produces bile, which emulsifies fat.
- **Gallbladder (behind liver)**: Stores bile.
- **Pancreas (behind stomach)**: Produces and releases digestive enzymes and bicarbonate ion into small intestine.
- **Stomach**: Mixes food; enzymatic digestion of proteins.
- **Small intestine**: Final enzymatic breakdown of food molecules; main site of food absorption.
- **Large intestine**: Absorbs water and minerals to form feces.
- **Rectum**: Regulates elimination of feces.
- **Anus**
Let's see an overview.

http://www.valdosta.edu/~stthompson/animations/Chapter34/organs_of_digestion_final.swf
The food moves along by . . .

Peristalsis, which propels food using rhythmic waves of muscle contraction.

Sphincters regulate the entrances and exits.
In more detail, starting at the top . . .

The mouth is where . . .

Chemical digestion begins. Salivary amylase in saliva breaks down starch to maltose.

And mechanical digestion occurs by the mixing, mashing, and tearing of food using the teeth and tongue.

Say “AHHHH”
Then the...

- Food goes on to the...
- Pharynx (throat), where the...
- Epiglottis covers the opening of the trachea so food is routed to the esophagus (usually, or you choke).
- The esophagus is the...
- Muscular tube leading to the stomach.
- Peristalsis pushes the food through.
Leading to the...

- Stomach, which is a muscular bag. It...
- Can expand to hold up to 3-4 Liters. Both...
- Mechanical digestion – waves of peristalsis churn its contents – and...
- Chemical digestion – stomach (gastric) juice contains water, mucus, salts, hydrochloric acid, and enzymes (pepsin) – occur within the stomach.
- Acidity denatures food and kills most disease-causing microorganisms.
- Pepsin begins the chemical digestion of proteins.
Let’s zoom in on the stomach.
But why doesn’t the...

* Stomach digest itself? This is because it...
* Produces little gastric juice until food is present.
* And mucus coats and protects the stomach lining. Plus...
* Tight junctions (remember these) join its cells into an impermeable sheet.
* The stomach itself does not absorb many nutrients.
* Chyme – the semifluid mass of food and gastric juice in the stomach.
* The entrance into the small intestine is guarded by the pyloric sphincter, controlled by a feedback loop.
Here it is... Another negative feedback loop!

- Duodenum full
  - Pressure on stretch receptors in duodenum wall
  - Neural impulses signal pyloric sphincter muscle to contract; sphincter closes

- Duodenum empty
  - Chyme moves from stomach to duodenum
  - Pyloric sphincter muscle relaxes; sphincter opens
  - Chyme movement from stomach slows

- Stretch receptors in duodenum activated
  - Stretch receptors in duodenum relaxed
The human small intestine...

- Is small in diameter, but about seven meters long. It...
- Completes digestion and absorbs nutrients. It has...
- Three main regions – duodenum, jejunum, and ileum.
- Villi line the surface and each is coated with microvilli.
- This increases available surface area for nutrient digestion and absorption around 600 times over what it would be otherwise.
- Inside each villus is a capillary to absorb nutrients into the blood and a lymphatic capillary for fat transport.
- There are also many enzymes for chemical digestion.
- And the pancreas sends pancreatic juice containing buffers and pancreatic enzymes as well.
- The liver manufactures bile, which is stored in the gall bladder.
Let's zoom in on the lining of the small intestine.
Still in the small intestine . . .

- Water, minerals, free amino acids, cholesterol, and vitamins can all be directly absorbed without processing.

- But most foods must be broken down by the enzymes that are there.

- Bile helps to break large fat globules down and increases the available surface area for digestion.

- And there's a slew of microbes there too, helping to stave off infection by bad guys (that's the big deal with probiotics).
Where the enzymes are ...

<table>
<thead>
<tr>
<th>Nutrient molecule</th>
<th>Carbohydrates</th>
<th>Proteins</th>
<th>Fats</th>
<th>Nucleic acids</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location of enzyme activity</td>
<td>Salivary amylase</td>
<td>Smaller polysaccharides</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mouth</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stomach</td>
<td>Pancreatic amylase</td>
<td>Pepsin</td>
<td>Emulsified fat droplets</td>
<td>Nuclease</td>
</tr>
<tr>
<td>Small intestine</td>
<td>Disaccharides</td>
<td>Trypsin and chymotrypsin</td>
<td>Bile</td>
<td>Nucleotidase</td>
</tr>
<tr>
<td></td>
<td>Carbohydrase</td>
<td>Peptidase</td>
<td>Lipase</td>
<td></td>
</tr>
<tr>
<td>End product of digestion</td>
<td>Monosaccharides</td>
<td>Amino acids</td>
<td>Fatty acids and monoglycerides</td>
<td>Nitrogenous bases, sugars, and phosphates</td>
</tr>
</tbody>
</table>
Then on to the large intestine.

- It's also called the colon, and is much shorter in length (only about five feet), but much greater in diameter than the small intestine.
- It's main functions are to receive indigestible components, absorb water and salts, and eliminate feces.
- Plus, there's at least 500 different species of Bacteria and Archaea living there! In fact...
- The genomes of our gut microbes probably contain around 100 times more genes than our own genome, providing us with traits we never developed on our own.
- They produce the 'stink' of feces and farts.
- But they also prevent pathogenic microbes from invading, produce B and K vitamins, and help us in all sorts of ways most people never realize.
Human health depends on bacteria!

- As long as your immune system remains healthy, symbiotic bacteria help keep invaders out by competing for limited resources. They are useful — so useful, in fact, that we could not live without them.

- They help humans digest food, mitigate disease, regulate fat storage, produce vitamins that we can’t make on our own, and even promote the formation of blood vessels in our colons.
Bacteria benefit their human hosts by increasing digestive efficiency and helping to extract key nutrients from your ingested diet. In return, these microbes are given a safe haven in a nutrient-rich environment. (Similarly, cows can digest cellulose thanks to the good bacteria that live in their rumens.)

What Good Bacteria Do

Some things we know about good bacteria, besides the generalization that they help to counteract pathogens:

- Good bacteria can break down certain foods, such as plant starches, that we cannot digest on our own. “This enables us to extract more energy from what we consume,” says Jeffrey I. Gordon, director of the Center for Genome Sciences at Washington University School of Medicine in St. Louis. (Similarly, cows can digest cellulose thanks to the good bacteria that live in their rumens.)

- Good bacteria promote the storage of energy as fat. According to Gordon, this raises the possibility that “an individual’s predisposition to obesity or leanness may be partly determined by the composition of the microbes living in the gut.”

- Good bacteria help shape our postnatal development. For example, they help to form our intestinal blood vessels, through which we absorb nutrients.

- Good bacteria synthesize vitamin K and other vitamins that we cannot generate on our own. They break down carcinogens. They also may influence the metabolism of drugs.

- Good bacteria increase the rate at which the cells of the intestinal lining renew themselves, ridding us of damaged cells that could bring on gastrointestinal cancer.

- The good bacteria that infants acquire from their mothers and from the general environment at birth “educate the newborns’ immune systems,” says Gordon. “This appears to reduce allergic responses.”

- Each human carries a different set of bacteria, and its composition varies along the length of the gut. Some of these bacteria are permanent residents; others are transient “tourists,” just passing through.


The genomes of our gut microbes probably contain 100 times more genes than our own genome, microbial and 10 percent human,” says Gordon. “The genomes of our gut microbes are packed within us, especially around the time of World War II, when the newly discovered, often life-saving antibiotics proved to work more rapidly and effectively. Antibiotics were also used to treat infections in the gut or vagina. This practice ended when it was realized that antibiotics sometimes became bad, and vice versa? Are many of them simply straying bodies is good? How many are pathogenic? How many good bacteria are in the gut.”

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The British and Swedish efforts, and other clinical studies of this sort, generally paint an optimistic picture of probiotics. But many scientists remain skeptical, and few such treatments are currently in use. The real hurdle is to identify some 800 different strains of bacteria found living in the eustachian tubes (which connect the nose and middle ear) of healthy children at a daycare center. Among these microorganisms, they identified some 800 different strains of microbes probably contain 100 times more genes than our own genome, microbial and 10 percent human,” says Gordon. “The genomes of our gut microbes are packed within us, especially around the time of World War II, when the newly discovered, often life-saving antibiotics proved to work more rapidly and effectively. Antibiotics were also used to treat infections in the gut or vagina. This practice ended when it was realized that antibiotics sometimes became bad, and vice versa?”

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Here's a diagram of the human intestines. Typically our feces is only one fourth undigested food, one fourth sloughed cells from our own system and one half microbes by weight!
The accessory organs of the digestive system are essential.

* The pancreas is a mixed gland (as we've already seen).
  * In its digestive role it makes pancreatic juice, which contains . . .
  * Trypsin, chymotrypsin, pancreatic amylase, pancreatic lipase, and nucleases, as well as . . .
  * Sodium bicarbonate to neutralize the acidic chyme.

* The liver is also a mixed function organ. It has . . .
  * Over 200 functions. For our digestive system it . . .
  * Produces bile and stores it in the gallbladder until triggered for release by chyme in the small intestine.
  * However, bile can crystallize forming gall stones. Ouch!
Here's the diagram of those parts.

**Liver**: produces bile. Bile contains bile salts and facilitates fat digestion.

**Stomach**

**Gallbladder**: stores bile until needed.

**Pancreas**: produces sodium bicarbonate and enzymes trypsin, chymotrypsin, carboxypeptidase, amylase, lipase.

**Duodenum**
**In review, the tissues of the...**

<table>
<thead>
<tr>
<th>Main tissue types</th>
<th>Examples of Locations/Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epithelial</td>
<td>Secretes hormones, enzymes, and mucus into digestive tract; absorbs products of digestion; protects mouth, esophagus, and anal canal from pathogens and abrasion.</td>
</tr>
<tr>
<td>Connective</td>
<td>Blood (a connective tissue) transports nutrients from the digestive system to all parts of the body; supports esophagus, liver, and digestive lining.</td>
</tr>
<tr>
<td>Muscle</td>
<td>Smooth muscle moves food along digestive tract and aids in mechanical digestion; skeletal and smooth muscle controls mouth, tongue, esophagus, and anal canal.</td>
</tr>
<tr>
<td>Nervous</td>
<td>Stretch receptors signal presence of food in stomach; nerves regulate activity of digestive organs.</td>
</tr>
</tbody>
</table>
But you can only be as healthy as what you put into the system!

- Two main components of proper eating include . . .
- Your caloric content must balance your activity level. And . . .
- You have to get your essential nutrients.
- As we saw with plants there are two classes of these:
  - Macronutrients are . . .
    - Required in large amounts and include . . .
      - Water, carbohydrates, proteins, and lipids. And . . .
  - Micronutrients, which are . . .
    - Required in very small amounts. These include . . .
      - Vitamins and minerals.
The U.S. government requires foods to be labeled with the nutritional values.

http://www.valdosta.edu/~stthompson/animations/Chapter34/food_label.swf
<table>
<thead>
<tr>
<th>Mineral</th>
<th>Food Sources</th>
<th>Functions in the Human Body</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bulk Minerals</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcium</td>
<td>Milk products, green leafy vegetables</td>
<td>Bone and tooth structure, blood clotting, hormone release, nerve transmission, muscle contraction</td>
</tr>
<tr>
<td>Chlorine</td>
<td>Table salt, meat, fish, eggs, poultry, milk</td>
<td>Digestion in stomach</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Green leafy vegetables, beans, fruits, peanuts, whole grains</td>
<td>Muscle contraction, nucleic acid synthesis, enzyme activity</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>Meat, fish, eggs, poultry, whole grains</td>
<td>Bone and tooth structure</td>
</tr>
<tr>
<td>Potassium</td>
<td>Fruits, potatoes, meat, fish, eggs, poultry, milk</td>
<td>Body fluid balance, nerve transmission, muscle contraction, nucleic acid synthesis</td>
</tr>
<tr>
<td>Sodium</td>
<td>Table salt, meat, fish, eggs, poultry, milk</td>
<td>Body fluid balance, nerve transmission, muscle contraction</td>
</tr>
<tr>
<td>Sulfur</td>
<td>Meat, fish, eggs, poultry</td>
<td>Hair, skin, and nail structure, blood clotting, energy transfer, detoxification</td>
</tr>
<tr>
<td><strong>Trace Minerals</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chromium</td>
<td>Yeast, pork kidneys</td>
<td>Regulates glucose use</td>
</tr>
<tr>
<td>Cobalt</td>
<td>Meat, eggs, dairy products</td>
<td>Part of vitamin B&lt;sub&gt;12&lt;/sub&gt;</td>
</tr>
<tr>
<td>Copper</td>
<td>Organ meats, nuts, shellfish, beans</td>
<td>Part of many enzymes, storage and release of iron in red blood cells</td>
</tr>
<tr>
<td>Fluorine</td>
<td>Water (in some areas)</td>
<td>Maintains dental health</td>
</tr>
<tr>
<td>Iodine</td>
<td>Seafood, iodized salt</td>
<td>Part of thyroid hormone</td>
</tr>
<tr>
<td>Iron</td>
<td>Meat, liver, fish, shellfish, egg yolk, peas, beans, dried fruit, whole grains</td>
<td>Transport and use of oxygen (as part of hemoglobin and myoglobin), part of some enzymes</td>
</tr>
<tr>
<td>Manganese</td>
<td>Bran, coffee, tea, nuts, peas, beans</td>
<td>Part of some enzymes, bone and tendon structure</td>
</tr>
<tr>
<td>Selenium</td>
<td>Meat, milk, grains, onions</td>
<td>Part of some enzymes, heart function</td>
</tr>
<tr>
<td>Zinc</td>
<td>Meat, fish, egg yolk, milk, nuts, some whole grains</td>
<td>Part of some enzymes, nucleic acid synthesis</td>
</tr>
<tr>
<td>Vitamin</td>
<td>Function(s)</td>
<td>Food Sources</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>---------------------------------------------------</td>
</tr>
<tr>
<td><strong>Water-Soluble Vitamins</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B complex vitamins</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thiamine (vitamin B₁)</td>
<td>Growth, fertility, digestion, nerve cell function, milk production</td>
<td>Pork, beans, peas, nuts, whole grains</td>
</tr>
<tr>
<td>Riboflavin (vitamin B₂)</td>
<td>Energy use</td>
<td>Liver, leafy vegetables, dairy products, whole grains</td>
</tr>
<tr>
<td>Pantothenic acid*</td>
<td>Growth, cell maintenance, energy use</td>
<td>Liver, eggs, peas, potatoes, peanuts</td>
</tr>
<tr>
<td>Niacin</td>
<td>Growth, energy use</td>
<td>Liver, meat, peas, beans, whole grains, fish</td>
</tr>
<tr>
<td>Pyridoxine (vitamin B₆)*</td>
<td>Protein use</td>
<td>Red meat, liver, corn, potatoes, whole grains, green vegetables</td>
</tr>
<tr>
<td>Folic acid (folate)</td>
<td>Manufacture of red blood cells, metabolism</td>
<td>Liver, navy beans, dark green vegetables</td>
</tr>
<tr>
<td>Biotin*</td>
<td>Metabolism</td>
<td>Meat, milk, eggs</td>
</tr>
<tr>
<td>Cobalamin (vitamin B₁₂)</td>
<td>Manufacture of red blood cells, growth, cell maintenance</td>
<td>Meat, organ meats, fish, shellfish, milk</td>
</tr>
<tr>
<td>Ascorbic acid (vitamin C)</td>
<td>Growth, tissue repair, bone and cartilage formation</td>
<td>Citrus fruits, tomatoes, peppers, strawberries, cabbage</td>
</tr>
<tr>
<td><strong>Fat-Soluble Vitamins</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Retinol (vitamin A)</td>
<td>Night vision, new cell growth</td>
<td>Liver, dairy products, egg yolk, vegetables, fruit</td>
</tr>
<tr>
<td>Cholecalciferol (vitamin D)</td>
<td>Bone formation</td>
<td>Fish liver oil, milk, egg yolk</td>
</tr>
<tr>
<td>Tocopherol (vitamin E)*</td>
<td>Prevents oxidation of some compounds</td>
<td>Vegetable oil, nuts, beans</td>
</tr>
<tr>
<td>Vitamin K*</td>
<td>Blood clotting</td>
<td>Liver, egg yolk, green vegetables</td>
</tr>
</tbody>
</table>

*These vitamin deficiencies are rare in humans, but they have been observed in experimental animals.*
Check out how some common foods compare.

http://www.valdosta.edu/~stthompson/animations/Chapter34/nutrient_density_final2.swf
Do I need to worry about exactly what I eat then?

- The most important guideline is that...
- Eating a wide variety of foods best helps to meet your nutritional requirements.
- The U.S. government food pyramid emphasizes whole grains, fresh vegetables, and low-fat dairy products along with a variety of fruits and limited amounts of meat and fat.
- And indigestible fiber is super important too for flushing stuff through (reduces cancer risk, cholesterol levels, and regulates blood sugar)!
There are endless schemes from the government that help.
And they modify them for children.

http://www.valdosta.edu/~stthompson/animations/Chapter34/childrens_food_pyramid_final.swf
Because nutrient needs change as we develop.

http://www.valdosta.edu/~stthompson/animations/Chapter34/nutrient_needs_age_gender.swf
Here are the final ‘pyramids’ from the USDA.

The United States Department of Agriculture created the North American food guide pyramid. It was designed to represent a total diet, providing sufficient protein, vitamins and minerals for good health. This set of recommendations is now used widely for diet planning. The pyramid is based on foods of similar origin and composition being grouped together.

http://www.valdosta.edu/~stthompson/animations/Chapter34/food_guide_pyramid_final.swf
But where do the numbers come from?

* Food’s caloric content is determined by burning food in a bomb calorimeter immersed in water.

* One kilocalorie (one food Calorie) raises 1 kg of water 1° Celsius.

* When we take in more calories than we expend, our weight increases. Duh!

* “Healthful” weight is commonly measured by body mass index or BMI.
Here's a more up to date BMI chart than that used in lab.

But it puts me in the overweight category, and I work so hard at keeping my weight down — damn. Where do you fall?
And a cool interactive one.

Welcome to the McGraw-Hill BMI Calculation Tool. This device will calculate Body Mass Index from anyone’s weight and height measurements.

The data calculated can be compared to the information in Table 10.1 of Contemporary Nutrition.

http://www.valdosta.edu/~stthompson/animations/Chapter34/bmi.swf
Starvation, self-inflicted, or not . . .

A starving human body begins to digest itself. First it gets food from stored fat and then from muscle protein. Eventually it will dismantle immune system proteins.
And obesity . . .

* Is increasingly common in the U.S.A. Due to a . . .
* Combination of diet, lifestyle, and genetics.
And it's gotten much worse over the years.

It contributes to a slew of serious health problems, among them type II diabetes, hypertension, atherosclerosis . . . .
Just for fun . . .

Calories in a Sandwich

Top bun
Mayonnaise
Mustard
Ketchup
Pickle
Tomato
Onion
Lettuce
Cheese
Chicken breast
Burger patty
Bottom bun

Ingredient | Total
--- | ---
Calories
Protein (g)
Carbs. (g)
Fat (g)

Reset

http://www.valdosta.edu/~stthompson/animations/Chapter34/calories_in_sandwich_final.swf

Thursday, April 7, 2011
We're winding down for the semester. Two more lecture topics and then the Section IV Exam!

Next time — immunology.