Part I - Nutrition.

I. How to obtain food:

This is descriptive - general zoologists might be interested in this.

suspension feeders - whales, gills, clams.
substrate feeders - live in or on food source
fluid feeders - mosquitos
bulk feeders - eat large pieces of food.

(what about parasites (substrate feeders)? corals?)

II. What kind of food:

plant (herbivore)
animal (carnivore)
both (omnivore)

also - note that food can be live or dead or "in between":

- carrion/fungus/(mention parasitoid wasps)

III. Reason for feeding:

1) to obtain energy! Biological organisms need energy. Most biological molecules have some kind of energy associated with them (Krebs cycle).

-plants get energy from sunlight (usually) => autotrophic.
-animals get energy from other organisms (usually) => heterotrophic.
-some strange bacteria get energy from heat or other sources (they're also autotrophic).

2) to get raw materials for synthesizing needed compounds (differs from # 3, since these are "raw" materials).

3) to get essential nutrients that can't be synthesized (a little similar to # 2, but these materials are not synthesized).

The details:

i) Energy:

Energy is obtained by oxidation of organic molecules. Remember the Krebs cycle - demonstrates how ATP is produced in the presence of oxygen from organic molecules. Primary molecules for providing energy are:

i) fats ii) carbohydrates iii) proteins

Fats give about twice the energy of the other two.

ii) Energy balance - short term:

Excess energy is stored as glycogen (consists of glucose sub-units) in the liver (and muscle). If energy is needed, glycogen is released and metabolized (oxidized).

iii) Energy balance - long term **[Fig., not in book]**:

Excess energy is stored as fat. Great for living through rough times, but in U.S. (fortunately) we have more than enough food to go around. Result = > obesity is a serious problem (has very negative influences on health).

- diet and exercise are huge industries in the U.S., partly due to the obesity problem. **[Fig. 21.15,p. 442]**. This illustrates the need for balance.

Insufficient energy causes weight loss, then protein breakdown, muscle breakdown etc. Result => undernourishment and in extreme cases, death.

iv) raw materials:

Briefly, animals need organic carbon to manufacture needed organic molecules. Another example is nitrogenous compounds - can't fix nitrogen, so animals need to get this from diet. Important for amino acids (see below).

v) essential nutrients:

These are compounds the animal can not manufacture, but are needed for survival. A good example is Vitamins.

Note the following:

- not all animals work the same - some can make Vitamin C, for instance.

- four classes of essential nutrients:

1- amino acids (animals make about half of these). They are essential for protein synthesis.

2- fatty acids (most diets are more than sufficient in these) one example - cell membranes rely on linoelic acid (see text book).

3- vitamins (required in small amounts, but are essential). These are

needed for various functions throughout the body. See **table 21.18A on page 444**. Memorize columns 1 and 4 for exam (know what vitamins go with a given symptom) for Vitamins A, C, D, E & K (ignore B's).

Note that excess vitamins are bad for you. (Give example of carnivore livers).

4- minerals (again, required in small amounts). See table 21.18, p. 445. Please look it over, but don't worry about memorizing stuff.

Part II - Anatomy and physiology of digestion:

Overview:

Ingestion --> Digestion --> Absorption --> Elimination **[Fig. 21.2A, p. 431]**

For animals we're most familiar with, digestion takes place outside the cells:

Usually in a gastrovascular cavity.

Snakes (venom), spiders, etc. start digesting their prey outside the body.

Gastrovascular cavities may be of two types:

1) single opening - e.g., hydras, flatworms. Mouth and "anus" in the same place.

2) two openings, food proceeds from mouth to anus. Most higher animals.

[Fig. 21.3A & B, p. 432].

Mammalian digestion (not too dissimilar from other vertebrates).

Oral cavity -> Pharynx -> esophagus -> stomach -> small int. -> lg. int.
[OVERHEAD, fig. 21.4, p. 433]

1) Oral cavity **[Fig. 21.5, p. 434]**:

Physical and chemical digestion of food starts here:

- teeth break food into smaller pieces

- taste monitors the food being eaten (why?)

- saliva lubricates food and begins chemical digestion with **amylase** which breaks down **starch** and **glycogen** [try this - leave a piece of bread in your mouth for

several minutes!]. Also, note that smell of food can start triggering release of amylase.

2) Pharynx and esophagus:

- food moves past trachea (windpipe). As it does, the epiglottis closes off the opening to the trachea (the glottis). Prevents food from entering lungs (i.e., prevents choking) - **[Fig. 21.6A, p. 434]**

- esophagus conducts food from pharynx to stomach using peristalsis.

    - Peristalsis -> a muscular contraction that forces something (e.g. food) in a particular direction. DEMONSTRATE **[Fig. 21.6B, p. 435]**.

3) Stomach:

- food is broken down chemically and mechanically:

- gastric juice -> has a pH of 2. Disrupts extracellular matrix (i.e., dissolves stuff that holds cells together). Note: gastric inhibitors (medicines such as prilosec, etc.) seem to show that one can manage with a higher pH. But indications are that the low pH is very important in fighting pathogens.

- pepsin -> breaks proteins down into smaller polypeptides.

- [stomach actually releases pepsinogen, which is converted to active form (pepsin) by stomach acids (WHY?)].

- contents are mixed and slowly released through the pyloric sphincter as "acid chyme".

- pyloric sphincter acts as a control to prevent particles that are too large from entering the small intestine.

    [- cardiac sphincter controls entrance to stomach]

4) Small intestine:

- The first 25 cm or so is known as the duodenum. Several substances are released in this area **[Fig. 21.10A, p. 438]**:

    pancreas:

        buffer (neutralizes acid).

        hydrolytic enzymes (e.g. trypsin; these break up proteins further)

nucleases (deal with nucleic acids)

amylase (starch (also found in oral cavity))

lipase (deals with fats, but only after bile has been released!)

various other compounds (see table 21.10 on p. 438 if interested)

liver :

bile (stored in gall bladder). This acts as a "detergent", breaking fat down into small pieces so that lipase (from pancreas) can break down fat.

- in essence, carbohydrates, fats, nucleic acids & proteins can all be digested this way (within limits).

- The rest of the small intestine is used to absorb resulting nutrients and water. Most of the nutrients are absorbed in the capillaries lining the small intestine

- blood from the capillaries moves into the hepatic portal vein and thence into the liver. Liver processes and stores nutrients, as well as breaking down toxins **[Fig. 21.11, p. 440]**.

- But fats are absorbed by the lymphatic system (which returns blood to the heart).

- structure of small intestine: Folded structure. Folds have villi. Villi have microvilli, which absorb nutrients. Nutrients are then taken either to lymphatic system (fats) or blood vessels to liver **[Fig. 21.10B, p. 439]**.

5) Large intestine (=colon) **[Fig. 21.12, p. 440]**:

- The large intestine reabsorbs any leftover water.

- if material moves too slowly -> constipation.

- if material moves to rapidly -> diarrhea.

- terminal portion of colon is rectum. Feces are stored there until they are eliminated.

6) Cecum:

- helps digest cellulose (this is difficult to digest - bacteria help break it down).

- In humans is small, but does have a little lymphatic tissue (appendix), and so seems to function in the immune system.

- Many herbivores (like rabbits) have proportionately much larger cecums **[Fig. 21.13 441]**.

- Other ways of dealing with cellulose:

    - be big - elephants, for example, are big enough to ferment some of the plant material.

    - have a four chambered stomach - by pre-treating cellulose with bacteria, and then re-chewing (cud), many more nutrients can be extracted **[Fig., not in book]**.

Control of digestion

- how is all this controlled? (a simple example - more if we do hormones):

[Fig., not in book, but see first part of fig. 21.8, p. 436]

stomach:

food (smell, taste, etc.) --> release of gastrin from stomach wall.

gastrin --> stomach releases more gastric juices.

if pH becomes too low --> gastrin release inhibited.