BIOZONE

Student Workbook

# Senior Biology 2

SB1-2-SP

**FREE Sample**

*for classroom trial*

# Phylogenetic Systematics

The aim of classification is to organize species in a way that most accurately reflects their evolutionary history (**phylogeny**). Each successive group in the taxonomic hierarchy should represent finer and finer branching from a common ancestor. Traditional classification systems emphasize morphological similarities in order to group species into genera and other higher level taxa. In contrast, **cladistic analysis** relies on **shared derived characteristics** (**synapomorphies**), and emphasizes features that are the result of shared ancestry (homologies), rather than convergent evolution. Technology has assisted taxonomy by providing biochemical evidence for the relatedness of species. Traditional and cladistic schemes do not necessarily conflict, but there have been reclassifications of some taxa (notably the primates, but also the reptiles, dinosaurs, and birds). Popular classifications will probably continue to reflect similarities and differences in appearance, rather than a strict evolutionary history. In this respect, they are a compromise between phylogeny and the need for a convenient filing system for species diversity.

## Constructing a Simple Cladogram

A table listing the features for comparison allows us to identify where we should make branches in the **cladogram**. An outgroup (one which is known to have no or little relationship to the other organisms) is used as a basis for comparison.

| Comparative features | Taxa: Jawless fish (outgroup) | Bony fish | Amphibians | Lizards | Birds | Mammals |
|---|---|---|---|---|---|---|
| Vertebral column | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ |
| Jaws | ✘ | ✔ | ✔ | ✔ | ✔ | ✔ |
| Four supporting limbs | ✘ | ✘ | ✔ | ✔ | ✔ | ✔ |
| Amniotic egg | ✘ | ✘ | ✘ | ✔ | ✔ | ✔ |
| Diapsid skull | ✘ | ✘ | ✘ | ✔ | ✔ | ✘ |
| Feathers | ✘ | ✘ | ✘ | ✘ | ✔ | ✘ |
| Hair | ✘ | ✘ | ✘ | ✘ | ✘ | ✔ |

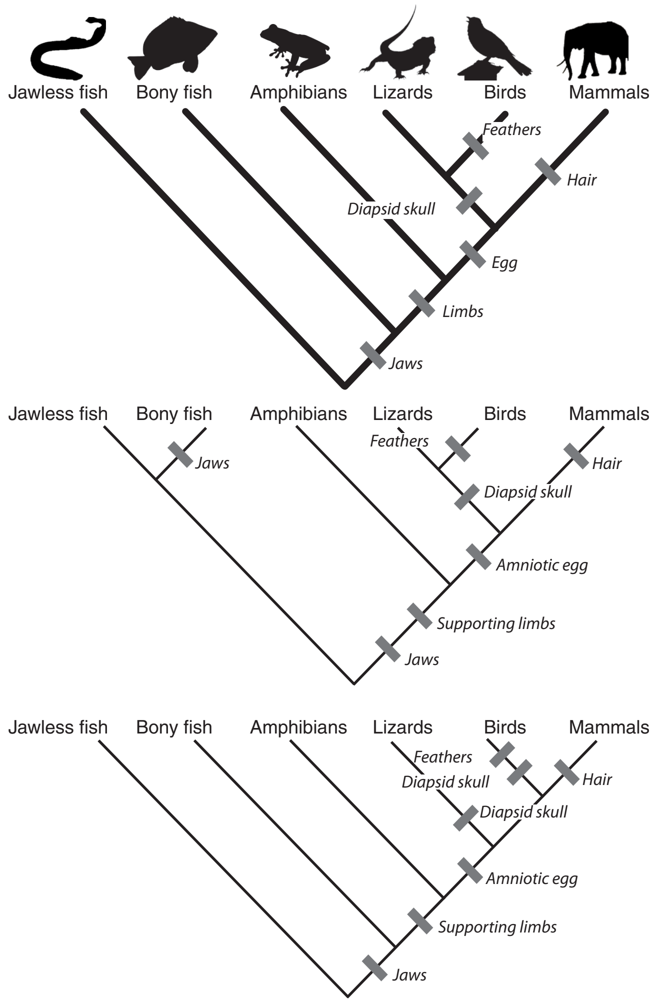
The table above lists features shared by selected taxa. The outgroup (jawless fish) shares just one feature (vertebral column), so it gives a reference for comparison and the first branch of the cladogram (tree).

As the number of taxa in the table increases, the number of possible trees that could be drawn increases exponentially. To determine the most likely relationships, the rule of **parsimony** is used. This assumes that the tree with the least number of evolutionary events is most likely to show the correct evolutionary relationship.

Three possible cladograms are shown on the right. The top cladogram requires six events while the other two require seven events. Applying the rule of parsimony, the top cladogram must be taken as correct.

Parsimony can lead to some confusion. Some evolutionary events have occurred multiple times. An example is the evolution of the four chambered heart, which occurred separately in both birds and mammals. The use of fossil evidence and DNA analysis can help to solve problems like this.

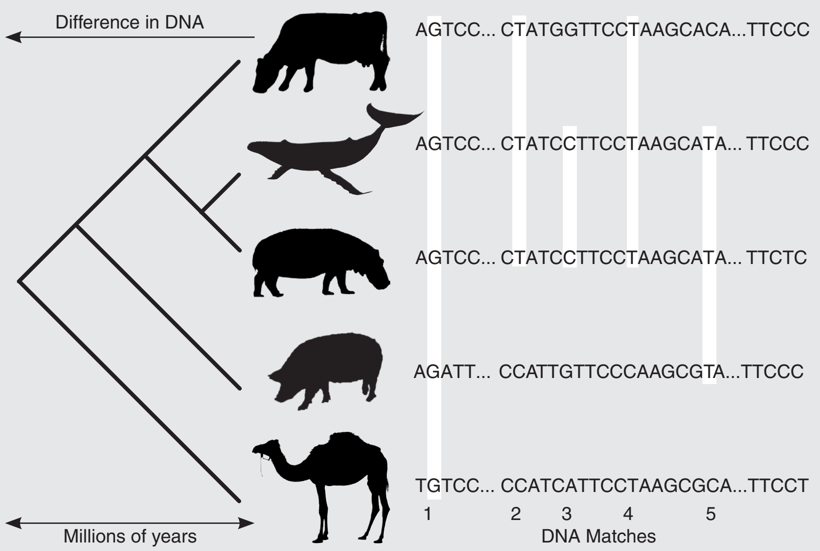
## Possible Cladograms




## Using DNA Data

DNA analysis has allowed scientists to confirm many phylogenies and refute or redraw others. In a similar way to morphological differences, DNA sequences can be tabulated and analyzed. The ancestry of whales has been in debate since Darwin. The radically different morphologies of whales and other mammals makes it difficult work out the correct phylogenetic tree. However recently discovered fossil ankle bones, as well as DNA studies, show whales are more closely related to hippopotami than to any other mammal. Coupled with molecular clocks, DNA data can also give the time between each split in the lineage.

The DNA sequences on the right show part of a the nucleotide subset 141-200 and some of the matching nucleotides used to draw the cladogram. Although whales were once thought most closely related to pigs, based on the DNA analysis the most parsimonious tree disputes this.

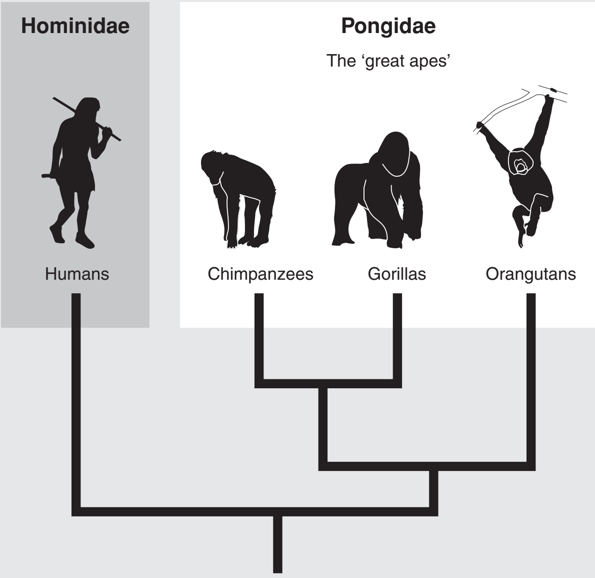






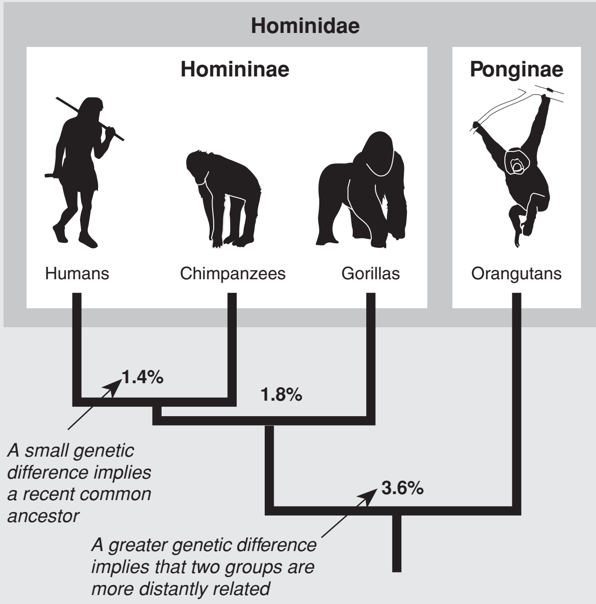

***Related activities**: Classification System, The New Tree of Life*

## A Classical Taxonomic View




On the basis of overall anatomical similarity (e.g. bones and limb length, teeth, musculature), apes are grouped into a family (Pongidae) that is separate from humans and their immediate ancestors (Hominidae). The family Pongidae (the great apes) is not monophyletic (of one phylogeny), because it stems from an ancestor that also gave rise to a species in another family (i.e. humans). This traditional classification scheme is now at odds with schemes derived after considering genetic evidence.

## A Cladistic View




Based on the evidence of genetic differences (% values above), chimpanzees and gorillas are more closely related to humans than to orangutans, and chimpanzees are more closely related to humans than they are to gorillas. Under this scheme there is no true family of great apes. The family Hominidae includes two subfamilies: Ponginae and Homininae (humans, chimpanzees, and gorillas). This classification is monophyletic: the Hominidae includes all the species that arise from a common ancestor.

1. Briefly explain the benefits of classification schemes based on:

   (a) Morphological characters: ______________________________

   ______________________________

   ______________________________

   (b) Relatedness in time (from biochemical evidence): ______________________________

   ______________________________

   ______________________________

2. Explain the difference between a shared characteristic and a shared derived characteristic: ______________________________

   ______________________________

   ______________________________

   ______________________________

3. Explain how the rule of parsimony is applied to cladistics: ______________________________

   ______________________________

4. Describe the contribution of biochemical evidence to taxonomy: ______________________________

   ______________________________

5. In the DNA data for the whale cladogram (previous page) identify the DNA match that shows a mutation event must have happened twice in evolutionary history.

   ______________________________

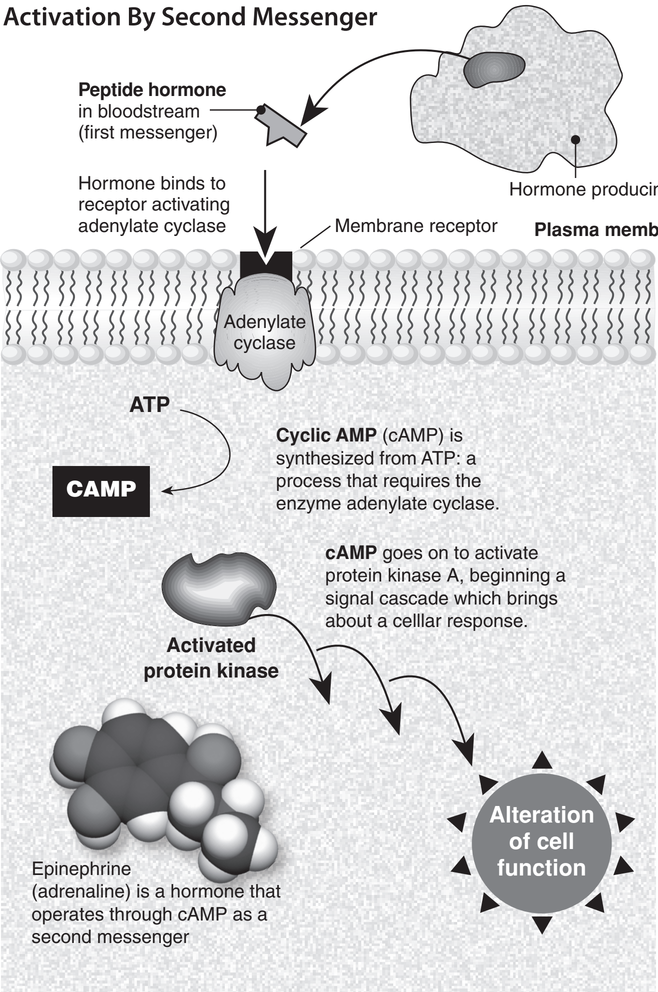
6. Based on the diagram above, state the family to which the chimpanzees belong under:

   (a) A traditional scheme: ______________ (b) A cladistic scheme: ______________

# Signal Transduction

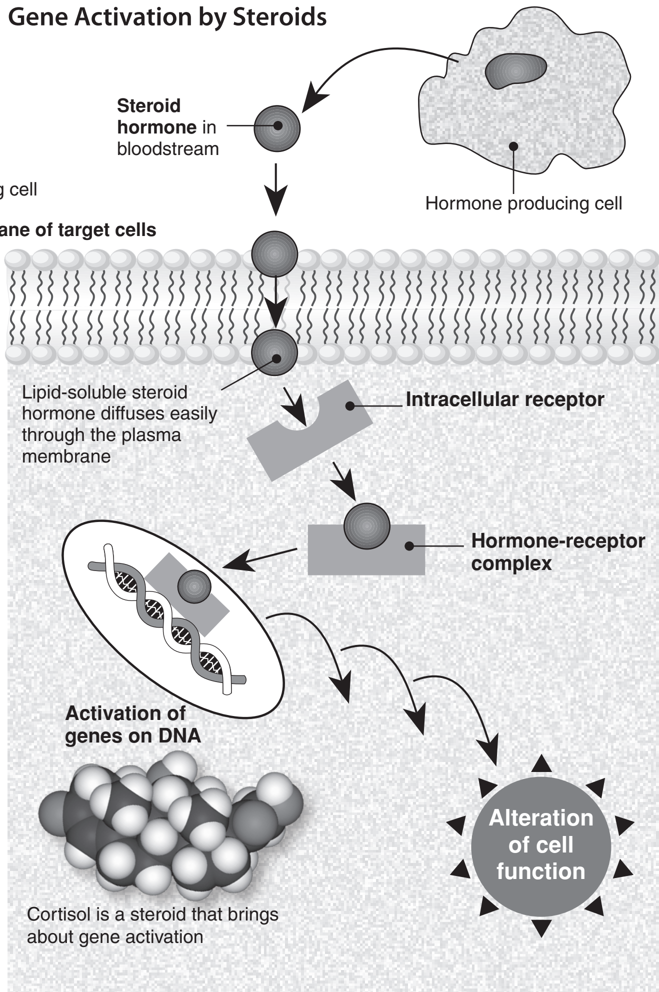
Once released, a hormone is carried in the blood to affect specific target cells. Water soluble hormones are carried free in the blood, whilst steroid and thyroid hormones are carried bound to plasma proteins. Target cells have receptors to bind the hormone, initiating a cascade of reactions which results in a specific target cell response (e.g. protein synthesis, change in membrane permeability, enzyme activation, or secretion). **Peptide hormones** operate by interacting with transmembrane receptors and activating a second messenger system (e.g. cyclic AMP). **Steroid hormones** enter the cell to interact directly with intracellular cytoplasmic receptors. Once the target cell responds, the response is recognized by the hormone-producing cell through a feedback signal and the hormone is degraded.

### Activation By Second Messenger




Cyclic AMP is a **second messenger** linking the hormone to the cellular response. Cellular concentration of cAMP increases markedly once a hormone binds and the cascade of enzyme-driven reactions is initiated.

### Gene Activation by Steroids




**Steroid hormones** alter cellular function through direct activation of genes. Once inside the target cell, steroids bind to intracellular receptor sites, creating hormone-receptor complexes that activate specific genes.

1. Describe the two mechanisms by which a hormone can bring about a cellular response:

   (a) ______________________________

   ______________________________

   (b) ______________________________

   ______________________________

2. State in what way these two mechanisms are alike: ______________________________

   ______________________________

   ______________________________

3. Explain how a very small amount of hormone is able to exert a disproportionately large effect on a target cell:

   ______________________________

   ______________________________

   ______________________________





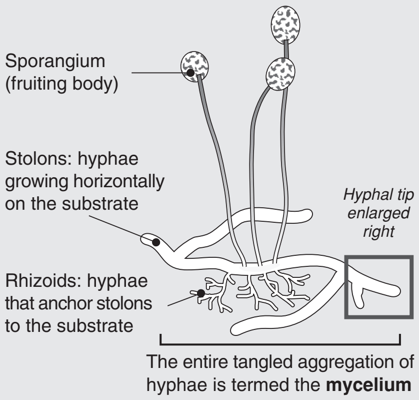
***Related activities:*** *Hormonal Regulatory Systems, Cell Signaling*
***Web links:*** *Signal Transduction, First and Second Messenger System*

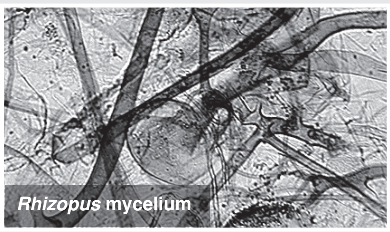
# Saprophytic Nutrition

All fungi lack chlorophyll and are **heterotrophic**, absorbing nutrients by direct absorption from the substrate. Many are **saprophytic** (also called saprotrophic or saprobiontic), feeding on dead organic matter, although some are parasitic or live in a relationship with another organism (mutualistic). Parasitic fungi are common plant pathogens, invading plant tissues through stomata, wounds, or by penetrating the epidermis. Mutualistic fungi are very important: they form lichens in association with algae or cyanobacteria, and the mutualistic mycorrhizal associations between fungi and plant roots are essential to the health of many forest plants. Saprophytic fungi, together with bacteria, are the major decomposers of the biosphere. They contribute to decay and therefore to nutrient recycling. Like all fungi, the body is composed of rapidly growing filaments called **hyphae**, which are **usually** divided by incomplete compartments called **septa**. The hyphae together form a large mass called a **mycelium** (the feeding body of the fungus). The familiar mushroom-like structures that we see are the above-ground reproductive bodies that arise from the main mycelium. The nutrition of a typical saprophyte, *Rhizopus*, is outlined below.

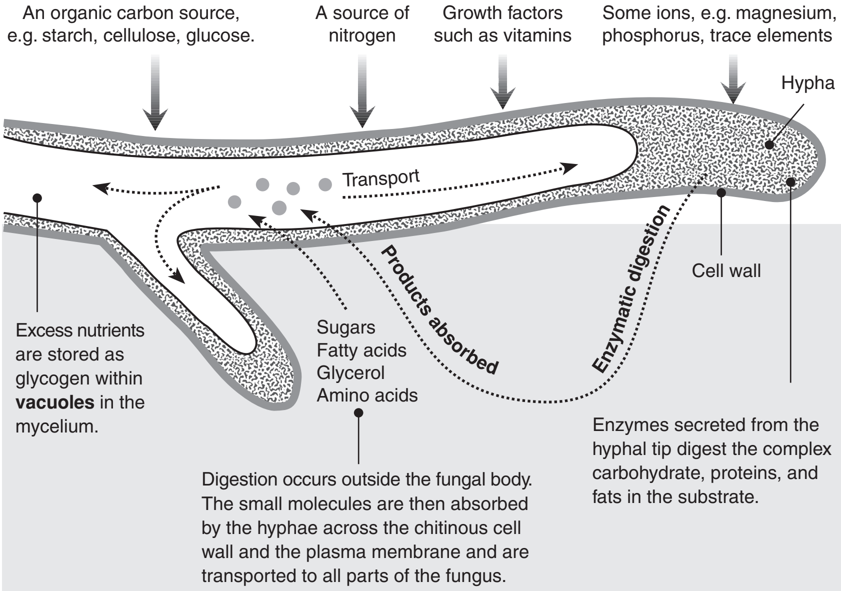
### Bread Mold (*Rhizopus*)

Saprophytes grow best in dark, moist environments, but are found wherever organic material is available. *Rhizopus* is a common fungus, found on damp, stale bread and rotting fruit. Unlike many fungi, *Rhizopus* has hyphae that are undivided by septa.




### Saprophytic Nutrition in Bread Mold (*Rhizopus*)




The environmental requirements of fungi are met by the substrate on which they are growing:

- Temperature between 5° and 25°C
- Water (the fungal body is about 90% water)
- Oxygen (very few fungi are anaerobic)
- Neutral to slightly acid pH (pH 5.6-7) .

1. (a) Clearly describe the structure of the feeding body of a saprophytic fungus: ______________________

   (b) Explain why a moist environment is essential for fungal growth: ______________________

2. Identify four nutrients required by a saprophytic fungus:

   (a) ______________ (c) ______________

   (b) ______________ (d) ______________

3. State where these nutrients come from: ______________________

4. Describe the way in which a saprophytic fungus obtains its nutrients: ______________________

5. Contrast digestion and absorption in a saprophytic fungus and a holozoic animal: ______________________

Eating to Live

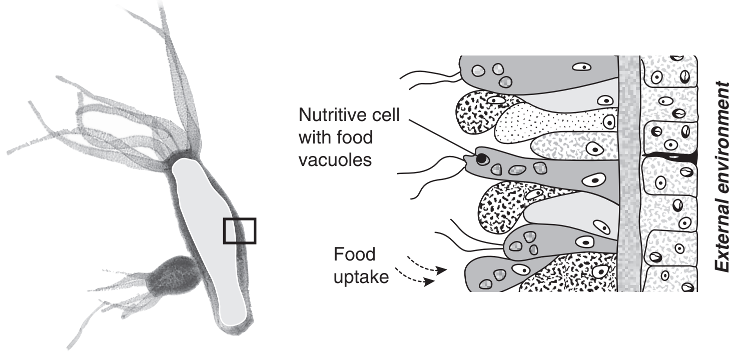
# Absorbing Nutrients

All chemical and physical digestion is aimed at the breakdown of food molecules into forms that can be absorbed across a gut lining. Absorption of the simple components of food (e.g. simple sugars, amino acids, and fatty acids) must occur before the nutrients can be **assimilated** (taken up by all the body's cells). In cnidarians, specialized cells lining the gut ingest partly digested food particles by phagocytosis. In animals with a tubular gut, the inner surface area of the gut is increased by various means (described below) to maximize the **absorption** of nutrients as the digested food passes through. After absorption, nutrients must be transported to where they are required. In vertebrates, this is facilitated by the structure of the intestinal villi. Some nutrients are absorbed directly into the bloodstream, while others are transported in the lacteals of the lymphatic system (overleaf).

### Cnidarian Gastrovascular Cavity

EXAMPLE: *Hydra*

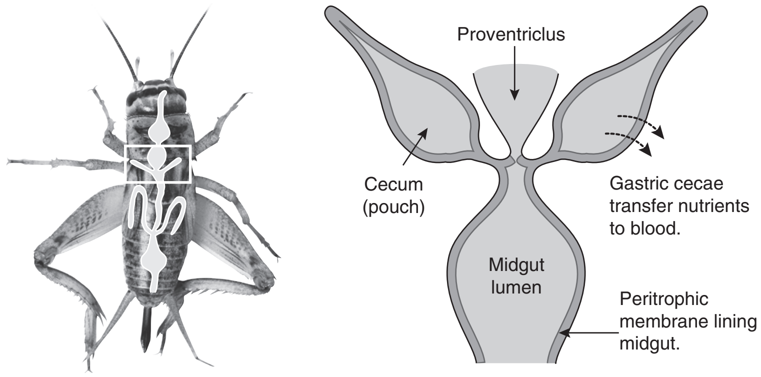
In *Hydra*, specialized cells line the gastrovascular cavity. Some of these secrete enzymes into the cavity to begin digestion. Special nutritive cells (illustrated) take in the partly digested fragments by phagocytosis, to form food vacuoles where digestion is completed. These cells have beating hair-like flagella that create currents and improve the delivery of food to the cells.




### Insect Gastric Cecae

EXAMPLE: Grasshopper or locust

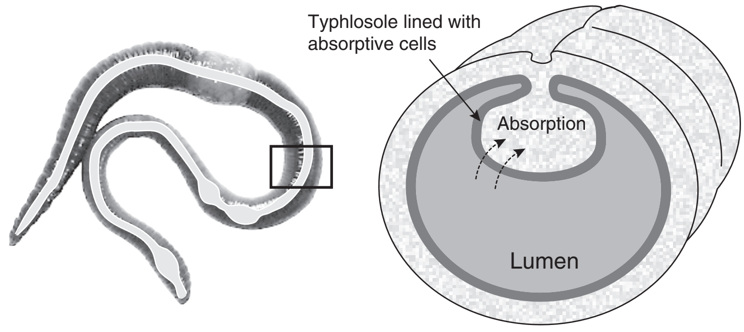
In insects of the grasshopper family (and others), the gastric cecae are midgut pouches just behind the proventriculus. The cecae improve absorption by transferring nutrients into the blood. Secretion of enzymes and absorption of nutrients occurs in the midgut. Unlike the fore- and hindgut (which are lined with chitin), the midgut is lined with a permeable peritrophic membrane which allows nutrient absorption.




### Annelid Typhlosole

EXAMPLE: *Lumbricus* (earthworm)

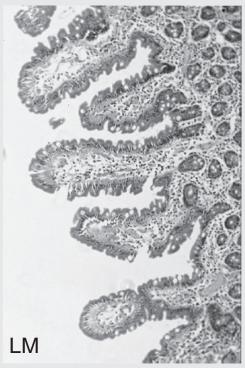
In earthworms, the entire length of the small intestine is folded into a structure called the typhlosole. Secretion of enzymes, digestion and absorption all occur in the intestine and the typhlosole increases the amount of surface area for absorption of nutrients. Not all annelids have a typhlosole, although many have similar foldings to increase surface area.

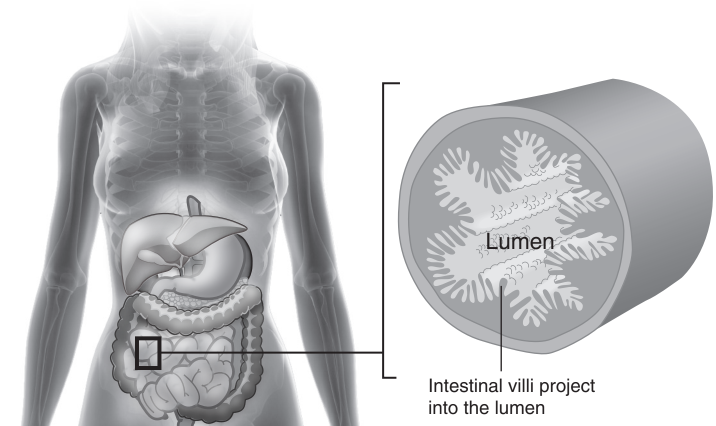



### Mammalian intestine

EXAMPLE: Human

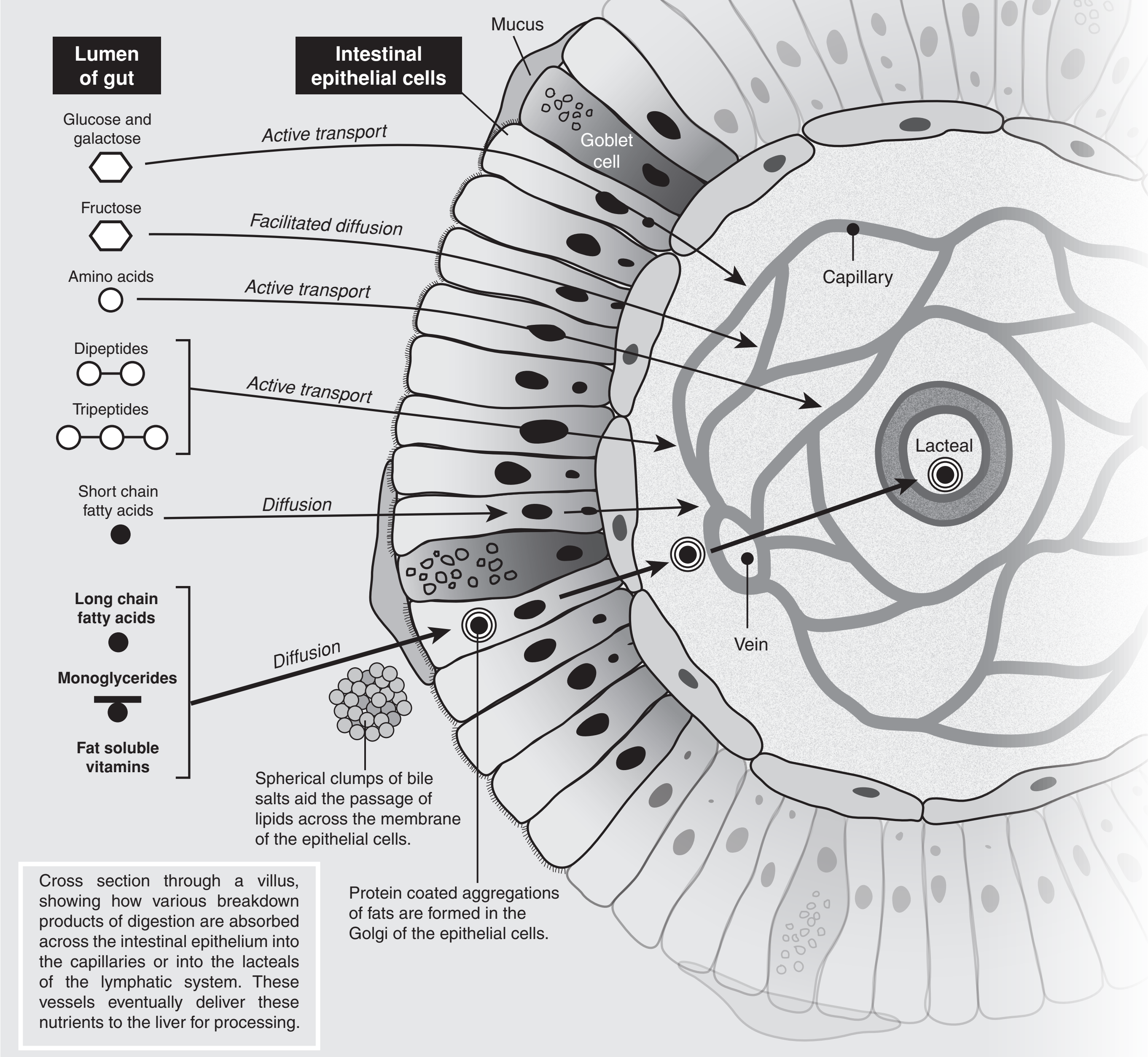
In mammals, the gut is broadly divided into the stomach and the intestines and associated glands. There may also be a cecum between the large and small intestines. The stomach mechanically and chemically breaks down the food before it passes into the small intestine. The wall of the intestine is folded into microscopic finger-like structures called villi (below and right), which increase the surface area for absorption of nutrients into the blood. After most of the nutrients ave been absorbed, the semi-solid waste passes to the large intestine (colon) where water and some ions and vitamins are absorbed.


Cross section through the intestine

## Nutrient Absorption by Intestinal Villi




Cross section through a villus, showing how various breakdown products of digestion are absorbed across the intestinal epithelium into the capillaries or into the lacteals of the lymphatic system. These vessels eventually deliver these nutrients to the liver for processing.

1. Describe the advantage of a tubular gut over a gastrovascular cavity (as in *Hydra*): ______________________

2. Describe how each of the following nutrients is absorbed by the intestinal villi in mammals:

   (a) Glucose and galactose: ______________ (e) Tripeptides: ______________

   (b) Fructose: ______________ (f) Short chain fatty acids: ______________

   (c) Amino acids: ______________ (g) Monoglycerides: ______________

   (d) Dipeptides: ______________ (h) Fat soluble vitamins: ______________

3. Discuss adaptations for increasing the surface area of the absorptive surface of the gut and the advantages of this: