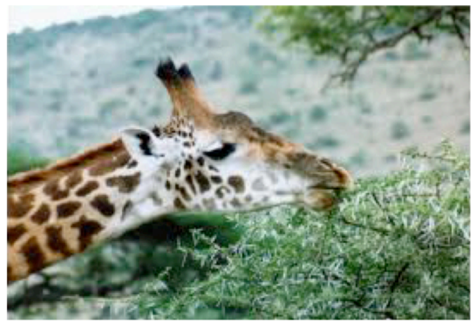
Interaction of Plants and Herbivores

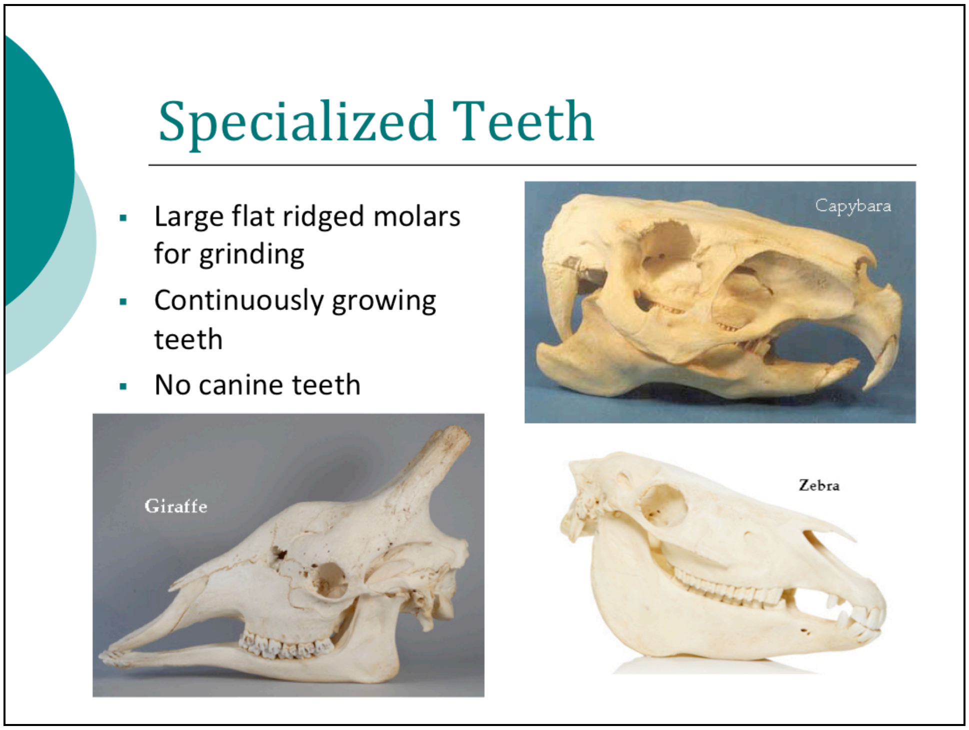
We have already discussed how plants and animals are interconnected through the food web. Plants and herbivores are also in an evolutionary arms race; this refers to organisms which are constantly adapting, evolving, and proliferating, not merely to gain reproductive advantage, but also simply to survive while pitted against ever-evolving opposing organisms in an ever-changing environment.

Physical Adaptations

- Specialized Teeth
- Specialized Digestive Systems
- Physical/Chemical Defenses for plants
- Camouflage



Herbivores have both physical and behavioral adaptations that have evolved in response to their plant diets. Let us take a closer look at some of the physical adaptations listed here that plants and animals have developed that help them to coexist and survive by using examples from our Zoo collection.



As you remember in the mammal unit, mammal teeth reflect their diet. Mammals are **heterodonts**, with most having three types of teeth: incisors, canines, and cheek teeth (molars and premolars).

Cellulose is part of plant cell walls and is where the majority of the nutrients are, but is a difficult component to digest. Animals do not have an enzyme that breaks the cellulose down for them. To help with cellulose digestion, herbivores have developed a grinding surface on their teeth that aids in the digestion of fibrous material. Their molars are large, flat and ridged. Additionally, the side to side and up and down movement of the herbivore jaw facilitates the grinding and crushing of plant cellulose. In contrast, carnivores have tight jaw attachments to the skull for up and down movement, but little side-to-side movement.

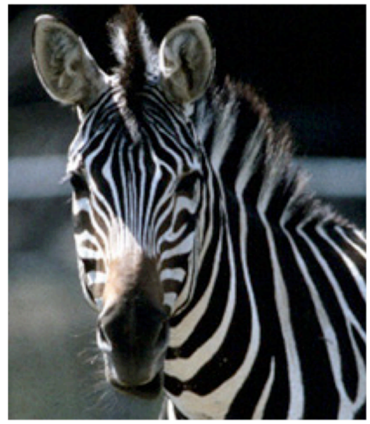
The capybarra, a rodent, has sharp incisors to clip plant stems and a **diastema** a space between the incisors and the other teeth providing the tongue room to move the food around and room for the base of the incisors. Rodent incisors are continually growing, which compensates for the abrasion from foraging. They need to gnaw to keep them worn down. They also have the characteristic large premolars and molars for grinding. **Note:** most herbivorous mammals have a diastema between the front teeth (incisors and canines) and cheek teeth (molars and premolars). Examples include rodents, lagomorphs as well as most ungulates (hoofed animals).

Ruminants, like this giraffe have no upper incisors but strip acacia leaves with lower teeth and lips against the upper roof plate. A giraffe's long prehensile tongue is able to grab the acacia leaves and has plenty of room to maneuver and pass food back to the molars. Zebras have a diastema but have both the upper and lower clipper-like incisors allowing them to break off plant material. They are a grazer and like to eat the tips of the grass stem.

Note: The teeth of most vertebrates are replaced continuously throughout the animal's life. Early on in evolution mammals all had continually growing teeth but lost the capacity to do so. Most mammals grow two sets of teeth in their life and that is it.

Specialized Digestive Systems

- **Hindgut Fermentation**
- Koala, zebra, rabbits, rodents



A lengthy intestinal tract is a hallmark of many herbivores. Food remains for longer periods in the longer gut, allowing for additional chemical digestion and more absorption of nutrients. Since herbivores do not produce enzymes that break down the cellulose of plant cell walls, they need special microorganisms in their intestinal tract that further aid in the digestion of cellulose. In some, these "gut flora" are housed in the cecum, a pouch-like section of the large intestine; this is known as **hindgut fermentation**. Hindgut fermentation occurs after digestion in the stomach.

The koala has a 7 foot long, enlarged cecum, which houses microorganisms, that help break down fiber in eucalyptus leaves. This adaptation, in addition to a digestive system that detoxifies the toxic oils in the leaves has enabled koalas to eat eucalyptus leaves. It is thought that eucalyptus trees produce the oil as a protection against leaf eating animals such as insects. Because the koala is one of only a couple animals able to eat eucalyptus leaves, they have exclusive access to an ecological food niche and the eucalyptus trees are less apt to be over foraged.

Koala young need to build up their immunity to the eucalyptus toxins. They are fed "a fecal pap" for about 30 weeks, which prepares their own digestive tract for the adult diet, allowing them to tolerate the toxins and fibrous eucalyptus. To facilitate this feeding, a koala's pouch faces down and backward.

Note: Eucalyptus trees which grow on less fertile soils seem to have more toxins than those growing on good soils. This could be one reason why koalas will eat only certain types of eucalyptus, and why they will sometimes even avoid them when they are growing on certain soils.

Hind-gut fermentation is less efficient for digesting grasses than is the foregut fermentation of ruminants as fewer nutrients are produced in the process. Herbivorous, non ruminant ungulates such as horses and zebra, compensate by ingesting more forage than do ruminants.

In **foregut fermentation**, the gut flora is housed in the multi-chambered stomach rather than in the intestinal tract. Foregut fermentation takes place before digestion and produces more absorbable nutrients than does hindgut fermentation. It is a slower process, but is more efficient; hindgut fermentation is 2/3 as efficient as is foregut and two times faster. **Ruminants** such as the greater kudu, yellow-backed duiker, and the giraffe have microbes in their four-chambered stomach. Kangaroos are ruminant-like with a two part stomach. Hippos do not ruminate, but they have three-chambered stomachs.

Black & white colobus monkeys are **folivores** and have an enlarged salivary gland and a multi-chambered stomach. The first chamber is sacculated with microorganisms and is very large. They appear to have pot-bellies because cellulose-containing food is bulky and fermentation is relatively slow. Their long periods of inactivity are associated with digestion. Their ruminant-like digestive systems have enabled these leaf-eaters to occupy niches that are inaccessible to other primates.

Rumination is major contribution to the success of the Order Artiodactyla (the even-toed ungulates).

Specialized Digestive Systems

- Birds have muscular gizzards for grinding
- Some birds have crops for softening

Hoatzin
Opisthocomus hoazin

As a weight reduction strategy, birds lost their teeth. To compensate for the lack of mastication, most birds have a two-chambered stomach. The first part produces gastric juices while the second part is the **gizzard,** which is muscular and used for grinding and digesting cellulose. Grain-eating birds pick up grit and small rocks as they peck seeds from the ground to help in this process. The shape and structure of the stomach differ more than any other organ among bird species.

Some birds have **crops** where moistening and softening begins prior to the gizzard. Seed eaters usually have larger crops, which help soften the seed before passing through the digestive track.

The hoatzin of the Amazon of South America is a **folivore** with an enlarged two-chambered crop, and is the only bird that is a ruminator. To accommodate for this large crop, the anterior portion of sternum is greatly reduced. This results in less surface for muscle attachment and a reduced flight capacity.

Heavy-bodied, largely terrestrial birds such as chickens, pheasants, turkeys and currassow have large muscular gizzards with two large ceca. The cecum has a muscular wall that can help with the digestive process.

Some plants have evolved physical structures to prevent animals from preying on them. Examples are the spines of cacti and the large, rough thorns of the acacia that is the favorite food of giraffes. Other plants have developed **chemical defenses**. The toxic or injurious plants are more likely to be left uneaten compared with nontoxic plants and therefore are more likely to produce more seeds and more progeny. Animals have found clever ways to avoid these defenses.

The Chacoan peccary is confined to hot, dry areas and feed on various species of cacti. It uses its tough, leathery snout to roll the cacti on the ground, rubbing the spines off. It may pull off the spines with its teeth and spit them out. Their kidneys are specialized to break down acids from the cacti.

Thorny acacias grow straight up and then laterally, trying to stay out of reach of the giraffe. Giraffes avoid the acacia thorns by maneuvering around them with their long prehensile tongue. If the giraffe does get a thorn, their thick saliva coats it to protect the giraffe from any punctures. Acacia leaves contain a lot of water, so giraffes can go a long time without drinking. When the giraffe eats an acacia leaf, a non-palatable chemical, called tannin, is pumped into the leaves. The tree then warns other acacia trees in the area by emitting a chemical into the air. The other acacia trees respond by pumping these alkaloids into their leaves so the giraffe will not eat them. The giraffe adapts by eating the most downwind leaves of the acacia first and moving around from tree to tree. Kudu also eat acacia showing similar behaviors.

The thorny acacia tree also protects itself through its symbiotic relationship with acacia ants. The ants live in the large, hollow acacia thorns. The plant makes a substance on the tips of its leafs used by the ants as food. The ants in turn defend the tree from herbivores by attacking/stinging any animal that even accidentally brushes up against the plant. The ants also prune off seedlings of any other plants that sprout under “their” tree.

Parrots/macaws eat seeds and bitter green fruits that are full of toxins. They will eat clay which combines with the toxins and neutralizes them.

Some insects are protected from predators by their unpleasant taste. Their noxiousness is often derived from chemicals they absorb by feeding on chemically defended plants. Monarch butterflies and caterpillars are foul-tasting and poisonous due to ingesting toxic chemicals in milkweed.

Protective coloration is one way prey animals can hide from their predators; coloring helps an animal blend into its environment and avoid detection. A savanna animal may be tan or brown, a rainforest animal may be be glossy green, and so forth. Coloring may also have a physiological benefit; lighter colors reflect more of the sun's radiation than a darker one and thus helps them to remain cool.

Some chameleon species are well known for their ability to change their skin coloration, camouflaging themselves against a background. In general, chameleon's change color to regulate their temperatures or to signal their intentions to other chameleons. A chameleon that gets cold might change to a darker color to absorb more heat and warm its body.

Other animals use textures and patterns to help them to blend in; the patterns may resemble shadows and windblown vegetation. Other patterns may appear confusing for predators and make it hard to find an individual in a group.

Many examples of **camouflage** can be seen at the Zoo. Lions are well hidden in the grasslands of the savanna. The two subspecies of tiger show how coloration can change according to their habitat. The Sumatran, who lives in the dark rainforest, is darker in color than Siberian who lives in a more open habitat of deciduous & coniferous forests.

Phasmids, or leaf and stick insects are among the best-camouflaged animals. Their body shape and coloring mimics the vegetation of their habitat, making them extremely difficult to spot. You can see here that the leaf insect blends in with the leaves and that the stick insect on the right blends in with the branches of a tree.

Other animals have **countershading** camouflage where they have dark backs and light underneath. For example, koalas spend all their time sitting in a tree and have whitish fur below and darker fur along their backs and head. From above, the koala is hard to see amongst the trees and from below, the white fur blends in with the lightness of the sky.

Insects use **mimicry** to blend into their surroundings. For example, a phasmid's walk is slow and deliberate and they often slowly sway from side to side as if it is being blown by the wind. This movement further conceals them among the swaying leaves.

Summer and rainy seasons in temperate environment bring a peak availability of food. During dry seasons or winter food availability decreases. This is the primary motivation for birds to migrate. Birds **migrate** to exploit seasonal feeding and nesting opportunities while living in favorable climates all year round. As the days shorten in autumn, migratory birds return to warmer regions where the available food supply varies little with the season. As the warmer months set in, migration from tropical areas vastly increases the amount of space available for breeding, reduces aggressive territorial behavior and reduces the competition for food. We see evidence of these migrations in the San Francisco Baylands; shorebirds migrate along this part of the Pacific Flyway. When you spend anytime along the shores of the Bay you will see different bird species depending on the time of year.

Zebra and wildebeast of the African savanna will migrate due to the seasonal nature of the savanna which has dry and wet seasons. These herbivores depend on an adequate supply of water and grazing material. During the dry season, huge herds will travel wherever the rain brings water and fresh green grass. Zebras migrate first, eating the top part of the grass whereas the wildebeast eat the more tender, lower part and follow the zebra.

Hibernation is a response by animals to the seasonal availability of plants. Some animals, for example the ground squirrels, lower their body temperature, slow their breathing, and lower their metabolic rates, which reduces their energy requirements and bypass winter when food is low.

Bears are not true hibernators; they will **den up** in response to decreased food supply. They lower their metabolism to decrease their energy needs, but they require a higher body temperature than true hibernators in order to meet the demands of pregnancy, birth, and then nursing.

White tail deer will time their births when plants are most abundant and there is new and succulent growth. Mating occurs in the fall and the doe has about a seven months gestation period. Fawning comes for the fittest does that have survived the winter. Any fetus that has survived is likely to become a very durable fawn.

Shrikes of Africa will kill lizards and insects. They do not have a beak or teeth that are strong enough to tear off meat, so instead, they impale their prey on acacia thorns. This helps them to tear the flesh into smaller-sized fragments, and serves as a cache so that the shrike can return later to the uneaten portions and then wait for it to soften in the sun. They will leave the toxic lubber grasshoppers until the toxins are degraded in a couple of days and then they will eat it.

As you can see, the relationships and interactions between plants and animals are varied and complex and can provide you with a wealth of interpretive information and stories.

Mutual Alliances
Angiosperms and Pollinators

- Pollinators gain energy from a plant's pollen, nectar and/or fruit
- Insects are attracted to plants for reproduction sites, protection from predators and food
- Plants benefit from pollinators by being fertilized
- Plants gain cross-fertilization that produces genetic diversity

Both the plant and the pollinator benefit from each other and exert selective pressure on the other, so they evolve together. This **coevolution** is seen in the hummingbirds in South America; multiple species are adapted to a specific flower, commonly red, by the length and curvature of their beak. This excludes others from getting nectar of this species; others do not have the right shaped beak. With this relationship, the hummingbird engages in flower constancy, which means they are more likely to transfer pollen from one plant to another of its own species.

In another example seen in the Insect Zoo, sphinx moths, a nocturnal analogue of the hummingbird, are attracted to white and highly scented flowers. Their very long tongues allow them to reach the flower nectar. Moth-pollinated plants often have spurs or tubes the exact length of a certain moth's "tongue". Charles Darwin predicted the existence of a moth in Madagascar based on the size and shape of a flower he saw there. The moth was actually discovered about 40 years later.

The origins and diversification of birds overlapped with the origins of flowering plants, which occurred about 130 million years ago. These early birds were probably seed dispersers. This was quickly followed by the origins and explosive diversification of many pollinating insects. Insects were attracted to plants because they provided places for insect reproduction, a shelter or protection against predators and/or provided food for developing offspring as well as adults.

Ruffed lemurs feed primarily on fruits and nectar and are significant pollinators of the traveller's tree (*Ravenala madagascariensis)*. They lick the nectar from deep inside the flower using their long muzzles and tongues, collecting and transferring pollen on their snouts and fur from plant to plant. The lemur and the tree have reciprocally affected each other's evolution.

Another tactic to lure insects is seen in the Arctic poppy flower, which follows the sun collecting the sun's rays and warmth. The warmth attracts insects which are unable to generate heat of their own. These insects in turn pollinate the poppies.

Key Plant/Animal Concepts

- Plants adapt to changing conditions; they are trying to survive just as animals.
- Plants and animals are interconnected; they evolve together.
- Herbivores need to have special adaptations to break down the cellulose in plant walls to get nutrients.

Corresponds to pages 12- 18 Botany Study Guide of the Docents Notebook.

Key Plant/Animal Vocabulary

- Cellulose
- Diastema
- Hindgut, foregut, ruminate
- Coevolution
- Mimicry, camouflage
- Heterodont, homodont
- Folivore

Camouflage: a structural adaptation that enables species to blend with their surroundings; allows a species to avoid detection by predators; a visual form of mimicry

Cellulose: Cellulose is an an organic compound is the main component of plant cell walls; it gives wood its remarkable strength.

Coevolution: The process of reciprocal evolutionary change that occurs between pairs of species or among groups of species as they interact with one another; two (or more) species reciprocally affect each other's evolution; the evolutionary change of one species triggered by interaction with another species.

Countershading: a method of camouflage in which an animal's coloration is darker on the upper side and lighter on the underside of the body.

Diastema: a space or gap between two teeth.

Foregut: the first part of the digestive tract beginning from the mouth through the stomach.

Folivore: a herbivore that specializes in eating leaves.

Heterodont: an animal possessing more than one tooth morphology; an animal having different teeth types such as incisors, canines and molars.

Hindgut: the last part of the digestive tract including the colon and rectum.

Homodont: an animal having teeth of a similar form.

Mimicry: a selection of traits that look, sound and smell like something else so that it ends up protecting that organism from being eaten; a similarity of one species to another which protects one or both.

Ruminate: to chew cud; to regurgitate and chew again what has been swallowed.