BIOFACTS

BIOFACT DEFINITION
A biofact is any item of biological information; it is an item relating to life. This may include a skull or bone, antlers, an animal's pelt or feathers or a preserved forefoot. Biofacts provide a hands-on nature based teaching tools used to educate the public on how an animal lives and is adapted to their environment.

ANIMAL SKULLS
Each species of animal has a characteristic skull shape that is suited to its particular way of life. If you look at a skull, it will tell you a lot about how that animal lives and eats. The skull's size and shape are a result of adaptations to a particular lifestyle. Form follows function. Here are the basic parts of the skull that scientists use when they study skulls. It helps scientists to better understand how animals live. One way that scientists classify animals is by grouping animals with similar skulls (teeth, etc.).

TEETH
All mammals have teeth except for monotremes, anteaters and certain whales. (Birds do not have teeth.) Mammal teeth have to do many different jobs - chewing, crushing, cracking, gnawing, grooming, digging, defending and communicating. Teeth give many dues about their owner, from the type of food eaten to the age of the animal. The most important characteristic in identifying a mammal is its teeth.

Mammals have four types of teeth and each type of tooth is adapted to perform a specific function:

- Incisors (I) = designed for biting, cutting and stripping
- Canines (C) = designed for grabbing, piercing and tearing
- Premolars (P) = designed for grinding, crushing, slicing, shearing
- Molars (M) = designed for grinding and crushing

The kind of teeth, their shape, size and number helps you determine the animal's lifestyle and diet. For example, carnivores have sharp premolars and molars that are shaped like knives or blades. These teeth, called carnassial teeth, cut and chew off chunks of meat. If you look at an animal skull and you see this kind of sharp teeth, you know that the animal was a meat-eating carnivore such as a lion.

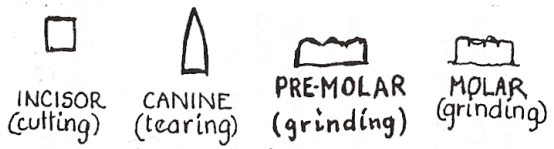
On the other hand, if you see premolars and molars that are tall and have a flat upper surface, you know that the animal was a herbivore like a giraffe. The broad teeth of herbivores are like grinders that grind vegetation into a pulp.

If you saw wide teeth with low bumpy surfaces, the animal was probably an omnivore (eats both plants and animals). Examples of omnivores include bears. (Feel the bumpy surfaces of your molars with your tongue - humans are omnivores!).

SKULLDUGGERY AMONG THE MAMMALS

or Food-Getting Adaptations

Tooth and jaw structure tell us so much about the eating habits of mammals that a good student can tell by the skull alone what animal it belongs to. Each species has its characteristic dentition ("arrangement of teeth," cf. "dentist"): combinations of the following:



The teeth of mammals are adapted in different ways to get food.

HERBIVOROUS

grinding molars
clipper-like incisors
no canines

Gnawers of seeds, roots, and stems. **Rodents**

Field mice and **woodchucks,** like all rodents, have long incisors, and a space between the incisors and molars. The chewing area can be closed off by a fold of skin for food storage.

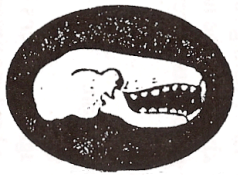
Stem croppers. Ungulates ("having hoofs")

Cows and **deer** have no upper incisors. They tear grass with lower teeth and lips against the upper roof plate. **Sheep** and **goats** have similar dentition, but crop the grass closer as their jaws are narrower, and lips thinner. Sheep are not popular on cattle ranches!

Horses bite grass stems. They have both upper and lower front teeth.

INSECTIVOROUS

All teeth sharp-pointed, suitable for catching, holding and cutting prey.



Insect Eaters. Insectivores

Insects are attracted to plants of the fields and grasslands, and they, in turn, attract **moles** and **shrews.** These animals have a battery of small teeth useful in seizing and crunching hardshell beetles and other small fry.

Toothless. Some Mammals don't have any teeth. They feed primarily on insects such as Ants and Termites. Examples: Pangolins and True Anteaters.

CARNIVOROUS

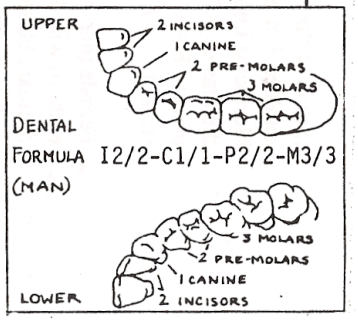
sharp molars for tearing and cutting,
canines for slashing.

Meat Eaters. Carnivores

Field mice, moles, and shrews attract **foxes,** who feed on them and on rabbits, abundant in grassy meadows. Foxes have teeth equipped to handle meat. The canine teeth help seize and tear prey.

OMNIVOROUS

Such animals as **opossums, skunks, coons,** and **man** are omnivorous; literally eating anything. This broad diet is reflected in the teeth which are less specialized than in most mammals.



Dentition is expressed in a dental formula. The example given means that in one-half of man's jaw, from front to back, there are 2 upper and 2 lower incisors, 1 upper and 1 lower canine, 2 upper and 2 lower pre-molars, and 3 upper and 3 lower molars.

JAW ATTACHMENT TO SKULL
The way that the lower jaw attaches to the skull also tells something about the animal's diet. Carnivores have tight jaw attachments to the skull for up and down movement, but little side-to-side movement. Carnivore jaws work like scissors (up and down), emphasizing the cutting function of the carnassial teeth. Herbivores eat plants that are fibrous. Its better their jaws move up and down and side to side. Plants must be ground and crushed into smaller pieces before they are swallowed. The side-to-side movement helps in grinding food.

EYES
Eye sockets that are very large in relation to the size of the animal's skull indicate that the animal may be nocturnal (active at night). The eye socket is bigger to accommodate a larger eyeball that evolved from the need or better vision at night. Remember this Predator and Prey rhyme: Eyes to the front, the animal hunts (predator). Eyes to the side, the animal hides (prey).

Eyes that face forward on the skull mean that the animal has binocular or stereoscopic vision. If you have this kind of vision, you have excellent depth perception. Predators (like cats and owls) need good depth perception because they need to be able to judge the distance between them and their prey before jumping on it. Monkeys also have eyes in front because they need depth perception as they leap and swing from branch to branch. Prey animals have evolved eyes located on the sides of their heads. Having eyes more on the side of the skull allows prey animals to have a wide peripheral vision - they can keep an "all around" watch for predators.

SNOUTS
An animal with a longer snout probably relies on a good sense of smell. A longer snout is needed to house smell organs. For example, a coyote relies on its sense of smell more than humans do and their noses are larger. A human has 5 million "smell cells"; a coyote has at least 100 million "smell cells".

BONES
Bone is a connective tissue forming the skeleton of vertebrates. It consists of living cells embedded in a matrix of bone salts and collagen fibers. The bone salts are mostly calcium, and make about 60% of the mass and give it hardness. Bone support and protects body organs; it gives shape to the body and provides anchorage points for muscles and levers for movement. Bone marrow is found inside certain bones of amphibian, reptiles, birds, and mammals and is important in the production of blood cells. One way of teaching animal adaptations or feeding strategies is to compare bones of different animals.

1. SKULLS
   The skull is the most anterior part of the skeleton consisting of the cranium and facial skeleton. The cranium is made up of a number of fused bones that enclose and protect the brain.

   The movement of the jaws is related to the eating methods of the animal. InLbird3i the lower jaw is made up of several bony components. The hinge is composed of one bone from the lower jaw and one from the upper jaw. This type of structure is fine for a jaw thqt will just hold or rip off parts of prey or plants.

Mammals on the other hand, have developed teeth for chewing, gnawing, grinding and cutting. The jaw that evolved to allow for these feeding methods consists of a single bone lower jaw connected to the upper skull by muscles.

Bird skulls do not have teeth but do have beaks widely modified according to food habits. Bird skulls are thinner and lighter, an adaptation for flight, than mammal skulls. This thin bone would not support teeth, and teeth would add considerable weight.

2. TEETH
   Typically, mammals have two sets of teeth; the "milk" set often differing from the adult set. All mammalian teeth consist of a core of bone-like dentine wrapped in a hard case of enamel. Once most mammals are adults, their teeth cease to grow. Mammal teeth lie in sockets that can be shown on any skull with, missing teeth.

   There are a few major differences generally found between the teeth of herbivores and those of omnivores and carnivores. Chewing movement is generally horizontal, either side to side or front to back. The wear from chewing on these continuously growing teeth limits their length. Enamel ridges may wear away exposing the valley of softer dentition. The ridges of the teeth run in a direction perpendicular to the direction of the chewing movement. If the ridges go from side to side chewing movement will be from front to back. In this way the ridges of the top and bottom teeth move across each other, grinding the food.

   Each type of tooth, if present, may have a different shape or purpose, depending on the mammal and it's eating habits. Elephants have only upper incisors with one on each side, growing continuously to form the tusks. Canines also form tusks in many mammals. Pre-molars can vary in structure and may be canine like or molar like.

DENTAL FORMULA

The most important characteristic used in the identification of mammals is the dentitions or teeth. Animal lifestyles can be revealed more by examining, their teeth, than by perhaps any other single physical characteristic. For example, their large slicing canines indicate the diet and method of feeding of large carnivores. In contrast, the porcupine has no canines, but instead has extremely large specialized incisors for gnawing.

A mammal's dental formula designates the number of each type of tooth found in its dentition. The numbers in the dental formula' represent the number of teeth in each half of the upper and lower Jaws. Dental formulas represented as follows:

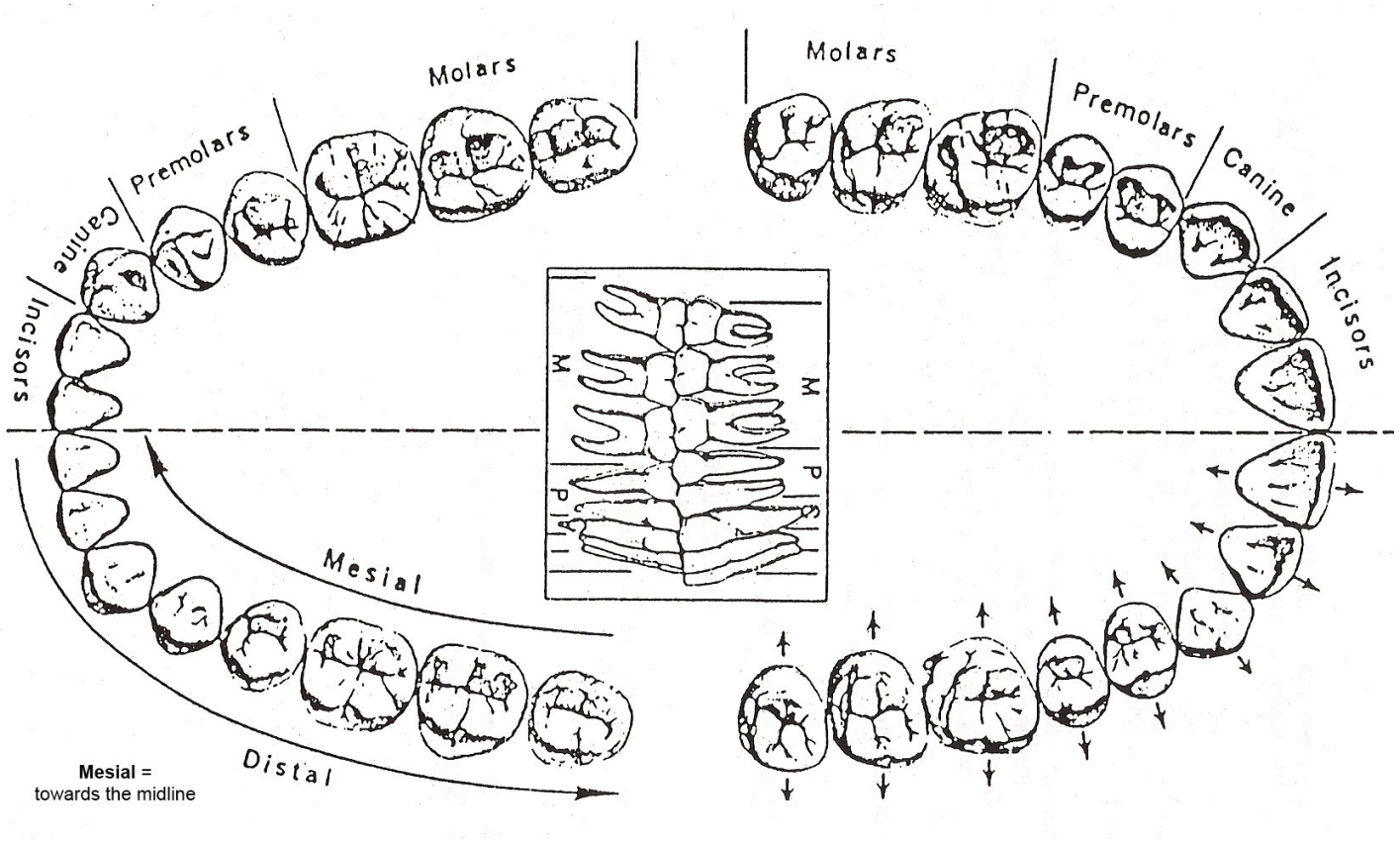
Upper left jaw - Upper right jaw
Lower left jaw - Lower right jaw

For example, the dental formula for a human is:

$$\text{I } \frac{2\text{-}2}{2\text{-}2} \quad \text{C } \frac{1\text{-}1}{1\text{-}1} \quad \text{P } \frac{2\text{-}2}{2\text{-}2} \quad \text{M } \frac{3\text{-}3}{3\text{-}3} \quad = 16 \quad = 16 \quad \text{Total}=32$$

Tooth count differs from animal to animal, so in many cases this counting method is used in identifying genus and species.

DENITION GUIDE



GENERAL BIOFACTS GUIDELINES:
When using a mammal skull, point out the different type of teeth and how they are related to the type of food eaten. It is very helpful to be able to tell at a glance what type of animal you have and what type of diet it eats. The teeth and shape of the skull can tell you these general facts without you even knowing what species you are handling. This mainly applies to mammalian species, but you can tell a lot about bird beaks, as well.

As a general rule, meat-eaters will have canines and sharp check teeth, omnivores will have canines and flattened cheek teeth, and herbivores will have reduced or canines absent, flat, large cheek teeth and large flat incisors for cropping vegetation.

- **HERBIVORE**
  Herbivores typically have a long toothless portion from the premolars to the incisors called a "diastema". In some species, like camels, canines may be present, mostly on the upper jaw, or in pigs, upper and lower, but there is still a large empty space leading to the nostril area. Deer, cow-like species, giraffe and several others have only lower, flat shaped incisors that meet the upper toothless gum. There is a plate of bone under the skin instead, to grind against; horse-like species have large upper and lower incisors.

  Ruminants can be identified by the grinding surfaces of the molars and premolars; the premolars have the shape of molars, and you can see the ridges formed on these teeth running in a back to front direction. Grinding wears away the lighter ridges of enamel, and the darker dentine valleys can be seen, showing that ruminants grind their food with a side-to-

side motion. The lower jaw canines have the shape of incisors and along with the incisors form a cutting edge of eight teeth against a hardened, toothless upper gum.

Rodents have long, recurving incisors, no canines and flat grinding molars. The large ever-growing and rootless incisors are characteristic of the rodent. These chisel-like teeth allow the rodent to cut and chop its food, which can then be passed back to the molars. With no canines and all or most of the premolars absent, a gap is left between the incisors and the molars, which allows for the long growing base of the incisors. Because their teeth grow continually, rodents must gnaw continually to keep them the proper length.

Lagomorphs (hares and rabbits) have a second, spike-shaped, incisor behind each upper incisor. The molars and premolars of rodents and rabbits form a grinding surface that is used to break down tough plant material.

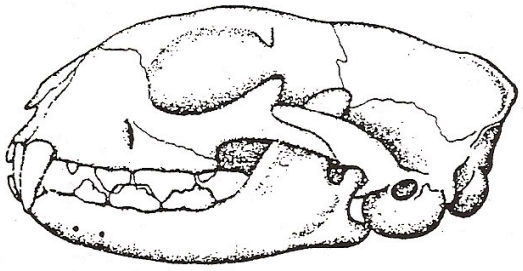
Primates have forward facing, large ocular bones or eye sockets, as most have binocular visions. In many there will be exaggerated canines, where some may be reduced like humans. All will have flattened cheek teeth and larger incisors. Prosimian species will have longer muzzles, while apes and monkeys will have a more blunt skull that appears more human-like.

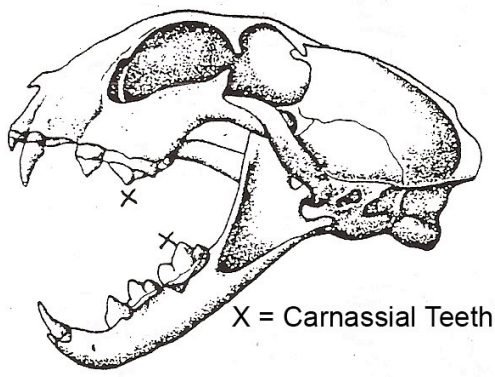
- **CARNIVORE**

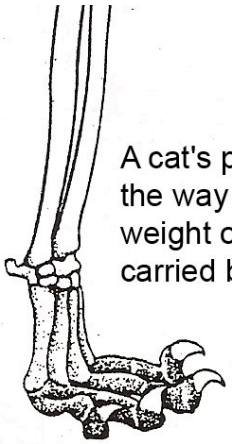
  Carnivores have full sets of teeth; canines, incisors, molars, premolars. With a carnivore skull (such as a cat), all the teeth are covered with enamel. The canines are long and pointed for stabbing and holding prey during capture. The incisors are small and used for snipping, but not for ripping off pieces of flesh. This is left to the premolar and molars; these teeth come together like scissors and form a shearing surface. The shape of molars may vary among carnivores. Those with a more omnivorous diet, such as bears or raccoons, will have the more rounded molars needed for chewing plant material.

  Feline species have reduced numbers of check teeth called "carnassials" that are sharp and grind against each other like scissors. Cats have short, flat skulls, tiny incisors and usually long, sharp canines. Cats are obligatory carnivores. Cats "guts" are much shorter than ours. They do not have the ability to fully digest and utilize the nutrients in plant material and they need taurine or they will go blind. Taurine is found primarily in the muscle meat of animals, and is most highly concentrated in the heart and liver.

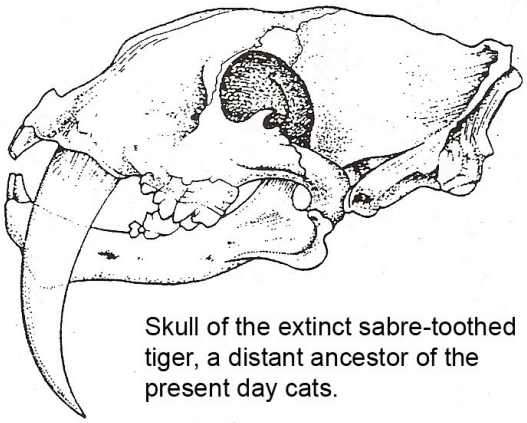
The two diagrams of the skull of a cat illustrate how wide the jaws can be opened when the cat kills its prey.



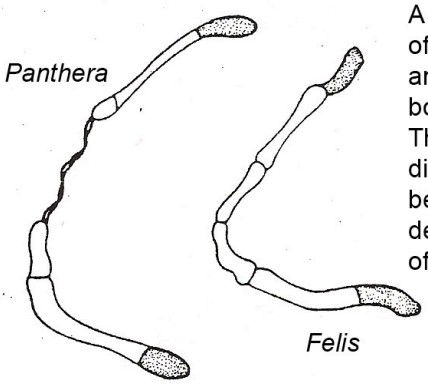




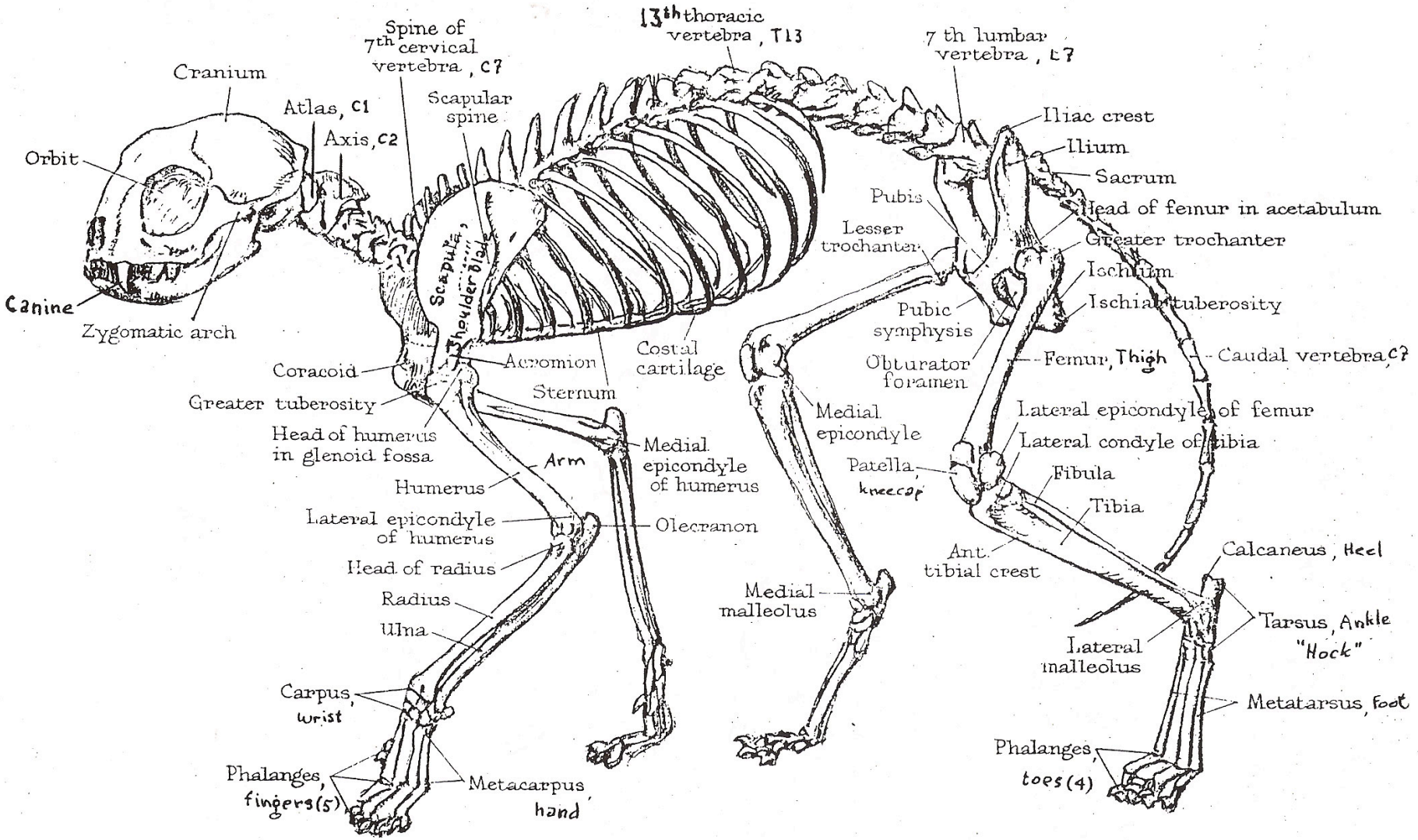
A cat's paw showing the way in which the weight of the body is carried by the digits.



Skull of the extinct sabre-toothed tiger, a distant ancestor of the present day cats.

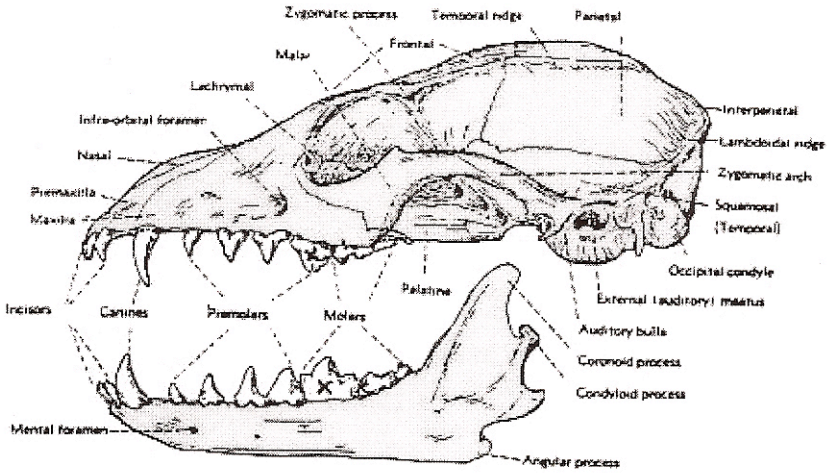


A partially ossified hyoid bone of a cat of the genus *Panthera* and a completely ossified hyoid bone of a cat of the genus *Felis*. The degree of ossification is a distinguishing characteristic between the two genera and determines the nature of the voice.



SKELETON OF THE DOMESTIC CAT (Felis catus), A TYPICAL CARNIVORE

Canine species typically have a long muzzle portion of the skull, many sharp molars/premolars, and relatively large incisors.

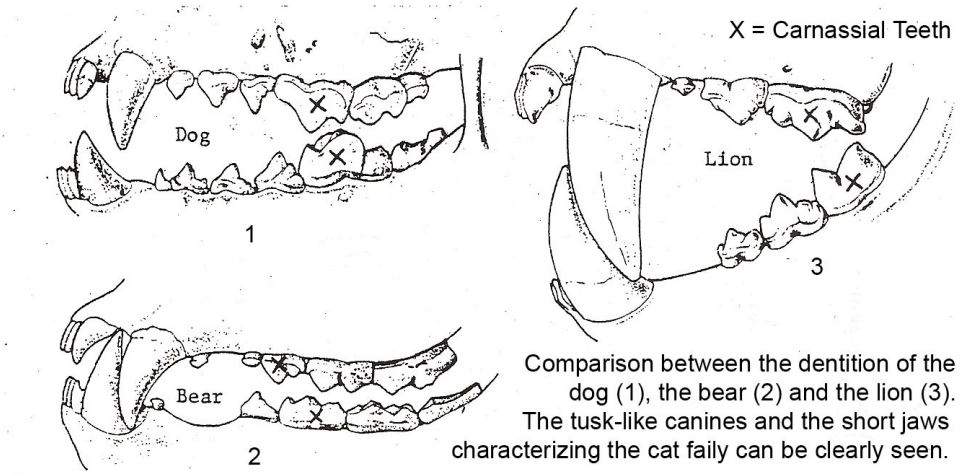


X = Carnassial Teeth

Side view of the skull of a Gray Fox (Carnivora), showing teeth and bones

Dental Formula: I3/3 - P4/4 - M2/3, total 42 (typical of Canidae)

Bear species usually have a longer muzzle like dogs but their premolars/molars are flattened due to their varied diet and they usually have a large opening where the nostrils are located as they use smell a great deal.



Comparison between the dentition of the dog (1), the bear (2) and the lion (3). The tusk-like canines and the short jaws characterizing the cat faily can be clearly seen.

Status and Conservation Outline for Biofact Carts/Bags

- **AZA** (Association of Zoos and Aquariums) - dedicated to the advancement of accredited zoos and aquariums in the areas of animal care, wildlife conservation, education, and science.
- **IUCN** (International Union for Conservation of Nature) - helps the world find practical solutions to critical environmental and developmental challenges. According to IUCN "Threatened" includes 3 categories: vulnerable, endangered, and critically endangered ("Threatened" and "Vulnerable" are often used interchangeably).
- **SSP** (Species Survival Plan) - helps ensure survival of selected wildlife species.
- **CITES** (Convention on International Trade in Endangered Species) - international agreement between governments to control trade of wild animals.

Note: In any of the following areas you may always discuss the ecological significance of each animal and the interdependence of species. The removal of a single species from the wild has vast impacts on many different organisms that are ultimately affected by a change in their intricately balanced ecosystem.

1. Lemur Cart
    A. Most species are endangered or threatened
    B. Many have gone extinct in the last few centuries
    C. Sharp population decline due to hunting, domesticating as pets, and habitat loss by deforestation
    D. Black lemurs killed b/c they raid crops
    E. Commercial exportation (esp. black and white ruffed lemur)
    F. Breeding programs are in place; complicated for most species
    G. Madagascar's low economy makes it difficult to help protect lemurs

2. Primate Cart
    A. All primates, except humans, listed as endangered
    B. Habitat destruction, human predation, medical research, pet trades
    C. Use of firearms has eliminated large populations of primates

        i. Gorilla
            - Listed as endangered
            - Habitat destruction, poaching, bushmeat trade
            - Hands used as "leather"
            - Great Ape Survival Project (UN based)
            - Gorilla Agreement - first treaty to conserve gorillas and their territory

        ii. Chimpanzee
            - Endangered
            - Habitat loss, hunting by humans (food and crop disturbances), research, HIV
            - Commercial exportation for animal trade (pets, entertainment)
            - Strict regulations for captive animals
            - African Conservation Foundation- conservation projects

iii. Orangutan
- Sumatran is critically endangered
- Habitat loss (logging, mining, forest fires, oil palm plantations)
- Excessively hunted, used as alternatives to headhunting
- Mothers killed in collection of young for exhibitions in zoos and circuses and pets
- Less than 9200 in the wild
- Several conservation centers in Indonesia and Malaysia

iv. Mandrill
- Classified as endangered by IUCN due to hunting (crop raiding), habitat loss, and food/prey decline
- Hunted as bushmeat, considered a delicacy to some natives
- Wildlife Conservation Society - 3 phase program began in 1998

3. Giraffe Cart
   A. Not endangered but wiped out of S. and W. Africa
   B. Largest population found in Tanzania and nearby areas
   C. Native Africans hunt giraffes for hides (shields), hair jewelry and bowstrings), and meat
   D. Habitat destruction (for firewood and livestock)

4. Bear Cart
   A. Polar Bear
      i. Considered threatened but not endangered
      ii. Pollution (sea ice melting = inability to find food, loss of habitat, bears drowning), hunting, industrial disturbances
      iii. Polar bears help control seal populations
      iv. 5 PB nations (Denmark, Canada, Norway, Russia, US) helping to control nuisance bears, provide alternatives for native peoples, and save bears from extinction

   B. Spectacled Bear
      i. Only surviving species native to S. America
      ii. Listed as threatened, less than 2000 in wild
      iii. Hunted as trophies by sportsmen and by locals to protect livestock
      iv. Gull Bladders used for Asian medicines (international market)
      v. In Peru, hunted for meat, skin, and fat
      vi. Loss of habitat by logging and farming

   C. Kodiak Bear
      i. Population greatly reduced due to hunting for fur, habitat destruction, and viewing
      ii. After sea and river otter populations declined, Kodiaks declined (bear hide comparable to sea/river otter pelt)
      iii. Fishermen saw as threat to salmon industry
      iv. Kodiak Bear Conservation and Management Plan - conservation of bear population at current level; education, and habitat protection in Archipelago

D. Grizzly Bear
    i. Threatened in the U.S. and endangered in Canada
    ii. Hunting bears for sport, predatory persecution, habitat loss (deforestation)
    iii. Killed by trains and cars
    iv. Once native to Asia and Europe
    v. Still legally shot for sport in Alaska and parts of Canada
    vi. Used to be found across U.S., now only in a few states
    vii. All national parks have bear protection laws

5. Feline Cart
    A. Tigers
        i. All tigers listed as endangered
        ii. Until recently, there were 8 subspecies, now 3 extinct and almost 4 (South China Tiger)
        iii. 6 living tiger species: Bengal, Indochinese, Malayan, Sumatran, Siberian, and South Chinese
        iv. Largest subspecies is the Siberian, smallest is the Sumatran, both are critically endangered (around 500 left of each)
        v. For Sumatran tigers, habitat destruction is central, then poaching
        vi. Sumatran Tiger Breeding Industry in Indonesia
        vii. Regional Captive Sumatran Tiger Master Plan (SSP) - breeding plan for AZA zoos
        viii. WCS Siberian Tiger Project

    B. Lion
        i. Classified as vulnerable, but Asiatic subspecies is critically endangered
        ii. Habitat loss, hunting, and poisoning by agriculture and livestock interests
        iii. Subspecies *P. leo leo* (Barbary Lion) numbers less than 200 in wild and 200 in captivity
        iv. Lions once roamed most of Africa and parts of Asia and Europe
        v. Now only parts of sub-Saharan Africa, except for small population of Asian lions living in India's Gir Forest
        vi. Included in SSP
        vii. Set up of National Parks and Game Reserves for lion protection

    C. Puma
        i. Near threatened but subspecies *P. concolor coryi* (Florida Panther) classified as endangered
        ii. *Coryi* is a subpopulation in Florida with only 50 individuals in the wild
        iii. Habitat loss, depletion of prey species, hunting (pest animal)
        iv. Also called cougar or mountain lion
        v. Pumas control the population of their prey
        vi. Illegal to kill a puma anywhere in the US

    D. Snow Leopard
        i. Endangered but numbers unknown
        ii. Hunted for fur, and bones used in Asian medicine
        iii. Leopards prey on domestic livestock in winter
        iv. Education and financial support for inhabitants to prevent leopard killings

6. Puente al Sur
    A. Capybara
        i. Not threatened
        ii. Hunted for meat, pelts, skin (used for leather), and grazing activity (seen as competition for livestock)
        iii. Management plan in Columbia and Venezuela for licensed ranchers

    B. Tapir
        i. All four species endangered or threatened (Baird's, Malayan, Mountain, Brazilian)
        ii. Deforestation is central
        iii. Technical developments
            - portable battery-operated lamps allow hunting at night
            - single-barrel guns that can fire both rifle and shotgun cartridges
        iv. Many predators - mountain lions, jaguars, humans
        v. Tapir Specialist Group (IUCN based) to save, restore, and manage the four species of tapir and their habitats
        vi. Baird's Tapir Project of Costa Rica -longest ongoing tapir project in the world, having started in 1994
        vii. April 27 - World Tapir Day to raise awareness

    C. Giant Anteater
        i. Listed as vulnerable
        ii. Human encroachment on their territory - cars, habitat destruction
        iii. Largest of all anteaters and only species of its genus
        iv. Hunted by humans, pumas, and jaguars
        v. CITES listed as Appendix II to control trade and avoid overuse

7. Magellanic Penguin Bag
    A. Oil drilling, air and water pollution, fishing industry
    B. Many natural predators for adults and chicks
    C. Loss of burrows during guano mining
    D. Not threatened, numbers are in the millions

8. Rhinoceros Cart
    A. Poaching
    B. Chinese medicines
    C. Black Rhino - Critically Endangered
    D. Greater One-horned Rhino - Vulnerable

The Comparative Anatomy Of Eating

Milton R. Mills, M.D. | 11/21/09 from VegSource.com

Humans are most often described as "omnivores." This classification is based on the "observation" that humans generally eat a wide variety of plant and animal foods. However, culture, custom and training are confounding variables when looking at human dietary practices. Thus, "observation" is not the best technique to use when trying to identify the most "natural" diet for humans. While most humans are clearly "behavioral" omnivores, the question still remains as to whether humans are anatomically suited for a diet that includes animal as well as plant foods.

A better and more objective technique is to look at human anatomy and physiology. Mammals are anatomically and physiologically adapted to procure and consume particular kinds of diets. (It is common practice when examining fossils of extinct mammals to examine anatomical features to deduce the animal's probable diet.) Therefore, we can look at mammalian carnivores, herbivores (plant-eaters) and omnivores to see which anatomical and physiological features are associated with each kind of diet. Then we can look at human anatomy and physiology to see in which group we belong.

Oral Cavity

Carnivores have a wide mouth opening in relation to their head size. This confers obvious advantages in developing the forces used in seizing, killing and dismembering prey. Facial musculature is reduced since these muscles would hinder a wide gape, and play no part in the animal's preparation of food for swallowing. In all mammalian carnivores, the jaw joint is a simple hinge joint lying in the same plane as the teeth. This type of joint is extremely stable and acts as the pivot point for the "lever arms" formed by the upper and lower jaws. The primary muscle used for operating the jaw in carnivores is the temporalis muscle. This muscle is so massive in carnivores that it accounts for most of the bulk of the sides of the head (when you pet a dog, you are petting its temporalis muscles). The "angle" of the mandible (lower jaw) in carnivores is small. This is because the muscles (masseter and pterygoids) that attach there are of minor importance in these animals. The lower jaw of carnivores cannot move forward, and has very limited side-to-side motion. When the jaw of a carnivore closes, the blade-shaped cheek molars slide past each other to give a slicing motion that is very effective for shearing meat off bone.

The teeth of a carnivore are discretely spaced so as not to trap stringy debris. The incisors are short, pointed and prong-like and are used for grasping and shredding. The canines are greatly elongated and dagger-like for stabbing, tearing and killing prey. The molars (carnassials) are flattened and triangular with jagged edges such that they function like serrated-edged blades. Because of the hinge-type joint, when a carnivore closes its jaw, the cheek teeth come together in a back-to-front fashion giving a smooth cutting motion like the blades on a pair of shears.

The saliva of carnivorous animals does not contain digestive enzymes. When eating, a mammalian carnivore gorges itself rapidly and does not chew its food. Since proteolytic (protein-digesting) enzymes cannot be liberated in the mouth due to the danger of autodigestion (damaging the oral cavity), carnivores do not need to mix their food with saliva; they simply bite off huge chunks of meat and swallow them whole.

According to evolutionary theory, the anatomical features consistent with an herbivorous diet represent a more recently derived condition than that of the carnivore. Herbivorous mammals have well-developed facial musculature, fleshy lips, a relatively small opening into the oral cavity and a thickened, muscular tongue. The lips aid in the movement of food into the mouth and, along with the facial (cheek) musculature and tongue, assist in the chewing of food. In herbivores, the

jaw joint has moved to position above the plane of the teeth. Although this type of joint is less stable than the hinge-type joint of the carnivore, it is much more mobile and allows the complex jaw motions needed when chewing plant foods. Additionally, this type of jaw joint allows the upper and lower cheek teeth to come together along the length of the jaw more or less at once when the mouth is closed in order to form grinding platforms. (This type of joint is so important to a plant-eating animal, that it is believed to have evolved at least 15 different times in various plant-eating mammalian species.) The angle of the mandible has expanded to provide a broad area of attachment for the well-developed masseter and pterygoid muscles (these are the major muscles of chewing in plant-eating animals). The temporalis muscle is small and of minor importance. The masseter and pterygoid muscles hold the mandible in a sling-like arrangement and swing the jaw from side-to-side. Accordingly, the lower jaw of plant-eating mammals has a pronounced sideways motion when eating. This lateral movement is necessary for the grinding motion of chewing.

The dentition of herbivores is quite varied depending on the kind of vegetation a particular species is adapted to eat. Although these animals differ in the types and numbers of teeth they posses, the various kinds of teeth when present, share common structural features. The incisors are broad, flattened and spade-like. Canines may be small as in horses, prominent as in hippos, pigs and some primates (these are thought to be used for defense) or absent altogether. The molars, in general, are squared and flattened on top to provide a grinding surface. The molars cannot vertically slide past one another in a shearing/slicing motion, but they do horizontally slide across one another to crush and grind. The surface features of the molars vary depending on the type of plant material the animal eats. The teeth of herbivorous animals are closely grouped so that the incisors form an efficient cropping/biting mechanism, and the upper and lower molars form extended platforms for crushing and grinding. The "walled-in" oral cavity has a lot of potential space that is realized during eating.

These animals carefully and methodically chew their food, pushing the food back and forth into the grinding teeth with the tongue and cheek muscles. This thorough process is necessary to mechanically disrupt plant cell walls in order to release the digestible intracellular contents and ensure thorough mixing of this material with their saliva. This is important because the saliva of plant-eating mammals often contains carbohydrate-digesting enzymes, which begin breaking down food molecules while the food is still in the mouth.

Stomach and Small Intestine

Striking differences between carnivores and herbivores are seen in these organs. Carnivores have a capacious simple (single-chambered) stomach. The stomach volume of a carnivore represents 60-70% of the total capacity of the digestive system. Because meat is relatively easily digested, their small intestines (where absorption of food molecules takes place) are short&151;about three to five or six times the body length. Since these animals average a kill only about once a week, a large stomach volume is advantageous because it allows the animals to quickly gorge themselves when eating, taking in as much meat as possible at one time which can then be digested later while resting. Additionally, the ability of the carnivore stomach to secrete hydrochloric acid is exceptional. Carnivores are able to keep their gastric pH down around 1-2 even with food present. This is necessary to facilitate protein breakdown and to kill the abundant dangerous bacteria often found in decaying flesh foods.

Because of the relative difficulty with which various kinds of plant foods are broken down (due to large amounts of indigestible fibers), herbivores have significantly longer and in some cases, far more elaborate guts than carnivores. Herbivorous animals that consume plants containing a high proportion of cellulose must "ferment" (digest by bacterial enzyme action) their food to obtain the nutrient value. They are classified as either "ruminants" (foregut fermenters) or

hindgut fermenters. The ruminants are the plant-eating animals with the celebrated multiple-chambered stomachs. Herbivorous animals that eat a diet of relatively soft vegetation do not need a multiple-chambered stomach. They typically have a simple stomach, and a long small intestine. These animals ferment the difficult-to-digest fibrous portions of their diets in their hindguts (colons). Many of these herbivores increase the sophistication and efficiency of their GI tracts by including carbohydrate-digesting enzymes in their saliva. A multiple-stomach fermentation process in an animal which consumed a diet of soft, pulpy vegetation would be energetically wasteful. Nutrients and calories would be consumed by the fermenting bacteria and protozoa before reaching the small intestine for absorption. The small intestine of plant-eating animals tends to be very long (greater than 10 times body length) to allow adequate time and space for absorption of the nutrients.

Colon

The large intestine (colon) of carnivores is simple and very short, as its only purposes are to absorb salt and water. It is approximately the same diameter as the small intestine and, consequently, has a limited capacity to function as a reservoir. The colon is short and non-pouched. The muscle is distributed throughout the wall, giving the colon a smooth cylindrical appearance. Although a bacterial population is present in the colon of carnivores, its activities are essentially putrefactive.

In herbivorous animals, the large intestine tends to be a highly specialized organ involved in water and electrolyte absorption, vitamin production and absorption, and/or fermentation of fibrous plant materials. The colons of herbivores are usually wider than their small intestine and are relatively long. In some plant-eating mammals, the colon has a pouched appearance due to the arrangement of the muscle fibers in the intestinal wall. Additionally, in some herbivores the cecum (the first section of the colon) is quite large and serves as the primary or accessory fermentation site.

What About Omnivores?

One would expect an omnivore to show anatomical features, which equip it to eat both animal and plant foods. According to evolutionary theory, carnivore gut structure is more primitive than herbivorous adaptations. Thus, an omnivore might be expected to be a carnivore, which shows some gastrointestinal tract adaptations to an herbivorous diet.

This is exactly the situation we find in the Bear, Raccoon and certain members of the Canine families. (This discussion will be limited to bears because they are, in general, representative of the anatomical omnivores.) Bears are classified as carnivores but are classic anatomical omnivores. Although they eat some animal foods, bears are primarily herbivorous with 70-80% of their diet comprised of plant foods. (The one exception is the Polar bear, which lives in the frozen, vegetation poor arctic and feeds primarily on seal blubber.) Bears cannot digest fibrous vegetation well, and therefore, are highly selective feeders. Their diet is dominated by primarily succulent lent herbage, tubers and berries. Many scientists believe the reason bears hibernate is because their chief food (succulent vegetation) not available in the cold northern winters. (Interestingly, Polar bears hibernate during the summer months when seals are unavailable.)

In general, bears exhibit anatomical features consistent with a carnivorous diet. The jaw joint of bears is in the same plane as the molar teeth. The temporalis muscle is massive, and the angle of the mandible is small corresponding to the limited role the pterygoid and masseter muscles play in operating the jaw. The small intestine is short (less than five times body length) like that of the pure carnivores, and the colon is simple, smooth and short. The most prominent

adaptation to an herbivorous diet in bears (and other "anatomical" omnivores) is the modification of their dentition. Bears retain the peg-like incisors, large canines and shearing premolars of a carnivore; but the molars have become squared with rounded cusps for crushing and grinding. Bears have not, however, adopted the flattened, blunt nails seen in most herbivores and retain the elongated, pointed claws of a carnivore.

An animal, which captures, kills and eats prey must have the physical equipment which makes predation practical and efficient. Since bears include significant amounts of meat in their diet, they must retain the anatomical features that permit them to capture and kill prey animals. Hence, bears have a jaw structure, musculature and dentition, which enable them to develop and apply the forces necessary to kill and dismember prey even though the majority of their diet is comprised of plant foods. Although an herbivore-style jaw joint (above the plane of the teeth) is a far more efficient joint for crushing and grinding vegetation and would potentially allow bears to exploit a wider range of plant foods in their diet, it is a much weaker joint than the hinge-style carnivore joint. The herbivore-style jaw joint is relatively easily dislocated and would not hold up well under the stresses of subduing struggling prey and/or crushing bones (nor would it allow the wide gape carnivores need). In the wild, an animal with a dislocated jaw would either soon starve to death or be eaten by something else and would, therefore, be selected against. A given species cannot adopt the weaker but more mobile and efficient herbivore-style joint until it has committed to an essentially plant-food diet test it risk jaw dislocation, death and ultimately, extinction.

What About Me?

The human gastrointestinal tract features the anatomical modifications consistent with an herbivorous diet. Humans have muscular lips and a small opening into the oral cavity. Many of the so-called "muscles of expression" are actually the muscles used in chewing. The muscular and agile tongue essential for eating, has adapted to use in speech and other things. The mandibular joint is flattened by a cartilaginous plate and is located well above the plane of the teeth. The temporalis muscle is reduced. The characteristic "square jaw" of adult males reflects the expanded angular process of the mandible and the enlarged masseter/pterygoid muscle group. The human mandible can move forward to engage the incisors, and side-to-side to crush and grind.

Human teeth are also similar to those found in other herbivores with the exception of the canines (the canines of some of the apes are elongated and are thought to be used for display and/or defense). Our teeth are rather large and usually abut against one another. The incisors are flat and spade-like, useful for peeling, snipping and biting relatively soft materials. The canines are neither serrated nor conical, but are flattened, blunt and small and function like incisors. The premolars and molars are squarish, flattened and nodular, and used for crushing, grinding and pulping noncoarse foods.

Human saliva contains the carbohydrate-digesting enzyme, salivary amylase. This enzyme is responsible for the majority of starch digestion. The esophagus is narrow and suited to small, soft balls of thoroughly chewed food. Eating quickly, attempting to swallow a large amount of food or swallowing fibrous and/or poorly chewed food (meat is the most frequent culprit) often results in choking in humans.

Man's stomach is single-chambered, but only moderately acidic. (Clinically, a person presenting with a gastric pH less than 4-5 when there is food in the stomach is cause for concern.) The stomach volume represents about 21-27% of the total volume of the human GI tract. The stomach serves as a mixing and storage chamber, mixing and liquefying ingested foodstuffs and regulating their entry into the small intestine. The human small intestine is long, averaging from 10 to 11 times the body length. (Our small intestine averages 22 to 30 feet in length. Human body size is measured from

the top of the head to end of the spine and averages between two to three feet in length in normal-sized individuals.)

The human colon demonstrates the pouched structure peculiar to herbivores. The distensible large intestine is larger in cross-section than the small intestine, and is relatively long. Man's colon is responsible for water and electrolyte absorption and vitamin production and absorption. There is also extensive bacterial fermentation of fibrous plant materials, with the production and absorption of significant amounts of food energy (volatile short-chain fatty acids) depending upon the fiber content of the diet. The extent to which the fermentation and absorption of metabolites takes place in the human colon has only recently begun to be investigated.

In conclusion, we see that human beings have the gastrointestinal tract structure of a "committed" herbivore. Humankind does not show the mixed structural features one expects and finds in anatomical omnivores such as bears and raccoons. Thus, from comparing the gastrointestinal tract of humans to that of carnivores, herbivores and omnivores we must conclude that humankind's GI tract is designed for a purely plant-food diet.

SUMMARY

Facial Muscles	
Carnivore	*Reduced to allow wide mouth gape*
Herbivore	*Well-developed*
Omnivore	*Reduced*
Human	*Well-developed*

Jaw Type	
Carnivore	*Angle not expanded*
Herbivore	*Expanded angle*
Omnivore	*Angle not expanded*
Human	*Expanded angle*

Jaw Joint Location	
Carnivore	*On same plane as molar teeth*
Herbivore	*Above the plane of the molars*
Omnivore	*On same plane as molar teeth*
Human	*Above the plane of the molars*

Jaw Motion	
Carnivore	*Shearing; minimal side-to-side motion*
Herbivore	*No shear; good side-to-side, front-to-back*
Omnivore	*Shearing; minimal side-to-side*
Human	*No shear; good side-to-side, front-to-back*

Major Jaw Muscles	
Carnivore	*Temporalis*
Herbivore	*Masseter and pterygoids*
Omnivore	*Temporalis*
Human	*Masseter and pterygoids*

Mouth Opening vs. Head Size	
Carnivore	*Large*
Herbivore	*Small*
Omnivore	*Large*
Human	*Small*

Teeth (Incisors)	
Carnivore	*Short and pointed*
Herbivore	*Broad, flattened and spade shaped*
Omnivore	*Short and pointed*
Human	*Broad, flattened and spade shaped*

Teeth (Canines)	
Carnivore	*Long, sharp and curved*
Herbivore	*Dull and short or long (for defense), or none*
Omnivore	*Long, sharp and curved*
Human	*Short and blunted*

Teeth (Molars)	
Carnivore	*Sharp, jagged and blade shaped*
Herbivore	*Flattened with cusps vs complex surface*
Omnivore	*Sharp blades and/or flattened*
Human	*Flattened with nodular cusps*

Chewing	
Carnivore	*None; swallows food whole*
Herbivore	*Extensive chewing necessary*
Omnivore	*Swallows food whole and/or simple crushing*
Human	*Extensive chewing necessary*

Saliva	
Carnivore	*No digestive enzymes*
Herbivore	*Carbohydrate digesting enzymes*
Omnivore	*No digestive enzymes*
Human	*Carbohydrate digesting enzymes*

Stomach Type	
Carnivore	*Simple*
Herbivore	*Simple or multiple chambers*
Omnivore	*Simple*
Human	*Simple*

Stomach Acidity	
Carnivore	*Less than or equal to pH 1 with food in stomach*
Herbivore	*pH 4 to 5 with food in stomach*
Omnivore	*Less than or equal to pH 1 with food in stomach*
Human	*pH 4 to 5 with food in stomach*

Stomach Capacity	
Carnivore	*60% to 70% of total volume of digestive tract*
Herbivore	*Less than 30% of total volume of digestive tract*
Omnivore	*60% to 70% of total volume of digestive tract*
Human	*21% to 27% of total volume of digestive tract*

Length of Small Intestine	
Carnivore	*3 to 6 times body length*
Herbivore	*10 to more than 12 times body length*
Omnivore	*4 to 6 times body length*
Human	*10 to 11 times body length*

Colon	
Carnivore	*Simple, short and smooth*
Herbivore	*Long, complex; may be sacculated*
Omnivore	*Simple, short and smooth*
Human	*Long, sacculated*

Liver	
Carnivore	*Can detoxify vitamin A*
Herbivore	*Cannot detoxify vitamin A*
Omnivore	*Can detoxify vitamin A*
Human	*Cannot detoxify vitamin A*

Kidney	
Carnivore	*Extremely concentrated urine*
Herbivore	*Moderately concentrated urine*
Omnivore	*Extremely concentrated urine*
Human	*Moderately concentrated urine*

Nails	
Carnivore	*Sharp claws*
Herbivore	*Flattened nails or blunt hooves*
Omnivore	*Sharp claws*
Human	*Flattened nails*