Characteristics of Mammals

How do we know it's a fish—what about an eel or an octopus? How do we know it's a reptile—what about a sea snake or a toad? How do we know it's a plant—what about moss or seaweed? Biota are classified into groups based on genetic similarity. As we focus on mammals we are looking at a group of animals that share several distinct characteristics. The mammal class came from a group of animals that became genetically distinct about 220 million years ago. Those nascent mammals developed and speciated into the roughly 4000-5000 different mammal species now living on earth. All modern mammals share some key traits that began with that small group of new mammals 220 million years ago (mya). In this essay we'll look at five of those distinguishing traits: **hair, heterodont teeth, mammary glands, placental vivipary and advanced nervous systems.**

Mammals are warm blooded—a better term is endothermic meaning that mammals create their body heat internally rather than by lying out in the sun as turtles do. However, endothermy is not unique—birds (class *aves*) are also endothermic. But mammals and birds have evolved different means of *retaining* that costly heat. Birds have feathers and down while mammals have ***hair***. Biologists consider hair to be the mammalian trait most responsible for their ascendancy. Were it not for hair, they might be a very insubstantial little group of biota that survives on the fringe of some niche [niche will be discussed more later but for now niche is an animal's habitat, their food supply and their predators]. But hair is invaluable. It allows them to stay warm after they eat. And if they are warm, they can move and hunt and breed even when it is icy cold outside. Mammals were alive when dinosaurs were still alive but the mammals were a small class with few species at the time. Dinosaurs were dominant. But even dinosaurs couldn't be active at night. The furry warm mammals could. At night, the primitive shrew-like first mammals could run over the head and jaw of the cold, lethargic dinosaur. So mammals were able to be active at night! This was something the ectotherms (aka cold blooded biota) could not do. The combination of endothermy wrapped in fur was a winning combination that allowed mammals to exploit the vacant niche of nighttime. Fur also allowed mammals to occupy cold niches like mountains or the far north. It is because of this ability to colonize the night and the north that biologists consider hair/fur the most valuable of mammals' traits.

Figure 1. The sea otter *Enhydra lutris* has the most dense fur in the animal kingdom. The dense undercoat and oily guard hairs retain warmth in their cold water habitat. The otter above is preening—a major behavior for an animal that depends on its fur for survival.

Hair is synonymous with fur. If an animal has layered fur it is referred to as the *pelage*. The pelage consists of the undercoat which is the short, downy layer close to the animal's body. Picture the fur on long haired dogs like the husky. They have white, think, downy fur close to their skin—that's the undercoat. The long gray and black fur are the guard hairs. Most mammals in the northwest do have the two-part pelage. The main function of the undercoat is thermoregulation. The outer layer of longer hairs constitute the guard hairs. These hairs protrude through the undercoat and keep it dry. Guard hairs are the pigmented element of the fur. Not all mammals have pelages—some dogs, for instance have only the guard hairs. And of course some mammals seem not to have hair at al. Some whales, for example, have hair only when they are very young.

A hair shaft is not a cell but rather a protrusion from a special hair-producing cell on the skin. Hair is made from a protein called keratin. Certain cells in the dermis produce a ropey strand of keratin. Hair or fur grows when hair cells receive the proper hormonal signal. Once the signal is received, the hair production is turned on and the cell begins to create keratin. Keratin is the same substance that makes nails, hooves, claws, feathers and other substances. The keratin is extruded from the cell and grows until the DNA stops receiving the "produce keratin" signal. In most whales, that signal is on for only a very short time after birth then the molecular signal shuts down. In human men, the hair growth signal is turned off when they begin balding. In winter and summer some animals have increased and decreased production of keratin/hair.

Hair are often specialized. The whiskers of cats are sensory as are the incredible vibrissae if seals. Porcupine quills are derived from modified hair cells. Horns of goats, sheep and pronghorn also originate from hair cells. Deer fur grown in the winter is hollow and holds heat while in the summer the hairs are thin and rod-like. Some animals pigment their fur in the non-winter months then shut off the pigment production in the snowy months. Some hares and weasels are brown in the summer and white in the winter.

Figure 2. Vibrissae on a California sea lion. These are incredibly sensitive and can recognize the turbulence pattern of specific fish!

Another mammalian trait again related to endothermy is ***heterodont teeth***. Before mammals evolved, the extant fauna had mouths full of teeth that were fairly similar to one another. They were homodonts. Heterodonts have teeth of different function and form. For piercing and killing there are canine teeth. For biting food into small manageable pieces are incisors. For crushing and biting are the pre-molars and for crushing and grinding are the molars. The relation between endothermy and heterodont teeth is fascinating. Fossils older than 220 mya didn't display heterodont teeth but somewhere around 220 mya animals began to appear that indeed had different kinds of teeth in their mouth. Why did teeth become specialized?

Figure 3. Crocodile homodont teeth. Note that all the teeth are similar.

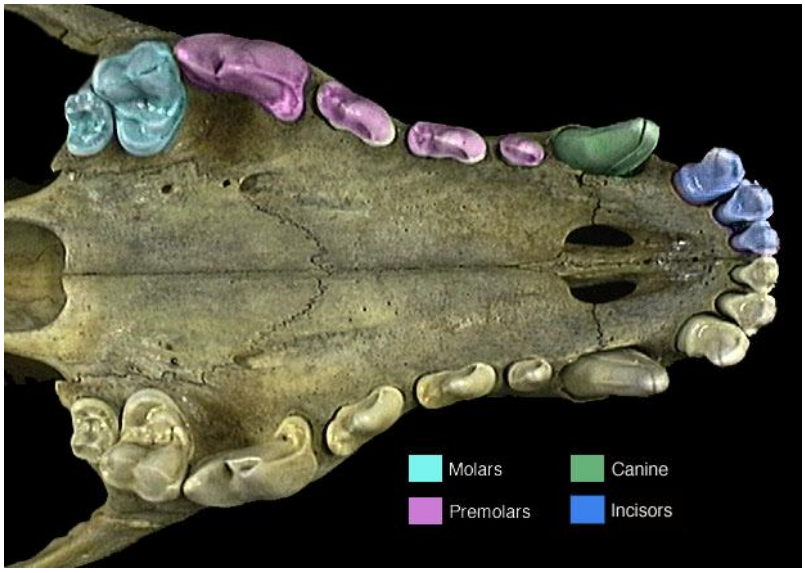

Figure 4 Heterodont teeth. Note the four types of teeth.

Why was the old homodont pattern insufficient for these newly evolved animals? What did they need that the homodonts struggled to deliver? Answer? These new animals needed more calories. They were warm blooded and needed to harvest all possible calories from their food. They benefitted from teeth that could efficiently extract every possible calorie from their food. The specialized teeth did just that—they were so efficient that they reduced the need for the animal to consume more food. Rather, they used what food they did consume more thoroughly than did their homodont neighbors. So when paleontologists noticed heterodonts they suspected that it was an important adaptation. In fact, heterodont teeth like fur was an adaptation that was necessary for the calorie demanding biology of an ectoderm.

Not all mammals have all four kinds of teeth. The two-toed anteater uses its tongue to gather food and no longer has teeth! Primitive shrews teeth seem almost like a homodont. Carnivorous mammals like coyotes have all four teeth types. Rodents have only the incisors and molars that their niche require (evolution if parsimonious and tends to discard unused elements).

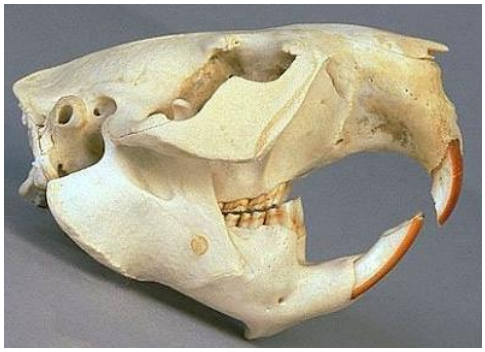

Figure 5. Beaver *Castor canadensis* have only incisors and molars.

A third trait and the one that gives the name to the class mammalia is the presence **of mammary glands**. As animals go, mammals are very glandular—sweat glands, scent glands, oil glands etc. But the foremost of these glands are mammary glands. These glands secrete a warm, nutritious, fatty food that perfectly matches the needs of the offspring. Other animals catch food and feed it to the babies or eat it and regurgitate it but mammals make their own perfect nutrition. Mammary glands are related to sweat glands. In most mammals they are inconspicuous until the mother begins nursing at which point they increase in size. Some mammals—whales—have glands and nipples concealed in a pocket. The primitive platypus has mammary

Figure 6. Coyote *Canis latrans* nursing babies.

glands but no nipples; the milk is extruded from a glandular patch of skin and runs down tufts of fur on the mother. The babies suckle the milk from the hair tufts! Evolutionarily speaking, the platypus is a primitive mammal. The platypus mammary glands are still similar to the sweat glands from which they evolved. Take a note here though. Sometimes when an animal is called primitive we think of it as inferior. Resist that conclusion. The platypus is primitive but it is also successful; they have been producing milk from those odd glands for 166 million years whereas humans females for instance, have only been making milk for two and a half million years. The platypus would argue that their primitive" adaptation is sufficient and "if it ain't broke, don't fix it." The platypus is primitive—or perhaps they would say "original"—in several ways including the fact that they lay eggs. For most mammals, live birth is a distinguishing trait of mammals.

Placental vivipary refers to animals whose young develop in the mother and are born live without an egg. Mammal embryos implant in the mother's placenta and develop there. Placenta is an organ that attaches to the uterus wall during gestation. In humans the placenta about the size of a thick pancake. It nestles up against the uterine wall on one side and on the other side, the umbilical cord leads away from the placenta and into the baby. The placenta transfers nutrients, wastes, O_2 and CO_2 between the mother's blood vessels and the baby's blood vessels. With placental mammals the gestation period is relatively long. The embryo remains in the mother and receives all it needs through the placenta. Placental development and live birth have several advantages for both mother and young. For mother, having the baby inside means mom isn't tied to a nest—she is free to roam for food or shelter. For the baby, the uterus offers a perfect temperature and constant protection for all elements. The placenta also delivers all the embryo needs—the perfect nutrition from mom, perfect levels of oxygen, perfect removal of cellular wastes—more than in other animal groups the placenta makes the baby a physiological extension of the mother. The arrangement is a successful way for mothers to ensure successful birthing of offspring.

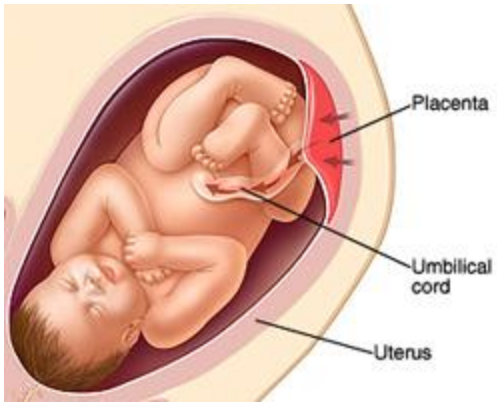

Figure 7. Human placenta is a 1 inch thick disc of tissue that transfers nutrition, oxygen and carbon dioxide between the mother and the embryo.

But of course, evolution is gradual and there are exceptions. The monotreme mammals lay eggs and don't have placenta or live birth! The pouched marsupials have a very rudimentary placenta and their gestation period is extremely short compared to their placental *eutherians (i.e. mammals with true placenta).* Placental vivipary has evolved independently in a few other animal groups including sharks and scorpions (Fascinating, I think!). So while it would not be perfectly accurate to say, "All mammals are distinguished by having placenta and live birth," it is nonetheless true that placental vivipary reaches its pinnacle in eutherians.

Advanced nervous system is a big term. It refers to an animal's ability to increase its cognitive and sensory functions. Yes it means that mammals are smart (a cognitive function) but it also includes the acute hearing prowess of bats (a sensory function) and the ability of wolves and whales to flourish with

group cooperation (a cognitive or emotion-bonding function). Humans often christen high cognitive function as the quintessential feature of all life but that position would be very hard to defend. Cockroaches—residents of planet earth for 166 million years—are mythical in their ability to survive and reproduce in diverse niches. Their success may be attributable to their superlative mating behavior or perhaps to their wide range of food sources but it certainly is not due to that esteemed trait of cognitive function. But though it may not be the champion of traits it is nonetheless an effective way to facilitate survival.

Humans, dolphins, chimpanzees, orangutans, elephants, pigs, canids, orca, rats and squirrels are prodigious in their ability to plan, problem solve and learn. Those cognitive abilities allow such "smart" (a subjective and debated term) animals to survive and reproduce. The killer whale is far too large to catch a fast agile salmon. But the whale knows the underwater rock formations and dead ends. Whales are known to herd salmon into dead-end rock formations and when the salmon reach the dead end and swim the other way, the whales are there agape! Bears are known for their ability to use their intelligence to exploit human food resources. Some mammals' nervous systems are adapted to establishing group behavior that facilitates survival. Such animals often make strong emotional attachments—one might say they have high emotional intelligence. Mammal's brains have a limbic system that is absent in earlier animal groups. The limbic system is the coordinated use of several brain structures (amygdala, hippocampus and others) that promote emotional function. The limbic system enables the emotional function that makes wolves such effective pack animals. It's the limbic system that promotes strong family ties in elk and whales and others. Other mammals that survive on group bonding and behavior include whales, horses, otter, elk, coyote and others. This means the part of the brain that can recognize social cues, that can expedite group cohesion and that can establish group roles, is very advanced.

Figure 9. Tool use by chimps.

Figure 8. Social behavior of wolves

Still other mammals display remarkable sensory acuity—and of course senses are neural based. The nonpareil hearing of the bat, the sensitivity of the wood rat's whiskers, the keen sense of smell in black bears, the nocturnal vision of several mammals all speak to a reliance on exceptional neural function. As a class, mammals demonstrate extraordinary advances in their neural function.

Figure 10. Acute hearing of bats.

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