Adaptation of Gestation or Egg-laying in Species Depends on the Amount of Internal Heat Generated in Digesting the Food

Karunakar Marasakatla
December 31, 2018
*Correspondence to: kmarasakatla@gmail.com

Abstract:
Anatomically and physiologically, the reproductive process of gestation or egg-laying, and dietary habits in vertebrates appear to be distinct processes. An in-depth analysis of the dietary habits of vertebrates reveals that the gestation or egg-laying characteristic in these species is tightly coupled with the digestive process. Once the food has been ingested, it is then broken down to the molecular level to be absorbed into the body. The amount of energy required to digest the food depends upon the amount and composition of the food material that was ingested. The denser (ex. bones and muscle) and bigger the size of the food bits ingested, the higher the amount of energy required to break down the material - that in turn requires higher amount of gastrointestinal acids. Where there is higher amount of energy is consumed, there will be an excess amount of heat gets generated. To protect the embryo from this heat, a layer develops around it. Therefore, it appears that the higher amount of heat generated in digesting the food results in egg-laying characteristic in species such as birds and reptiles, which ingest large chunks of raw meat. Rest of the vertebrates adapted to gestation due to chewing the food into small pieces before ingesting which generates less internal heat in digestion.

Key words: Dietary habits, Teeth, Chewing, Digestion, Gestation, Egg-laying.

This article has been posted on vixra.org preprint server.
Version: 1

Introduction:
Vertebrates are divided between mammals and non-mammals according to the way they tend to their newborn. A common characteristic of mammals, with few exceptions, is gestation by which they grow their embryos inside the womb. Non-mammal vertebrates lay eggs. As it is evident, there are few exceptions in mammals, like platypus and echidna lay eggs. However, an in-depth analysis of the dietary habits of the vertebrates reveal that these special cases no longer appears to be special. All the vertebrates, including the special cases, fall into two distinct groups that connect the dietary habits with the adaptation of gestation or egg-laying. It appears that the species that ingest small pieces of food adapted to gestation, and the other which intake large chunks of food, comparative to body size, adapted to egg-laying.

Analysis of dietary habits:
In this section, the dietary habits of vertebrates and their energy need in digesting the food after ingesting are analyzed. To categorize the dietary habits of vertebrates, a scale has been devised as shown in Table-1 based on the energy consumption in digesting a unit volume of food. Digestion is breaking down the food by gastrointestinal acids into the organic molecules for the consumption of body. For simplicity, it has been assumed that all the food ingested has been broken down into group of organic molecules in the digestion process. The process of digestion generates internal heat proportional to the amount of energy consumed in breaking down the food, which is proportional to the amount of gastrointestinal acids generated in the stomach.

Digestion:
Gastrointestinal acids + Piece of food = Group of Organic molecules + Internal Heat

It is important to note that small meal size comparative to the body generates less amount of internal heat per unit volume of the body excluding the limbs. Similarly large meal size comparative to the body generates large amount of internal heat per unit volume of the body.

Dietary Scale	Type of food	Energy requirements for digesting the food (Joules/m^3)	Internal heat generation
1	Liquid food such as nectar and honey; soft food such as squid and krill	Low	Low
2	Cooked food or vegetation chewed into small pieces	Low to medium	Low to medium
3	Whole seeds, insects, chewed raw meat	Medium	Medium
4	Chunks of raw meat, crushed bones	Medium to high	Medium to high
5	Bones and whole body consumption	High	High

Table-1: Dietary scale

In Table-2, the dietary habits of the birds and reptiles were analyzed. Table-3 describes the dietary habits of other vertebrates. Table-4 describes the dietary habits of the exceptional cases in vertebrates.

Species	Dietary habits	Dietary scale	Gestation/ Egg-laying
Sparrow	Small insects and seeds	3	Egg-laying
Parrot	Fruits and nuts	3	
Crow	Nuts and chunks of raw meat	3-4	Egg-laying
Fish	Whole body consumption of small fish comparative to their body	5	Egg-laying
Seagull	Seeds, Small fish and insects	3-5	Egg-laying
Eagle, Vulture	Chunks of raw meat, and whole body consumption of small prey	4-5	Egg-laying
Alligator	Chunks of raw meat and bones	4-5	Egg-laying
Snake	Whole body consumption of other vertebrates	5	Egg-laying
Lizards	Whole body consumption of insects	5	Egg-laying

Table-2: Dietary habits of birds and reptiles

In the absence of teeth to chew the food, birds and reptiles ingest pieces of food or whole body of the prey. As shown in Table-2, parrot and sparrow ingests whole seeds and pieces of fruit or insects. Because of their small body size, the amount of internal heat generated in digesting the food per unit volume will be large. Crow and eagle consume large pieces of raw meat, which requires large amount of gastrointestinal acids to digest the food. That in turn generates excessive amount of heat. Alligators, snakes and lizards ingest large amount of meal compared to their body size. Crocodiles have been observed to carry CO_2 to digestive system to generate excess gastrointestinal acids while digesting the food [1]. Therefore, digestion of large amount of food generates excessive amount of heat in reptiles. Excessive amount of internal heat coincides with the adaptation of egg-laying in birds and reptiles.

Species	Dietary habits	Dietary scale	Gestation/ Egg laying
Homo Sapiens	Cooked food or Nuts and Vegetation chewed into small pieces	2	Gestation
Cow	Vegetation chewed into small pieces	2	Gestation
Elephant	Leaves and small branches chewed into small pieces	2	Gestation
Bear	Honey and ants	1-3	Gestation
Lion	Chewed raw meat	3	Gestation
Dog	Chewed raw meat	3	Gestation
Hyena	Chewed or chunks of raw meat and crushed bones	3-4	Gestation

Dolphin	Small fish and pieces of raw meat	3	Gestation
Whale	Krill	1	Gestation
Bat	Honey, fruit pulp, crushed insects	1-2	Gestation

Table-3: Dietary habits of other vertebrates.

Rest of the vertebrates, with few exceptions, possesses the teeth to chew the food into small pieces before ingesting. Chewed food requires less amount of gastrointestinal acid to break down the material because of their small size. In turn, the process of digesting the food in these species generates less amount of internal heat. Small meal size and large body also reduces the amount of internal heat in digesting the food per unit volume of the body. As shown in Table-3, Homo sapiens ingest cooked and chewed food, which requires less amount of gastrointestinal acid to break down the material. Cow and elephant ingests the chewed vegetation. Due to their large body size, the amount of internal heat generated in digesting the food will be less per unit volume of the body. Bat consumes the food such as honey, fruit pulp and insects. Possession of teeth helps to break the food apart to make it easy to digest, comparative to eating nuts and whole insects. Therefore, it will generate less internal heat while digesting the food. This resulted in the adaptation of gestation in bats.

Whales don't possess teeth suitable for chewing or tearing down the food. Therefore it adapted to ingesting large amounts of krill, which is soft and easy to digest, that resulted in the adaptation of gestation in these species. Dolphins eat small fish and chunks of raw meat. Large number of teeth would have enabled the dolphin to crush the food into small pieces. Its stomach consists of three parts that facilitates efficient digestion of food. This enables less internal heat in digestion resulting in the adaptation of gestation in dolphins. Hyena appears to be an exceptional case in animals where they ingest excessive amount of crushed bones and chunks of raw meat. Does female hyenas avoid bones and chew only the meat at the time of gestation to avoid excess internal heat? It is also possible that their tolerance of internal heat is higher than other animals to support the gestation. In general, less amount of internal heat in this group of vertebrates due to the ingestion of soft or chewed food resulted in the adaptation of gestation.

Species	Dietary habits	Dietary scale	Gestation/ Egg-laying
Echidna	Whole body consumption of small vertebrates	5	Egg-laying
Platypus	Whole body consumption of small vertebrates	5	Egg-laying

Table-4: Dietary habits of the exceptional cases in vertebrates.

The general rule was that the placentals were considered as mammals and monotremes were considered as non-mammals. As shown in Table-4, some of the vertebrates didn't exactly fall under the general definition of mammals or non-mammals. Echidna and platypus were defined as mammals but anatomically they were monotremes. These two species ingest whole body of insects in the absence of teeth. Digesting large amount of insects generate excessive internal heat comparative to their body size. Therefore these two exceptional cases in mammals adapted to egg-laying.

Hypothesis:

Amount of energy consumed in digesting the food depends upon whether it is vegetation or meat, and how finely the food is chopped or chewed before consuming. Once the food is in the digestive tract, the amount of energy required to digest pieces of meat will be more than chewed vegetable products. At the same time, the amount of energy required would be more in digesting the whole animal compared to chopped or chewed pieces of meat. In the process, body generates the gastrointestinal acids in proportion to the meal size and strength of the food material. Gastrointestinal acids break the food material to organic molecular level for consumption. A byproduct of energy usage is generation of internal heat. As more and more energy is required to digest the food, more heat will be generated inside the body. It is important to note that the heat generated in chewing the food material doesn't add to the internal heat, instead it dissipates at head. Egg-laying or the gestation is the adaptation of species in protecting the embryo from the heat

generated in digesting the food. Species, which consume chunks of meat and whole body of prey, will generate more heat in digesting the food. As a result, these species adapted to egg-laying in the reproductive process to protect the embryo from the excessive internal heat. Species that ingest finely chopped or chewed food with small meal size requires less energy in digesting the food. In turn there will be less internal heat gets generated. These species adapted to gestation because of the conducive environment for prolonged nourishing of the embryo inside the womb.

Discussion:

After grazing the grass, cows spend lot of energy in chewing the regurgitated food to avoid excessive amount of gastrointestinal acid required to digest the food, therefore avoiding additional amount of internal heat. Heat generated in chewing the food gets dissipated at the head and doesn't add up to the internal heat. All known dinosaur species are egg-laying. Carnivore dinosaurs ingest large chunks meat, which resulted in the adaptation of egg-laying. Herbivore dinosaurs also adapted to egg-laying because of the possible absence of regurgitation to chew the vegetation into small pieces.

Molar teeth appear to be essential for species to adapt gestation. Molar teeth help in grinding the food into small pieces before entering into the digestive system, avoiding the excess generation of internal heat in digesting the food. In absence of molar teeth, whales adapted to eating soft material (krill) resulting in the gestation. Even though aardvarks have molar teeth, they were not efficient in chewing the food, therefore it adapted to eating only ants and termites, which were easy to chew before ingesting. This resulted in gestation in aardvark. Echidna has similar diet to aardvark but in the absence of molar teeth, echidna crushes the ants and termites before ingesting. This resulted in the adaption of egg-laying in echidna. Giant anteater has no teeth. Therefore it adapted to eating ants and termites similar to echidna. But it adapted to gestation instead of egg-laying. The giant anteater uses the formic acid of the prey to digest the food, which results in less internal heat compared to using gastrointestinal acids. This resulted in the adaptation of gestation in giant anteaters. Similar to giant anteaters, pangolins lack molar teeth and feed mostly on ants and termites. Its stomach contains inward pointing spines that enable crushing the food for efficient digestion. This enabled the pangolins to adapt gestation in the reproduction process.

Efficiency in melting the medullary bone to form the shell around the embryo in egg-laying species is possibly dependent on the amount of internal heat generated from digesting the food. Hard to digest food such as chunks of raw meat, insects, and nuts and seeds require more gastrointestinal acid to digest than the soft material, which in turn generate more internal heat. Higher efficiency in melting the medullary bone is possibly due to the higher amount of internal heat. A change in diet towards softer material possibly results in the lesser efficiency in melting the medullary bone.

It is also possible that the duration of gestation might also depend on the food as well. Soft food may result in prolonged gestation and hard to digest food might result in short gestation period. As the difficulty in digesting the food increases, species adopted to shortened gestation in the form of egg-laying. Marsupials gestation period range in few weeks. They might fall in the middle of egg-laying and gestation adaptation, where they generate medium internal heat in digesting the food.

Different species of sharks have been observed to exhibit various reproduction methods such as ovoviviparity, oviparity, and viviparity. Ovoviviparity is where the embryo in yolk sac hatches in the oviduct of the mother. Oviparity is where they lay the fertilized eggs in the water. Viviparity is where gestation occurs without using the yolk sac. Sharks posses teeth but they are not suited to break the food into small pieces. Therefore, they ingest small fish and large pieces of raw meat and bones. After digestion in initial chamber, they let through the soft material into rest of the digestive tract and discard rest of the material by vomiting. This reduces the need to digest hard materials such as bones. Sharks also vary in size from small to large with varying differences in the type of food they ingest. Body size and meal size variances might generate different levels of internal heat. This resulted in some species of sharks adapting to gestation and the other to egg-laying depending on the internal heat generated while digesting the food. Different species of frogs have also been observed to lay eggs or give birth to tadpoles [2]. Salamanders also appear to lay eggs and give birth to

tadpoles. The particular reproductive adaptation might be related to the type of food they ingest. All the insects are egg-laying species except the scorpion, which adapted ovoviviparity. Scorpions shred its prey into pieces using its claws and inject gastrointestinal acids into its prey. Then it intakes the resulting liquid food and discards rest of the hard material from its prey. By ingesting externally digested liquid food, it basically avoided the generation of internal heat, which helped it to adapt gestation.

The analysis presented in this article suggests that the difficulty in digesting the food determines the adaption of egg-laying or gestation in species. If the hypothesis presented in this article turned out to be true, it will pave the way for further study on the affect of internal heat in embryonic development.

Conclusion:
Even though the vertebrates were divided based on how they tend to their young ones after the birth, it is also possible to divide the vertebrates based on their dietary habits. Analysis of dietary habits of vertebrates strongly suggests that the these habits force the species to adapt egg-laying or gestation based on the internal heat generated while digesting a single meal. Birds and reptiles along with echidna and platypus adapted to egg-laying because of high amount internal heat generated while digesting the food. Rest of the vertebrates adapted to gestation because of less amount of heat generated while digesting the food. Therefore, the type and availability of food resource along with meal size and how finely food is broken down before ingesting are tightly coupled with reproductive process of egg-laying or gestation in the animal kingdom. You are what and how you eat.

Acknowledgements:
Author would like to thank Soumya Marasakatla for comments, discussion and editing the document.

References:
1. CG Farmer, TJ Uriona, DB Olsen, et al, (2008) The Right to Left Shunt of Crocodilians Serves Digestion. Physiological Biochemical Zoology, 81(2): 125-137.
2. DT Iskandar, BJ Evans, JA McGuire [2014] A Novel Reproductive Mode in Frogs: A New Species of Fanged Frog with Internal Fertilization and Birth of Tadpoles. PLoS ONE 9(12): e115884. Doi:10.1371/journal.pone.0115884.

Notes:
1. Anatomical structures, dietary habits and reproductive characteristics of the species listed in this article were gathered from online resources such as Wikipedia.org and Arkive.org.