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The Mammal with Heart

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“The Mammal with Heart” by Hannah Gaitan



Instructor’s Notes

All well-written texts incorporate appeals to pathos (emotions) as well as logos (logic). In this award winning essay, Hannah Gaitan effectively incorporates both into what could have been a solely logos driven, and thus, uninteresting, topic. After all, what is emotional about the circulatory system of a giraffe? Hannah shows her readers. Can you identify specific examples of pathos in this essay? How about specific examples of logos? Hannah also chose to include visuals in her essay. Why do you think she did so? What role do the visuals play? When might you choose to include visuals in a text of your own?

Writers’ Biography

Hannah Gaitan is a second-year Pre-veterinary Medicine major from Boulder, Colorado. Hannah enjoys scientific writing, specifically dealing with animals, but finds creative writing and poetry to be difficult. She spends most of her time, however, studying for her classes and gaining hands on experience in the field of veterinary medicine. Her hobbies include equestrian sports, running, and hiking. She also enjoys hanging out with her family, boyfriend, and black lab, Buddy.

The Mammal with Heart

The scene is an exotic African safari. The sun begins to set as excited tourists look out over the savannah. While looking out into the distance, the tourists spot a majestic giraffe leaning down to drink peacefully from a calm body of water. Then, to the surprise of all, as the magnificent creature raises its head from the water, it faints and collapses to the ground. This would be quite a sight! Of course, if one has ever seen a giraffe at the zoo or on a safari, he would notice that the giraffe does not, in fact, collapse dramatically onto the ground after it raises its head from drinking. However,

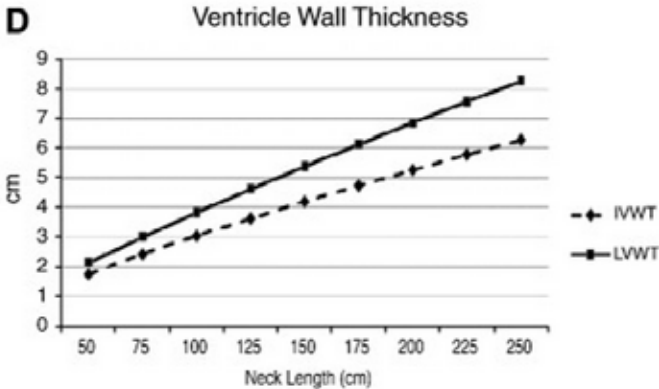
fainting is one of the many problems that could inhibit a giraffe if it did not possess the unique and perfectly designed circulatory system that it does. The giraffe towers over all the other mammals on earth. An average adult male can reach a height of eighteen feet; ten feet from the hoof to the shoulder and an additional eight feet coming from the length of the neck alone (Pitman, 2011). Due to the giraffe's extreme anatomical structure, its circulatory system must be uniquely designed. This essay explains the need for hypertension (high blood pressure) in the giraffe, the structure and size of the heart in the giraffe, and four unique mechanisms, located throughout the circulatory system, which prevent problems that occur as a result of hypertension.

The giraffe (*Giraffa Camelopardalis*) is the tallest mammal on earth. Since the giraffe's head ranges anywhere from eight to ten feet above its heart, its heart must pump extremely hard to supply the brain with the oxygen and nutrients it requires (Zhang, 2006). Therefore, compared to humans, giraffes have exceptionally high blood pressures (Zhang, 2006). The high blood pressure is referred to as hypertension. The average blood pressure is also commonly called arterial pressure. According to Ostergaard et al. (2011), giraffes have a mean arterial pressure (MAP) of 350 mmHg from the hoof to the brain and 250 mmHg from the heart to the brain. This is extremely high compared to the human MAP, which is roughly 100 mmHg. However, the "arterial pressure at the entrance to the skull is surprisingly similar to that of other mammals, including humans (approximately 100mmHg)" (Ostergaard et al., 2011, p. 691; Brondum, 2009; Hargens et al., 1987). The pressure of the blood entering into the brain is extremely low compared to the pressure it takes to send the blood from the hoof to the brain or from the heart to the brain. However, according to Zhang (2006), "The blood pressure would need to be higher than 205.6 mmHg for blood not only to reach the brain, but also to be able to perfuse the vascular bed and maintain normal function of the brain" (p. 64). Because of its remarkable height, the giraffe's heart must be strong enough to pump the blood a great distance in order to reach the brain at the proper pressure and supply it with oxygen and nutrients.

One may naturally assume that the giraffe's heart must be disproportionately large in order to overcome the force of gravity and carry the blood to the brain. However, that is not the case. It

was experimentally determined by Mitchell and Skinner (2009) that the giraffe's heart mass depends on the size of the giraffe. They dissected fifty-six giraffe hearts, weighed them, and compared the weight to the mass of the giraffe. They concluded that the heart's size is proportional to the weight of the giraffe. In the ten giraffe fetuses that they dissected, they found that the heart was larger than the body mass, but this is usually the case among all mammals (Mitchell & Skinner, 2009; Holt et al, 1968). Since the size of the giraffe's heart is not surprisingly big in proportion to its body, how does it supply the brain with the oxygen- and nutrient-rich blood it needs?

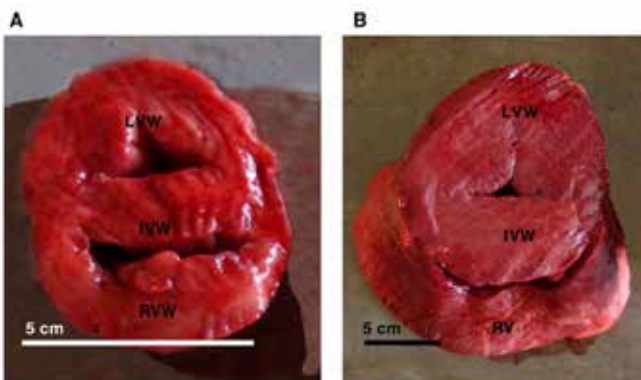
In order for the heart to pump the blood up the carotid artery to the brain, the heart must be strong enough and be able to overcome the hydrostatic, or pressure due to gravity (Zhang, 2006). However, the size of the heart does not determine its strength. Instead, it is the structure of the heart that determines its strength (Mitchell & Skinner, 2009). According to Mitchell and Skinner (2009), they found, experimentally, that the structure of the heart is determined by the neck length. The further the brain is away from the heart, the higher the blood pressure, thus the magnitude of hypertension in giraffes is dependent on the neck length (Mitchell & Skinner, 2009). The high blood pressure affects the thickness of the walls of the left ventricle of the heart. (Mitchell & Skinner, 2009). Therefore, the longer the neck, the more hypertrophy, or thickening, occurs in the left ventricle. The left ventricle is the lower left chamber in the heart that pumps blood to the entire body. Without the thickening and strengthening of this ventricle, the heart would not be able to pump a sufficient amount of blood to the brain or body of the giraffe (Mitchell & Skinner, 2009). The hypertrophy of this ventricle occurs because the ventricle must work exceptionally hard in order to pump the blood up the carotid artery to the brain of the giraffe. As the giraffe grows, the neck becomes longer and hypertrophy of the left ventricle increases. The graph below demonstrates this relationship between the neck length and the left ventricle wall thickness, where "LVWT" represents the left ventricle and the "IVWT" stands for interventricular wall thickness which is irrelevant to this study.



(Mitchel, Skinner, 2009, p. 526)

Hypertrophy of the left ventricle increases until full maturity is reached (Mitchel & Skinner, 2009). This was proven true by Mitchel and Skinner (2009) as they dissected the hearts and found that giraffes with longer necks possessed a left ventricle that was thicker. The picture below shows a cross section of a fetal giraffe's left ventricle, interventricular wall, and right ventricle (heart A) compared to the mature adults' (heart B). While looking at this picture, one will notice the increased hypertrophy in the left ventricle (labeled "LV") in the adult heart (B) compared to the fetal heart (A).

(Mitchel & Skinner, 2009, p.527)



According to Mitchel and Skinner (2009), "[Left ventricles] are massively hypertrophied in giraffes, a process [their] data show

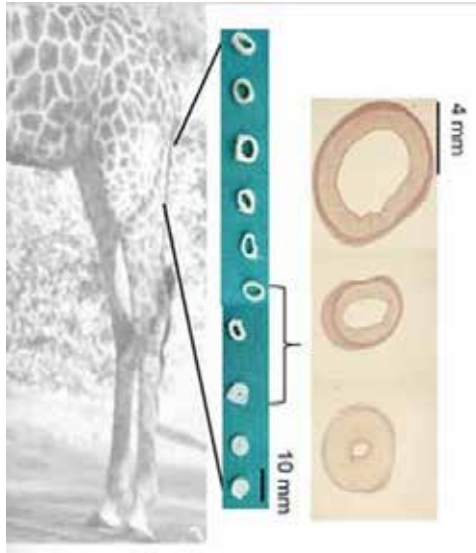
is gradual and starts after birth” (p. 526). After the giraffe is born, it experiences a continual growth in blood pressure as its neck becomes longer. Without the increase of hypertrophy of the left ventricle as the giraffe develops, it would not survive because its heart would not be strong enough to pump the blood to the brain. Although the giraffe’s heart is not surprisingly big for its body, the heart is extremely strong and is able to pump the blood to the brain.

The hypertension the giraffe needs to supply blood to the brain has the potential to cause multiple problems within the giraffe, however, there are four specific mechanisms that have been designed into its system that prevent these problems. The first of the four mechanisms are the jugular valves. The jugular vein is a large vein that returns blood to the heart from the head. When a giraffe lowers its head to take a drink of water, there is a possibility that blood could enter the jugular vein from the heart because of the high blood pressure. This must be prevented in order to keep the blood from flowing the opposite direction through the jugular vein and to maintain the cardiac output (the amount of blood pumped throughout the giraffe’s body) (Mitchell, Van Sittert & Skinner, 2009). Based on an experiment done by Mitchell, Van Sittert, and Skinner (2009), the jugular valves’ main function was indeed concluded “to direct the large amounts of blood, returning to the heart via the interior vena cava, into the right atrium, and to prevent its flow into the jugular vein” (p. 180). They also concluded that these valves develop during gestation. Giraffes have two jugular veins, right and left (Mitchell, Van Sittert & Skinner, 2009). During this experiment the jugular veins were opened and the number of valves and the position of valves were determined (Mitchell, Van Sittert & Skinner, 2009). It was discovered that the number of valves was of no significance. A long jugular vein could sometimes possess the same number of valves as a short vein (Mitchell, Van Sittert & Skinner, 2009). However, the position of the valves was found to be significant (Mitchell, Van Sittert & Skinner, 2009). According to Mitchell, Van Sittert, and Skinner (2009), while dissecting the jugular veins of twenty five adult giraffes and five fetal giraffes, they found a higher percentage of valves were located at the proximal end, close to the heart, than at the distal end, further from the heart. Four of the giraffes did not contain any valves at the distal segment of the jugular vein. According to Mitchell, Van Sittert, and Skinner

(2009), the fact that the jugular valves were found closer to the heart indicated that their primary function was to prevent “regurgitation of interior vena cava and right atrial blood into the jugular vein when the giraffe is in the head down position” (p. 179). As the giraffe lowers its head the valves close, and as the giraffe raises its head, returning to its original position, the valves reopen (Mitchell, Van Sittert & Skinner, 2009). The jugular valves, when closed, must withstand the hydrostatic pressure of the blood in the jugular vein and the pressure of venous blood that has already returned to the heart in order to be effective (Mitchell, Van Sittert & Skinner, 2009). The jugular valves do not develop with growth, but are in place during gestation. According to Mitchell, Van Sitter, and Skinner (2009), while dissecting the fetal giraffes, jugular valves were found to be present during gestation. This means that the valves do not develop as the neck elongates but are established before birth (Mitchell, Van Sittert & Skinner, 2009). If jugular valves were not present near the heart, then upon lowering the head blood from the heart would flow back into the jugular vein. Consequently, too much blood would flow back into the brain and not enough blood would remain in the heart to maintain a sufficient cardiac output.

The second mechanism that the giraffe possesses is a unique feature in its leg similar to the G-suit that fighter pilots wear. A G-suit is a specially designed suit that is worn by fighter pilots that places pressure on the legs and lower abdomen in order to keep the blood from pooling into their lower extremities when they begin to experience extreme forces. Giraffes have a built in “G-suit” that prevents leakages, due to hypertension, from capillaries in the giraffe’s legs (Khfahl, 1992). Based on an experiment performed by Ostergaard et al. (2011), the pressure exerted on the legs increases closer to the hoof. This is true because of the force of gravity. The maximum arterial pressure that was measured was 350mmHg (Ostergaard et al., 2011). Since there is an increase in pressure, the arterial lumen (the inside of the artery) knee adjusts by gradually narrowing toward the hoof (Ostergaard et al., 2011). The gradual narrowing of the arterial lumen happens two to four centimeters below the knee (Ostergaard et al., 2011). The picture below shows the site where the tissue can be located, and also displays the tissue which was surgically removed and stained to clearly show the

sudden narrowing that occurs in the arterial lumen about two to four centimeters below the knee.



(Ostergaard et al., 2011, p. 693)

This is the G-suit-like structure that giraffes contain in order to withstand the effects of hypertension. As found by dissecting the tibial arteries, Ostergaard et al. (2011) determined that the narrowing of the arterial lumen was found in the fetal giraffe as well. Indicating the giraffe is born with this feature, from the moment they stand up, they are able to adapt to the high blood pressure. The skin of the giraffe also thickens at the legs, preventing the capillaries from rupturing into the leg (Mitchel & Skinner, 2009). Without the drastic morphology of the arteries in the legs of giraffes and the increase in the thickness of the skin, the arterial pressure would be too great due to gravity, and the capillaries would burst causing blood to puddle in the hoofs (Ostergaard et al., 2011).

The third and fourth mechanisms that the giraffe possesses, in order to adjust to high blood pressure, are the rete mirabile and a special, complex series of mechanisms that restore the blood in the brain after the head is lifted (Pittman, 2011). These two mechanisms prevent the opposing problems of too much blood flow to the head and too little blood flow to the head. As the giraffe bends its long neck down to get a drink of water, the amount of blood flow to the

brain would cause the blood vessels in the brain and eyes to rupture if it were not for the rete mirabile or “marvelous net” (Pittman, 2011). According to Pittman (2011), “When the head is lowered, special shunts in the arteries supplying the head restrict blood flow to the brain, diverting it into a web of vessels” (p. 2). The marvelous net is a series of small blood vessels which form a web-like structure (Pittman, 2011). When the giraffe lowers its head to drink, the arteries direct the blood into special vessels which are elastic and keep the brain protected from an overflow of blood. The network of vessels near the base of the brain expands and allows the blood to enter the brain at a normal (100mmHg) arterial pressure (Pittman, 2011). The next mechanism is a “unique anastomosis [or connection] between the carotid and vertebral arteries” (Goetz, 1995; Lawrence, 1948 as qtd in Mitchell, Skinner, 2009, p. 523). This connection prevents fainting when a giraffe lifts its head (Mitchell, Skinner, 2009; Goetz, 1995; Lawrence, 1948). Mitchell and Skinner (2009) refer to Goetz (1957) by saying, “[the connection] directs carotid artery blood into the cerebral perfusion, and an increase in cerebral perfusion pressure [then results]” (p. 523). As the giraffe lifts its head, blood from the heart travels up the carotid artery which is connected to the blood vessels in the brain. The connection between the arteries then directs the blood to the cerebral perfusion, which is a series of blood vessels in the brain. The pressure of these vessels (cerebral perfusion pressure) then increases, and the blood is quickly restored to the brain (Mitchell & Skinner, 2009). Without the rete mirabile, as the giraffe lowers its head, the blood vessels in the head and eyes would burst. Similarly, without the special connection between the carotid and vertebral arteries the giraffe would lift its head up and then faint, due to lack of blood flow to the brain.

The circulatory system of the giraffe is a truly complex system which demands high blood pressure to provide the brain with a sufficient amount of blood, a specifically structured heart that has enough power to produce this pressure, and four mechanisms that allow the giraffe to function despite its high blood pressure. Now, imagine again, the group of tourists on the exotic African safari. They spot a giraffe lowering its head to get a drink of water. Now, when the giraffe raises its head from the drinking, one can appreciate the complexity of the circulatory system and all of the

steps it must successfully accomplish in order to keep a graceful, towering creature from collapsing.

Works Cited

Kofahl, R. (1992, March). Do drinking giraffes have headaches?. *Creation*, 14(2), 22-23. Retrieved from <http://creation.com/do-drinking-giraffes-have-headaches>

The article “Do drinking giraffes have headaches?” written by Robert E. Kofahl, Ph.D. summarizes the unique features that the giraffe’s body contains in order to cope with its high blood pressure. The author discusses the powerful heart of the giraffe and the features that allow the giraffe to bend over and take a drink without the heart pumping too much blood into the brain. Kofahl then discusses the importance of the giraffe spreading its legs and lowering its heart to drink water. He then explains the importance of the jugular valves located in the neck that open and close to allow and prevent blood flow. In this article he discusses the spongy tissue that is located under the brain that controls the blood flow to the brain. Then Kofahl discusses the importance of the counter-pressure mechanisms that prevent leakage of blood from the capillaries. The perfectly designed features that allow the giraffe to bend its head to drink water are presented clearly and simply in this article. I will be able to use this article to give an overall summary of the circulatory system of the giraffe and be able to explain its important adaptation that takes place when the giraffe lowers its head to drink.

Mitchell, G., & Skinner, J. D. (2009). An allometric analysis of the giraffe cardiovascular system. *Comparative Biochemistry & Physiology Part A: Molecular & Integrative Physiology*, 154(4), 523-529.

This scholarly article was written by G. Mitchell and J.D. Skinner who work at the Centre for Veterinarian Wildlife Studies in South America and The Department of Zoology

and Physiology at the University of Wyoming. The authors present data found by their calculations in the form of charts and graphs that compare the blood pressure and wall thickness of the ventricles to the mass and length of the giraffe's body and neck. The data was retrieved from previously derived allometric equations. They also discuss three hypothesis for why giraffes have high blood pressure. Mitchel and Skinner give explanations and average quantitative data of the cardiac hypertrophy, stroke volume, heart rate, and cardiac output that occurs in adult giraffes. This is invaluable information about the overall cardiovascular system in giraffes. This accurate, well written, scientific article will help me explain the anatomy of the circulatory system in giraffes and how the circulatory system functions uniquely with the giraffe's long neck.

Mitchell, G., Van Sittert, S., & Skinner, J. (2009). The structure and function of giraffe jugular vein valves. *South African Journal of Wildlife Research*, 39(2), 175-180.

This article was written by Graham Mitchel, Sybrand J. Van Sittert, and John D. Skinner. The authors are either faculty on the veterinarian staff or work in the Zoology and Physiology Department of the University of Wyoming or the University of Pretoria. This article discusses the anatomy of the jugular vein in the giraffe. They conducted an experiment which consisted of the dissection of the jugular veins of twenty five juvenile to adult giraffes and five fetal giraffes. Mitchel, Van Sittert, and Skinner discuss the results and come to a conclusion about the importance of location and anatomy of the valves located in the jugular vein in giraffes. The authors discuss the problem of blood re-entering the cranial veins and how it is prevented. They explain the anatomy of the uniquely designed jugular vein and valve placement that make the giraffe able to bend without blood regurgitating into the brain. This well-developed experiment and accurate, scholarly information will be helpful in explaining the anatomy of

the valve system and its important role in the giraffe's circulatory system.

Ostergaard, K., Bertelsen, M., Brondum, E., Aalkjaer, C., Hasenkam, J., Smerup, M., ... Baandrup, U. (2011). Pressure profile and morphology of the arteries along the giraffe. *Journal Of Comparative Physiology*, 181(5), 691-698.

This Scholarly article was written by Ostergaard K. et al. The authors measured the arterial and venous pressure in the foreleg of the giraffe. They also measured the area of the arterial lumen in the hind leg and found that it was suddenly narrowed below the knee of the giraffe. The tissue was collected from ten euthanized giraffes and the pressure was measured from four giraffes under local anesthesia. The data was expressed in the form of pictures and graphs that displayed the pressure related to the distance from the hoof. Ostergaard KH et al discussed the morphology they found in the arteries from the knee down. They also explained the importance of high blood pressure in giraffes and the morphology that takes place in the arteries below the knee due to the hypertension in the giraffe. The authors also measured the elastin in the arteries and provided the data in the form of a chart that related the volume fraction of elastin with the distance from the heart. This well conducted, well explained, and accurate experiment will help me explain the unique built in "G-suit" with which the giraffe is born and the importance of the morphology in the arteries to adjust to the high blood pressure.

Pitman, D. (2011, October). Giraffes: Walking tall by design. *Creation*, 33(4), 28-31. Retrieved from <http://creation.com/giraffe-neck-design>

The article "Walking Tall...by Design" was written by David Pitman and appeared in the magazine *Creation* on October 2011. Pitman summarizes the anatomical features that make the giraffe unique compared to other mammals. He discusses the circulatory system and the design it

has to prevent the giraffe from fainting when raising its head. In particular, he discusses the jugular valve system and the spongy membrane that is located below the brain. Pitman concludes this section by discussing the rapid response of these mechanisms that enable the giraffe to quickly raise its head when danger is evident. He also explains the thickness in the giraffe's leg skin that prevents the giraffe from losing too much blood when it is injured. This article is short and clearly highlights the special features of the circulatory system of a giraffe. I will be able to use this article to give a brief overview of the anatomy and functions of the giraffe's circulatory system and how the system prevents certain expected problems.

Zhang, Q. (2006). Hypertension and counter-hypertension mechanisms in giraffes. *Cardiovascular & Hematological Disorders Drug Targets*, 6(1), 63-67.

This article, written by Qiong Gus Zhang, discusses the high blood pressure in giraffes and how the organs within the giraffe adapt to the hypertension. He uses former research and mathematical equations to prove that giraffes do indeed have a higher blood pressure than humans. He then calculates average blood pressure in giraffes. Zhang also explains that giraffes must have a higher blood pressure in order to supply the brain with oxygen and nutrients due to their exceptionally long necks. The author discusses the negative side effects of hypertension that result in humans and then explains how the giraffe's body counteracts these. He specifically discusses the hypertrophy, or thickening, of the heart and in particular the left ventricle, and the kidney's normal function despite its location near the heart. This article was printed in a scientific journal, and the author Qiong Gus Zhang works at the California Institute of Technology. I found this article to be very helpful because it gave a good summary of other previously discovered data. This article will be used to help me explain the importance of hypertension in giraffes and how the organs are designed to handle it.