

“The Soul Made Flesh”: Introduction to the Nervous System

by Michelle Stanley

OVERVIEW

The purpose of this module is to introduce the nervous system in its original historical and cultural context, particularly how Thomas Willis went from a heart-centered view to a brain-centered view of emotions in the 1600s.

To orient students, this module begins with the case of Lady Ann Conway in the 1600s. This case demonstrates the importance of class and gender in the ability to study science at that time. It also introduces the notion of correspondence and debate for furthering knowledge, as well as introducing how theological and philosophical ideas might influence our scientific approaches to interpreting thought and emotion.

A short introduction of the circulatory system is included for the understanding of Willis’s perspective as he began to look at the brain and nervous system. The introduction of the circulatory system discusses the heart-centered view based on the work of William Harvey.

This module presents the political and social culture of the 1600s which gave Willis an opportunity to study illness by creating an environment filled with death and disease. It also presents the intellectual culture of the Oxford Circle and how members of the Oxford Circle worked together on projects, and created the instruments and techniques that aided in Willis’s work.

Two labs are included for exploring the anatomy of the brains belonging to different animals. The objective of the labs is to compare and contrast the different anatomy of the brains and relate that to knowledge of the animal’s behavior and intellect. This gives students an opportunity to think both critically and analytically about the relationships between anatomy and neurology.

Questions throughout stimulate the student to think critically in scientific matters and to address the important points introduced in this module.

Introduction: the Case of Lady Conway

Lady Ann Conway who was the wife of the Secretary of State to King Charles II, and one of the noblest women in England during the 1600’s. When Conway was 12 years old she suffered a fever which resulted in a lifetime of migraine headaches that grew so bad by the time she was in her twenties that she would vomit and have to stay in her darkened room for days. Her headaches continued to worsen. Lady Conway bore one child whom contracted smallpox at age two and died. Conway also contracted the illness and was in so much pain from the illness and headaches that she didn’t know where it began or where it ended. The headaches turned in to one long unrelenting headache.

Conway's story runs deeper than her illness. Conway was an intelligent woman who wasn't permitted to attend college because of her sex. Despite her illness and her sex she was able to self-educate herself in the liberal arts, literature, Latin and French by the age of 20. During her twenties she taught herself Greek and read Euclid. She corresponded with her brother John who was a student in Cambridge to stay abreast with the latest ideas. Through her brother John she began to correspond with Henry More, John's mentor.

Henry More believed the immaterial soul occupied the body and continued to live with a community of souls once the body died and that the soul occupied space but could change shape and penetrate material objects. During the 1600's the question of the soul was a hot topic. Conway was particularly interested in learning about the nature of the soul, possibly as a way for her to understand the nature of herself and her pain. Conway believed that the soul was a union with the entire universe.

Conway became well respected as a thinker. She invited Henry More and other philosophers and theologians to her residence to discuss the ideas pertaining to the nature of matter, souls, and God. Henry More "dedicated his book, *An Antidote Against Atheism*, to her, writing that 'you have not only outgone all of your own sex, even of the other also, whose ages have not given them over-much the start of you'" (Zimmer p.192). Her father also believed she rivaled men by stating that she wrote like a man. Conway was an exceptional woman of the 1600's where the common belief was that women were too weak minded to discuss the issues Conway was interested in.

1. What do you think were important contributing factors to Conway's self-education?

Ann's social class gave her opportunity, possibly exposing her to educated people, books, and resources to obtain materials needed for educating herself. Her class also put her in a position which gave her opportunity for gaining the respect she needed in order for men to discuss issues of philosophy and theology with her.

It is significant that Conway was interested in philosophy and theology because later on we are going to talk about one of Conway's physicians, Thomas Willis. Willis believed the soul could be found in the brain and spent his life exploring this. He believed that by understanding the nature of the soul, it would be possible to find the nature of the headaches and possibly cure them.

Discussion and correspondence were essential in facilitating ideas and knowledge in the 1600's. With many thinkers, gathered together in societies sharing ideas, theories could develop, blossom, diverge, or be disproved. Support and criticism drove motivation as the people worked hard to find ways to prove their theories, support others theories, as well as disprove theory's they didn't like.

With such a different culture than what we know today, it should be of little surprise that medical practices were also different.

2. What do you think causes migraines? Do you know any modern day treatments of migraine headaches? How successful are they?

3. Imagine yourself in the 1600s. What alternative treatments might you explore as a patient or a doctor?

Conway's first doctor was William Harvey who we will talk about more when we talk about the circulatory system. Conway found that Harvey was little help to her, showing a lack of interest to her afflictions due to his own illness. Physicians she had after Harvey gave her opium, put plasters of lead and soap on her head, gave her drops of mercury that nearly killed her, put drops of water on her head, and tried medicines like tobacco and coffee. Conway traveled to France to have her brain drilled but changed her mind and instead allowed the physician to bleed her jugular vein. Boyle gave her essence of copper twice and Valentine Greatrakes, perfumed with flowers, held her hand for days. None of these physicians were able to ease her pains. Willis became her physician but couldn't help either so Conway quit seeking treatment for four years until she summonsed Franciscus Mercurius von Helmont who showed Conway how to deal with the pain instead of cure it. She finally had a small amount of relief for a short time under his care.

4. Why do you think physicians used the treatments they did? Or how do you think they come up with their treatments?
5. Do you think people of higher social standings with money had an advantage over poor people who couldn't afford medical treatment?
6. What did you find interesting about Conway's story?

Harvey and the Circulatory System

As we have seen, one of the questions of interest in the 1600's pertained to how humans are governed and where their physical and emotional feelings come from. Willis was interested in showing that humans are governed by their brain instead of the more commonly held belief that these things come from the heart.

7. Have you heard that the heart is the center of feelings, possibly where the soul resides? What evidence supports this idea?
Note also such things as?...:
 - hearts as expressions of "love" on Valentine's day, in tattoos, etc.
 - our expressions: "being heartsick," "breaking someone's heart", "heartfelt" sympathies
 - getting in a "heated" argument, being "all steamed up" in anger
 - Harvey's observation that patients seemed to die of grief (shortly after losing a loved one, having exhibiting profound sadness before becoming ill); or that anxiety, envy and love can lead to ill health (ch. 15)
 - the racing and pounding of the heartbeat when one is emotionally excited

Where do you think we "feel" feelings? How do we come to such conclusions?

William Harvey was the physician to Charles I in the 1500's. He was an avid dissector of animals so most of his theories on the heart and circulatory system come from the anatomy of the animals he dissected. Because he didn't dissect humans some of his information has errors when pertaining to human anatomy; even so, Harvey was able to accurately paint a vivid picture of the system and its workings.

Harvey believed everything vital was carried in the blood and that the heart and blood were most essential for life. He based his beliefs upon observations such as how living creatures contain heat and color which are lost upon death. He believed blood received heat and spirits in the heart and then traveled to the extremities. In the extremities the blood lost its heat and spirits so the heart would draw the blood back to it to be revitalized. He believed the heart was important for digesting and distributing nourishment because it fed itself with blood as well as the rest of the body via arteries (Harvey, chapter 15.)

-----Show a diagram of circulatory system

*show how blood circulates

*discuss the experiments and observations of Harvey pertaining to circulatory system note how Harvey believed the heart cooled blood and hadn't discovered the function of the lungs or find the capillaries (Harvey could be looked at. Experiment on page 44. Chapter 17 on the heart).

*Discuss Boyles pump and the importance of air pertaining to life with examples of the experiments with animals in the pump (Zimmer p159-161).

*Discuss Hooke and Lower's experiments with dogs. These experiments included injections into a dog's heart showing the flow of blood. They discovered how there isn't a way for the fluid to enter the chambers via the vesicles, discrediting the idea that the heart is where blood is nourished with spirits. They also showed how the chambers didn't need blood in order to pump. More experiments displayed how even a small nick to the lung would cause a dog to stop breathing and how blood doesn't change color because of something in the heart, rather it is from something in the air (Zimmer, p212-213).

8. Why might Harvey have believed that the heart was important to cool the blood?
9. It may seem obvious that the lungs are important for blood to receive oxygen. Why do you think this is something people didn't realize in the 1500 and 1600's?

Willis and the Nervous System

Harvey wrote "the heart of animals is the foundation of their lives, the sovereign of everything within them, the sun of the microcosm, that upon which all growth depends, from which all power proceeds" (Zimmer, p70). The heart and blood are essential for life; however we will see how the work of Willis and other scientist in the 1600's helped to facilitate the change from the heart-centered view to the brain-centered view.

The 1600's were a turbulent time in England. King Charles was an arrogant leader who was incapable of working with parliament. He believed his royalty made him

supreme and above negotiating with council. Citizens were unhappy and Charles angered them by requiring all the coastal cities to build boats for the army or contribute money. Soon he was requiring the inland towns to give money. Angering citizens and parliament further he required the Scottish churches to teach from the *Book of Common Prayer*.

During this same time Bishop William Laud was Chancellor of Oxford and enforced strict control for “producing loyal priests to preach the authority of God and King” (Zimmer p.47). An angry parliament imprisoned Laud and in 1642 Charles declared war and headed to Oxford bringing typhus infected soldiers. Willis was forced to abandon school at Oxford and return home to care for his siblings when his parents died from the illness. After only a couple years Willis decided to return to Oxford as a soldier. Upon his return Willis encountered a changed city. “Charles had turned it into a fortress, with dams to flood the surrounding meadows and a giant earthen wall along its northern boundary, all built by the town on his orders....The few students remaining at the university were pushed into a ‘dark, nasty room’ in New College.the rest of the university was taken over by the army. The school of law was filled with supplies of corn and cheese, the school of astronomy with soldiers’ uniforms, the school of rhetoric with rope bridges. Cannon were hauled up into the highest rooms, and the lead roofs off the chapels were torn off and melted down for bullets” (Zimmer, p.62).

The town grew with seven thousand soldiers, the royal court with their families and cooks, as well as the artisans, musicians, astrologers, and actors seeking refuge. After a fire broke out, burning a sixth of the city, rats began to multiply spreading plague. Once a healthy and beautiful city, Oxford became sick as corpses were left out for days. John Taylor wrote a poem describing the Thames.

*“Dead hogs, dogs, cats, and well-flayed carrion horses
Their noisome corpses soiled the water sources;
Both swines’ and stable dung, beasts’ guts and garbage
Street dirt, with gardeners’ weeds and rotten herbage.
And from this water’s filthy putrefaction, our meat and
drink were made, which bred infection.”* (Zimmer p63).

10. What do you think could be learned about the brain by living in an unhealthy city such as Oxford?

With death and disease everywhere Willis began to write down case-history’s of his patients. He was able to make distinctions between fevers caused by different diseases. He wondered if the cause of the fevers had to do with something bad in the patient’s blood that caused the blood to heat up. He published a book about fevers in 1659. Willis, born a poor servitor who once had to work for Mr. and Mrs. Iles in order to attend the university, was now becoming a highly respected and sought after physician. (Class system consisted of fellow, fellow commoners, scholars, commoners, and lastly servitors.) With so many patients Willis searched for the cause of fevers, migraines, seizures, and stupidity and believed that the answers could be found with-in the body.

11. Suppose now that you are there in the 1600s. How might you begin to explore these illnesses?

With the reputation Willis gained for publishing his book on fevers, he was able to convince families of his deceased patients to see the importance of dissection. Many families granted Willis permission to dissect their deceased, trusting Willis would look for the cause of the illness. Before this, most dissections had been on executed criminals. This new opportunity for Willis was significant for two reasons. Firstly, Willis was able to dissect many body's which advanced his knowledge greatly. Secondly, the knowledge Willis gained by dissecting humans of all class levels would be more valuable to the people because they would see the observations pertaining to regular people and not only the possible defective criminals.

COMPARATIVE ANATOMY LAB

LAB COMPARING MASS OF BRAINS WITH RELATION TO MASS OF BODY OF DIFFERENT ANIMALS

Willis was motivated by religious beliefs to study the brain. He believed it was important for humans to keep their intellect up until death so he wanted to do everything he could to help his patients do this. He dissected and studied the brains of many humans and animals in order to make links between anatomy and intelligence and in order to discover reasons for the symptoms of many different illnesses. Some problems Willis encountered during his dissections included damaging the brain tissue before it could be studied. Brain tissue is soft and easily distorted and destroyed even with gentle manipulation. Brain tissue also decays quickly giving Willis very little time for studying it.

When it was discovered that alcohol could be used for preserving the brains and changing the texture of their tissue, Willis was able to take more time with his dissections and clearly see that the brain is composed of three distinct parts, the medulla oblongata, cerebellum, and medulla. The cerebrum covered the cerebellum and medulla. He was able to see this because he could cut into the tissue without damaging it.

Wren and Hook made a microscope that Willis used to examine the structure of nerves. He was able to see the vast networks of nerves that led into every muscle and organs where they branched into finer and finer networks.

Another important technique newly developed by Wren was injections. "He and Lower open a dog's skull and injected ink and saffron into one of the two carotid arteries that supplied the dog's brain with blood. They watched the blood carry the dark stain into its brain. A vast network of fine vessels appeared before their eyes, covering the entire brain" (Zimmer p.176). They saw that the four arteries that supplied the brain branched out and joined each other in a circle at the base of the brain before entering the brain itself. This is commonly referred to the Circle of Willis.

Willis and Wren did more experiments with dogs. In one experiment they injected dye into one of the carotid arteries and saw how the dye stained the entire brain. In another experiment they tied off three of the four arteries leading to the brain in a dog.

12. Do you think these are good experiments? What can be learned by performing these experiments?

After tying off three of the four arteries, they stitched the dog back up and after fifteen minutes the dog was running around as if nothing had been done to it. This demonstrated the importance of the Circle of Willis for insuring blood is received by the entire brain even when one to three of the arteries become blocked or damaged.

13. How do you feel about this experiment? Do you think it was ethical? Effective?

Willis believed that each section of the brain was important for different functions. He observed the branches of blood vessels branching off to cover different sections of the brain and thought that when blood vessels carried particles in the blood passed nerves in the brain, the particles could irritate the nerves and cause illness. This would explain how the recently popular coffee could alter a person's wakefulness and how other foods and drinks could change one's mood.

Willis was able to track nerves from the brain to different parts of the body. He believed that nerves in the brain sent spirits to the body and that senses from the body were sent up to the brain. The cerebellum was where spirits reside and perform tasks without knowledge of the being as well as where reflexes come from. The cortex was where memories, imagination, and reasoning occurred. The corpus callosum was a place for all the spirits to meet and then travel to the cortex or cerebellum.

14. How could Willis prove the theories of the functions of the cerebellum, cortex, and corpus callosum?

15. How could Willis prove there are links between the brain and the soul?

Willis thought the cerebellum was responsible for governing things people don't conscienceless think about, such as breathing and the heart beating, when he remembered how patients suffering from head injuries to this part of the brain suffered symptoms affecting the breathing and heartbeat.

To further test the theory's Willis and Lower did experiments with a dog tying off the nerves between the cerebellum and the heart.

16. Do you think this is a "good" experiment? Why or why not?

Is it "good" in the sense of ethical or effective?

17. What could be learned in this experiment?

When they tied off the nerve the heart became engorged with blood and the dog died.

18. How effective was this experiment?

19. How do you feel about this experiment? Do you think it was ethical?
20. Are your feelings about this experiment different from your feelings about the other experiments we discussed?

This experiment disturbed Willis and he didn't want to do anymore like it.

Willis and his friends continued to do dissections and experiments for years and in 1664 Willis published *Anatomy of the Brain and Nerves*.

-----Diagram of the brain showing the major parts and structures.

----- Diagram of the nervous system.

Conclusion

Willis and the members of the Oxford Circle made many advances in the study of anatomy and physiology in the 1600's. They were able to show how blood is pumped from the heart and that blood picks up something from the air in the lungs. Willis showed how nerves run throughout the entire body in different networks of branches carrying important messages in them. He showed how different parts of the brain have different function and how anatomy of the brain is important for its function. Working with a community of people helped to facilitate the science that led to Willis publishing many books.

There have been many advances in neurology since Willis and members of the Oxford Circle first examined the brains of Willis's patients, but for all that has been discovered there is much more that is unknown. Today there are treatments for migraine headaches that help those who suffer from them; however we still haven't found the cause. Without knowing the cause it is difficult to find the cure.

Neurologists today have instruments to view the brain that are less invasive. Tools and techniques such as MRI can show much more information than what could have been imagined for Willis. (See the 2003 Nobel Prize in Medicine for the invention of MRI.) With these advancements it is possible that in the future more of our difficult problems relating to neurology can be answered.

21. What were the important factors contributing to Oxford's unhealthy conditions in the 1640's?
22. How do you think human dissection changed science?
23. What problems did early scientists have with dissections especially while dissecting the brain?
24. Did Willis answer the question of the soul?
25. Where does the soul reside and how do we know?
26. Did Willis answer the questions of migraines, seizures, and stupidity? Why or why not.

Elegy written by Nathaniel Williams,

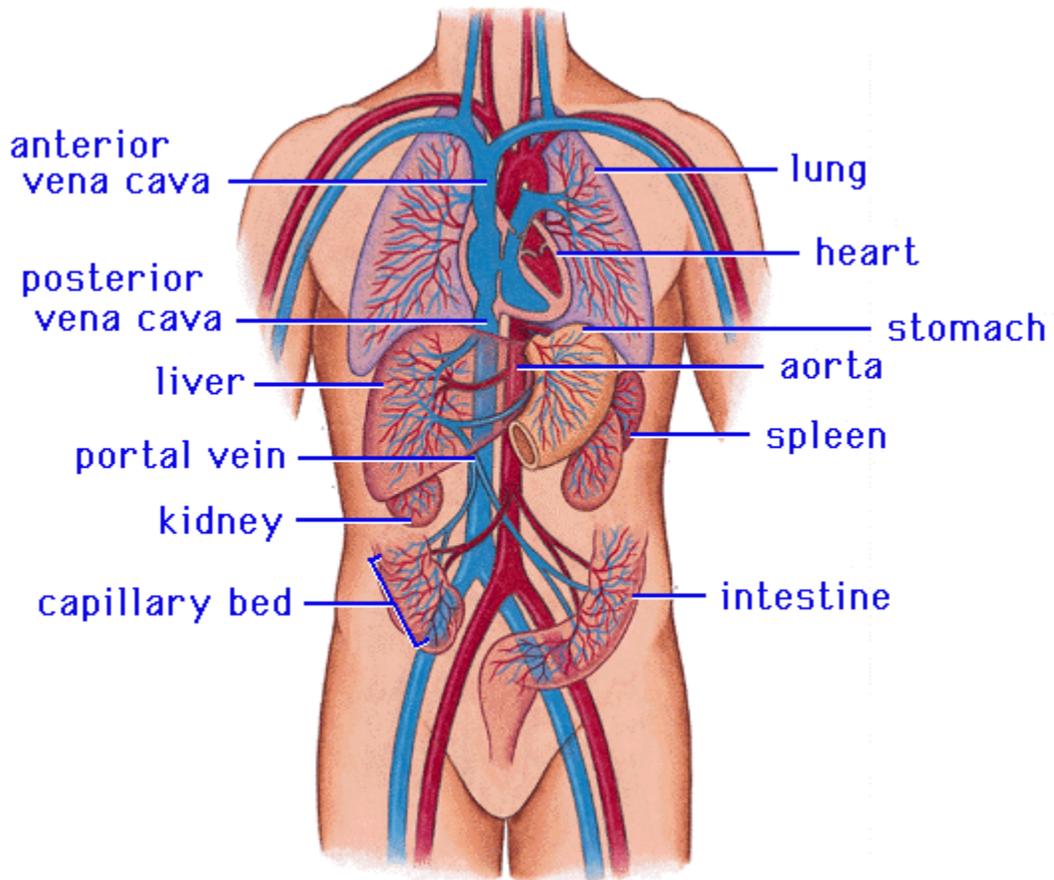
*“Thou knewst the wondrous art,
And order of each part,
In the whole lump, how every sense,
Contributes so the health’s defense.
The severall Channels which convey,
The vitall current every way,
Tracks wise Nature everywhere,
In every region, every sphere,
Fathomest the misery
Of deepe Anatomy.
The unactive carcasse thou hadst preyd upon,
And script it to a skeleton,
But now alas! The art is gone,
And now on thee
The crawling Worms experience their Anatomy.”* (Zimmer p.239).

Works Cited

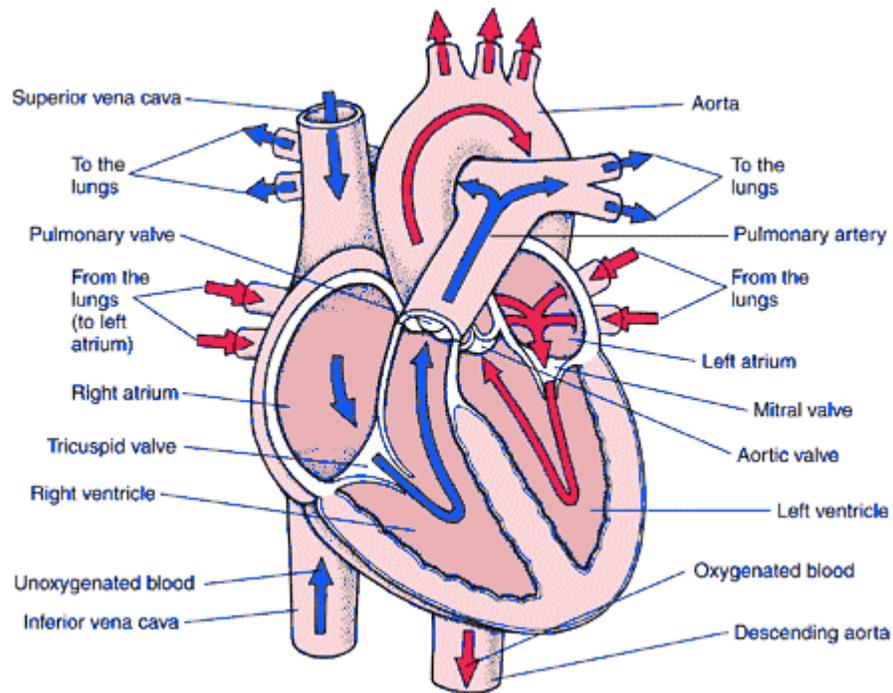
Harvey, William. **On the Motion of the Heart and Blood in Animals** (1628),
Translated by Robert Willis and Revised by Alexander Bowie. From *The Harvard
Classics, Volume 38, Scientific Papers (Physiology, Medicine, Surgery, Geology)*. Web
edition published by **eBooks@Adelaide**. Rendered into HTML by **Steve
Thomas**. Adapted by D. Allchin.

Zimmer, Carl, [Soul Made Flesh](#). Free Press, New York. 2005

Visuals and Labs



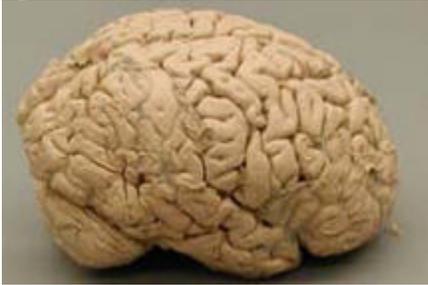
John M. Owens, Ph.D. **Biological Engineering Department at the University of Florida** Last edited: 01/09/06 09:31 www.agen.ufl.edu/.../lect/lect_20/30_04.GIF



www.shoppingtrolley.net/cardio-respiratory-system.shtml

LAB 1 Comparative Lab

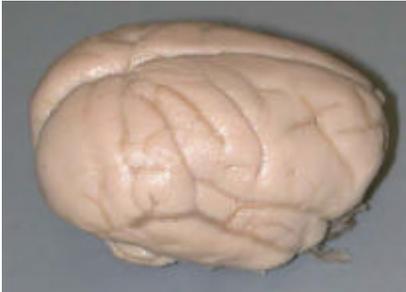
*picture of different brains



Human



Frog



Monkey



Cat



Rat

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1. Compare and contrast the brains from different animals.
2. What can the different anatomy of these brains tell us about their hosts?

LAB 2 Comparing the Mass of the Brains of Different Animals



approx body weight=62,000g



approx 1400g



approx body weight=30,000g



approx 140g



approx body weight=7,000g



approx 100g



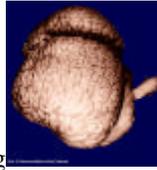
approx body weight=529,000g



approx 680g



approx body weight=160,000g



approx 1700g



approx body weight=35,000g



approx 56g



approx body weight=3,300g



approx 30g



approx body weight=4,290g



approx 39g



approx body weight=2500g



approx 12g



approx body weight=900g



approx 6g



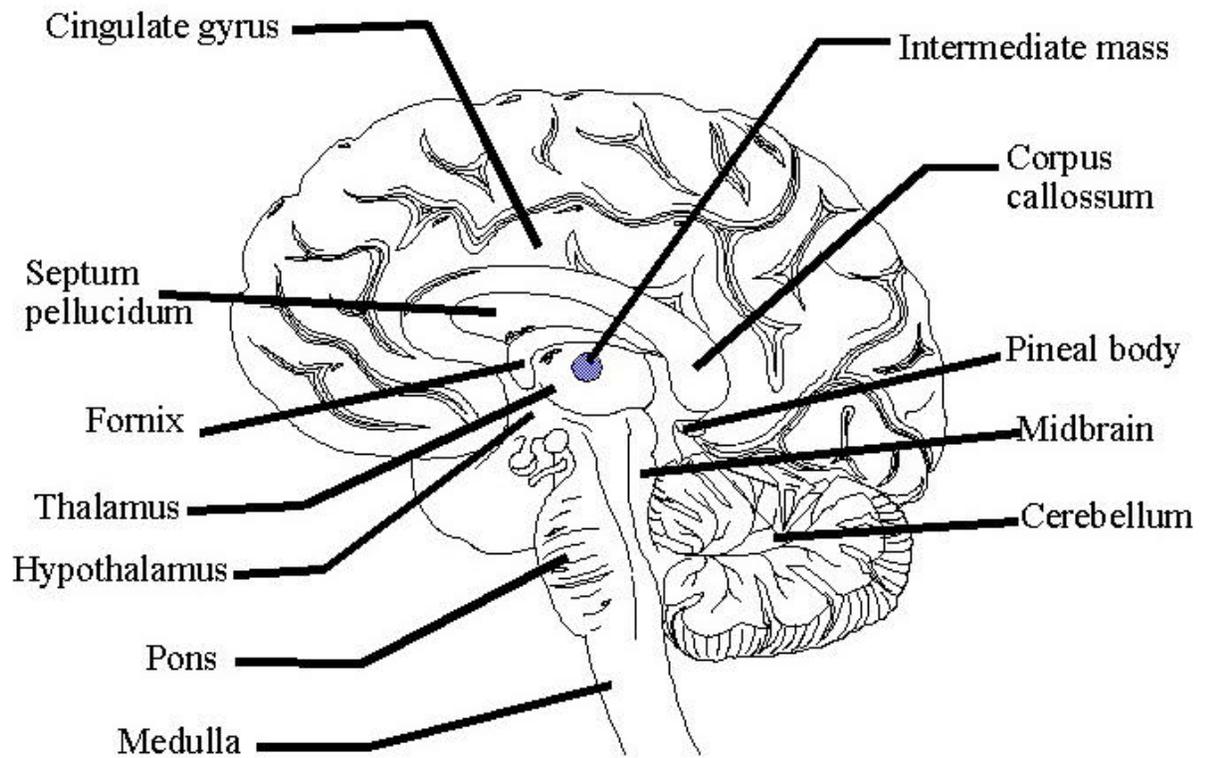
approx body weight=18g



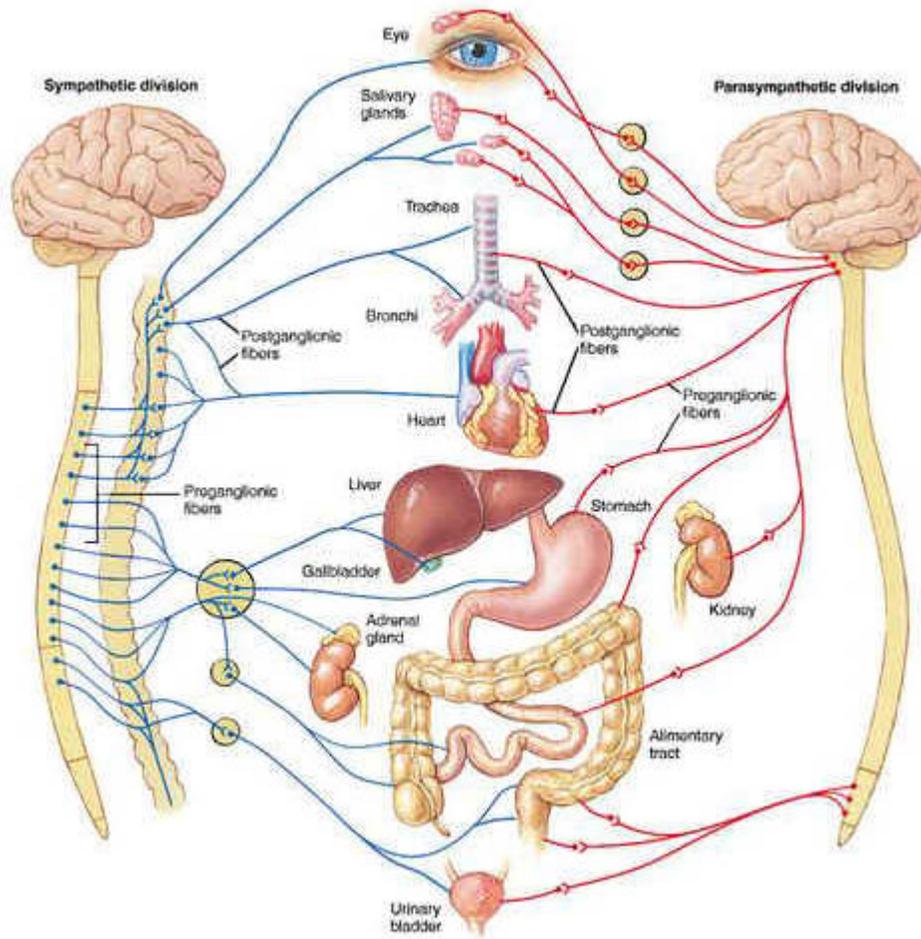
approx 0.1g

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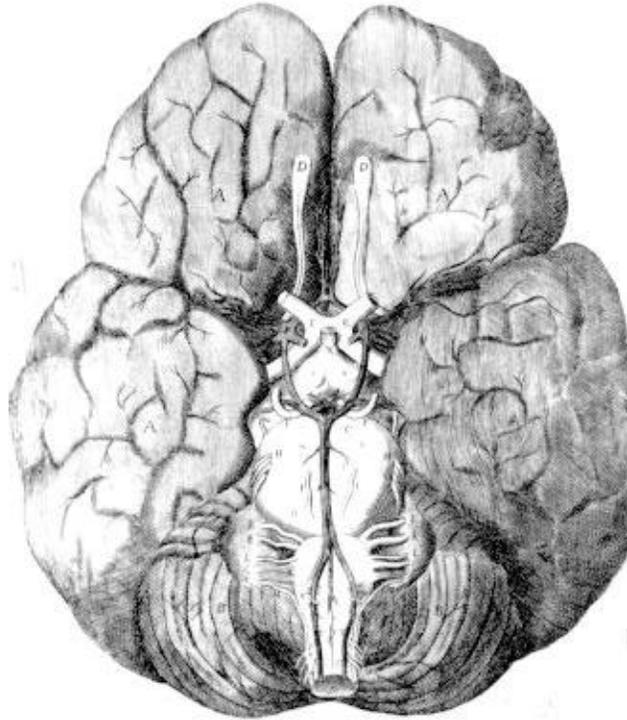
1. Graph the body mass vs. brain mass for each animal.
2. Does the size of the brain tell us anything about the intelligence of the animals?



webanatomy.net/anatomy/sagittal_brain-labeled.jpg Revised: November 12, 2006



<http://www.biologymad.com/master.html?http://www.biologymad.com/NervousSystem/NervousSystem.htm>



Wren's drawing of the Circle of Willis