1.

Spatial performance and maternal behavior in rodents can be influenced by hormones. I know that's a rather dry way to begin, but the story gets more interesting when considering how hormones act in male and female rats to either enable behaviors or shape the brain to be more receptive to future hormonal activation. These are the organizational and activational effects of hormones. They can create differences in behavior between the sexes, especially when considering spatial performance and maternal behavior.

First, I think it would be helpful to establish an idea of the difference between organizational and activational hormonal effects. We can think of the organizational effects like a primer, permanently readying neural structures during development to respond to circulating hormones throughout life. Many of the differences in hormonal response that we can observe between males and females can be attributed to organizational differences that arose during development. Activational effects of hormones do not have to rely on a brain influenced by organizational effects, but without the hormones in question, the behavior would not be observed. Strangely, some of the sex differences in behavior can also be attributed to activational effects, not because the brain of one sex or the other has been primed by hormones, but just because there are differences in hormonal levels between the two sexes; there is more of a given hormone, hence more of a hormonally-driven response, no organizational effects necessary. If experimental equalization of the hormonal levels causes an equalization of behavior, you know that the hormones have activational effects.

With regard to maternal behavior, we can see that hormones take a role in shaping rodent behavior. The actual behavior in question is a shift in mood in the female rat from being mostly aggressive towards young rodent pups to, after pregnancy, exhibiting nest building, retrieval of the offspring during birth (which involves a licking behavior critical to the survival of the pup), grouping, anogenital licking, and nursing. The new mother rodents become more aggressive towards intruders and less responsive to stress compared to nulliparous rodents (those that haven't yet given birth).

But showing some signs of maternal behavior is neither dependent on pregnancy (and the fluctuation in estrogen and progesterone levels that accompanies it) nor even on being a female. Environmental changes can catalyze changes in maternal behavior - aggressive behavior towards pups can be tempered by repeated exposure to them. Over a number of days, the aggression can even turn into nurturing behavior in 'sensitized' nulliparous rodents - male or female. Because we can observe maternal behavior in absence of maternal hormones, the role that hormones take with regard to maternal behavior is one of modulation or supplementation, not a role that fits in our definition of activation.

That being said, maternal behavior in virgin rodent can be induced by something so simple as an injection of blood (containing all of the maternal hormones) from a pregnant rodent. The maternal behavior itself is induced near the end of pregnancy, when progesterone falls and estrogen rises. This combination of hormones can induce maternal behavior in ovariectomized virgin female rats.

We can see that a lack of estradiol influx early in life can result in a rodent which is more prone to be aggressive towards pups (even to the point of infanticide). Estradiol interacts with estrogen receptors throughout the brain. Subtype ER-alpha, when mutated, shows the effects of a lack of estradiol - infertility, infanticide, and an increased latency for learning maternal behavior. Hormones, then, give the brain a head start towards learning maternal behavior.

So, clearly we have something very odd going on. Androgens don't strictly organize the brain for maternal behavior to the point of no return because the behavior can be learned and exhibited by males and non-pregnant females. Nor do hormones serve a completely activational role, as they are not necessary for this behavior. So what do they do? They shorten the time span of learning maternal behavior, increasing exhibition. If anything, they sensitize the brain for maternal behavior through the ER-alpha receptor. *If anything, the effect of hormones on maternal behavior is organizational.*

With regard to spatial ability, it appears as if androgenic hormones take an organizational role in brain development. Observation of rats solving spatial tasks shows that there is indeed a sexual difference in performance. This isn't due to memory storage or capacity, but is instead due to spatial task strategies.

In a test of spatial performance called the radial arm test, the rodent is put in the middle of a many-armed maze that looks a bit like the rim of a tire. Food is placed at the ends of some of these arms. Spatial task performance is measured by the rodent's ability to memorize which arms hold the food.

To 'solve' this task, male rodents use cues outside of the maze (room cues and angles) and landmarks. Females process all available cues and as a result aren't as fast as males at acquiring the spatial locations of the food.

Treatment of female rats in early development with estrogen or androgen will speed acquisition of spatial layouts. The female rats will use room shape and angles to complete the task - the estrogen has masculinized the female brain. The reverse is also true - males in early development show feminine navigation. It's clear that hormones have organizational effects on spatial task learning.

Also, it's worth briefly mentioning that while it isn't known exactly what mechanism that androgens use to cause morphological effects in the brain, every sexual dimorphism in the brain stands as evidence of these organizational effects.

Finally, it's important to note that neither organizational nor activational effects are set in stone. In the case of spatial task learning, exposure to hormones early in life that leads to differences in brain organization can be overcome by experience and training, which boost performance on spatial tasks and change regions in the brain either directly or indirectly. Likewise, maternal behavior doesn't require the expression of activational hormones. That being said, the simple manipulation of estrogens and androgens can modify performance on adult learning and memory tasks of all kinds - including maternal behavior and spatial tasks. Though activational hormones definitely can alter the morphology of the brain, it hasn't been proven that this change in morphology leads to effects in learning or memory. Both activational and organizational effects can change behavior, that much is clear, but the difference between them lies in their effectiveness over a period of time. If one thing is certain, it is that the relationship between the activational and organizational effects of hormones and behavior is a complex one.

2.

The environmental effect of a variation in season appears to have an effect on testosterone production in males and a corresponding variation in spatial ability. Levels of testosterone rise in autumn, when the days are shorter and weather becomes colder. When spring comes, the corresponding drop in testosterone levels brings with it increased performance on spatial ability tests. This fluctuation has to be due to changes in the environment - there is no strictly biological reason (as in the menstrual cycle) why testosterone should fluctuate

seasonally. As far as how this hormonal change can cause behavior, we learned earlier that the increase in testosterone that we see in the autumn can increase self-reports of spontaneous sexual thoughts, sexual desire and interest. And this goes along with studies on human reproduction and temperature - in the colder months, conception rates rise above normal, a fact which may have as much to do with a decrease in sperm levels in the warmer months as with fluctuations in testosterone. At any rate, testosterone can modulate the behavior of sexual motivation. And it is the seasonal environment that modulates testosterone.

One of the most interesting environmental effects of the environment on hormonal secretion is the steady march of the onset of puberty. Every year, the average age of menstruation gets younger and younger - it now stands at 13 years old, which could well be the youngest age biologically possible. The interesting part of this environmental change is its exceptionally complex nature. Just what has changed in the past fifty years that could cause this decrease in age?

Over the past half-century, the entire pace of life has accelerated. Improvements in health care have helped us develop faster and live longer. Living standards in general have improved - and both of these have been found to contribute to the decrease in the onset of puberty. Adding more complexity to the problem, studies have shown that girls in rural areas experience the onset of puberty significantly later than girls living in cities. The tangible differences in these two environments are vast - from social interactions to climate to cuisine. Even the greater amount of visual stimulation in cities has shown to have an effect on the acceleration of puberty - in this case, slowing the onset of puberty.

In this situation, I think that the environmental factors are sufficiently complex that we won't ever get a clear picture of their summation on a mechanism to decrease the onset of puberty and its ultimate cause - the increase in hormonal secretion. But we can measure its response to environmental cues.

The most well-known hormonal response to the environment are the fluctuations that encompass the 24-hour clock and the sleep cycle. The Suprachiasmatic Nucleus cells that respond to changes in environmental light and adjusts the secretion of hormones like melatonin accordingly. The SCN can moderate all types of daily rhythms - eating, drinking, activity levels, and, of interest here, sleep cycles.

The SCN causes the release of melatonin from the pineal gland less than two hours before sleep in lab rats. The mechanism of SCN activation is as follows: SCN activates the paraventricular nuclei of the hypothalamus, which sends a signal to the ganglion, causing synaptic release of the neurotransmitter norepinephrine onto the pineal gland. This secretion causes melatonin enzyme production and, as a result, production of melatonin itself. Levels of melatonin are high throughout the night and drop with the return of the light.

The environmental stimuli - light, in this case - can directly cause the fluctuation of a hormone that regulates behavior.

3.

Regarding sensorimotor function, there are several interesting behaviors that are sexually dimorphic in rats. For instance, both sexes perform evasive maneuvers when playfighting with other rats, but the muscular action of these maneuvers is different. Male rats will "pivot around a

point about their midbody" while female rats will keep their pelvis still and rotate their snout. Females are better at odor detection and identification than males

Some sensorimotor behavior can be attributed to hormonal fluctuations. Estrogen levels can affect taste preferences, organizing the young brain in order to make sweeter tastes more preferable in adults. In fact, the organizational effects of estrogen on the brain serves to create taste preferences and aversions in rats - a fact that can explain the differences in body mass between different species of rodent. The organizational effects on body mass go even further when there is a measurable difference between the effects of testosterone and estrogen on body weight exhibited by males (greater and less response, respectively) than in females. This points directly to a difference in organization of the brain early in life.

The play-fighting in male rats can also be attributed to the organizational effects of reproductive hormones. Androgen delivery in the critical period to the female amygdala produces masculine sensorimotor play behavior - more "nape attacks", less defensive behavior early in the fight, and more use of the body to block attacks.

In contrast, the activational effects of hormones serve to increase running wheel activity of female and male rats showing increased levels of estrogen. Conversely, progesterone has the opposite effect on running wheel activity.

Hormone levels can also affect activity. When given an injection of estradiol in the striatum, rodents temporarily walk more accurately and carefully along a balance beam. In an open field, locomotor activity and degree of exploration (measured by the number of arbitrary quadrants entered) can be increased with increased estrogen levels. As with all of these studies, it's difficult to draw the line where sensory function ends and motor function begins. What's clear is that this behavior can be modulated by reproductive hormones.

Regarding cognitive function in rats, the first problem already extensively explored one of its most significant contributors - the learning of spatial tasks. But perhaps the most significant effect of reproductive hormones on learning and memory has to do with the direct effects of estrogen on the growth and strengthening of synaptic connections, a concept at the heart of cognitive ability. In the hippocampus, the area of the brain that oversees learning and memory, injections of estrogen can actually cause the growth of dendritic spines within 48 hours, indicating a cyclical buildup and breakdown of synaptic connections based on estrogen and progesterone levels. What's more is that estradiol injections strengthen synaptic connections on the other half of the synapse. The same NMDA glutamate receptors that have been implicated in synaptic learning can actually be strengthened by estradiol injections. Now, estrogen is obviously not the sole requirement for the growth of dendritic spines, nor is estradiol the sole activator of LTP, but the increased level of synaptic connection seen with the influx of these two reproductive hormones. Their effects on cognitive function are activational.

Scientific ethics make impossible the kind of extensive experimentation necessary to uncover the exact organizational effects of hormones on the human brain. We just don't know if hormones are the true cause of the sexual dimorphism that we seen in the brain. Questionable claims of organizational effects of hormones on IQ scores between the sexes haven't been proven. The cognitive effects seen in spatial task learning are likely organized by early androgens, but for the rest of cognitive functioning, little is known.

What we do know about organizational effects in humans mostly comes from females with Congenital Adrenal Hyperplasia, a condition where females show overexpression of masculine hormones during the critical period. The spatial abilities and perceptual speed of

females with this condition mirror those of men, showing that at least in these areas of cognitive functioning, the effects of hormones on the brain are organizational. If the studies of other forms of behavior are any evidence, further studies of the organizational effects on cognitive function could likely be fruitful.

Given the natural fluctuation of hormones during the menstrual cycle, the activational effects of ovarian hormones are much easier to study. But studies of the oft-reported fluctuations in mood in the days before or during the early days of the menstrual cycle have not provided consistent results. During this time, levels of estrogen and progesterone fall sharply and remain low over the course of the menstrual phase. But despite the consistency of the hormonal response, universal activation of the changes in cognition (measured through mood) isn't observed.

Further studies of spatial ability and the activational effects of hormones shows that performance on spatial tests decreases during the preovulatory phase in women, giving the conclusion that high levels of estrogen can actually decrease spatial ability. These same high levels of estrogen actually serve to improve simple verbal output tasks for articulatory accuracy. Less evidence exists for the relationship between perceptual speed and estrogen and progesterone levels. Visual sensitivity increases with the increase in estrogen levels and drops during menstruation when estrogen levels also drop. There is some evidence that on some tests of motor ability, ovarian hormones can increase performance.

Ovarian hormones can be said to improve the skills in which females are known to excel and dampen performance in tasks where males typically show an advantage.

As far as non-ovarian hormones are concerned, in men, testosterone serves to aid spatial ability, but only up to a point. High levels of testosterone can actually serve to decrease performance.

With regard to sensorimotor function in humans, many of the sexual dimorphisms that exist in rats are exhibited also in human behavior. Taste preferences differ between the sexes, with females preferring sweeter foods, though not after a meal. Evasive movement behaviors, as we saw in class, differ between the sexes in the same way (with alternating pivot points) as in male and female rats.

That being said, the same kinds of sensorimotor tests done on rodents can't be replicated on humans. Humans don't run on running wheels, nor even can a similar open field test be administered. Our social play (usually) doesn't involve stereotyped behaviors and and the way we report data from our senses is colored by perception and cognition. As one would expect from Man the Thinker (as the great poet described us), our cognition outweighs our sensorimotor function.

Surely the picture of hormone activation and organization is much more clear for rats than it is for humans due to the differences in available experimental methods. In humans, this picture is made even more complicated because the majority of activational studies use the menstrual cycle as the distributor of hormones, giving a clear picture for only a handful of hormones. Further studies into activational effects of other reproductive hormones on cognitive behavior show that circulating hormones can modify cognitive functions, but, as with most human studies, more experimentation needs to be done.

That being said, in areas where the organizational effects of hormones is known in both men and rodents, remarkable similarities can be seen. The same is true for activational effects. When the brain is organized by hormones early in life, the effects are permanent and can be seen in adults. No amount of learning nor hormones administered can match a brain that has been

organized with one that hasn't. Likewise, the specific types of behavioral and cognitive performance can't be seen without certain activating hormones. Certainly the great framework of both of organizational and activational hormones has equal validity among humans and rodents.

4.

Bear would sway on her hind legs;
the organ would grind dregs of song, for the pleasure
of the children, who'd shriek
throwing coins at her feet
then recoiling in terror
- Joanna Newsom

A fight with a bear is no ordinary matter. Aside from the physical stress that accompanies an attack, the psychological stressors that arise help to explain just why it is that this scenario is far above even an elevated stress level for humans - say, for instance, the stress levels seen during the week of final examinations. That being said, the course of the event is six hours, making it an acute stressor, so many of the long-term effects of stress on the body thankfully won't come into play. I'll first explain the psychological stressors of this event, then move on to the physical stressors, and finally describe the biological response over the course of the six hours.

Direct physical arousal is not the only contributor to stress levels. The two examples given in the text are sufficiently convincing to show that psychological inputs can modulate the stress response: anesthetized patients still show the signs of stress even though they don't feel the physical effects of surgery and stressful - even harmful - physical stressors can lose their stressful effects when psychological perceptions of them changes in a process called habituation. The following conditions, which are purely psychological, can influence stress physiology.

The first is a lack of control. As I understand it, camping in the woods is an activity that people enjoy precisely because are in control - you're supposed to marvel at the grandeur of nature and how man can tame it for a time with a tent and a propane stove. You're supposed to feel like a pioneer - "climb every mountain, ford every stream" and all that. So imagine the shock that one must feel stumbling upon a mother bear and her cubs. Suddenly, you have lost all control over the situation. Certainly you cannot fight the bear, nor do much to make it stop if it chases you (despite the old wives tale, they can climb trees). This lack of control is extremely stressful.

The second is a lack of predictability. There's no telling how the bear will react to your presence. You don't know if there are more of them to contend with waiting around the bend. During the fight, there's no way of knowing how the bear will strike or bite you. Most importantly, there's no way of knowing when the fight will end - of knowing when you are truly safe. Until you are rescued, you can't predict when the stress will end.

The third is a bit more abstract. In species with well-defined social ranks, those near the top usually are saved from the level of everyday stress experienced by those in lower social ranks. This isn't just conjecture - it has been proven at the molecular level. And I wouldn't think it to be too much of a leap to extrapolate this observation to intraspecies rankings. Are we not the king of all beasts? Certainly we are not used to being attacked by members of any other species, a fact which explains the popularity of sensationalist television programs (Discovery Channel's "Shark Week" is a prime example). Certainly there is a baseline level of surprise and shock and

stress that comes from being attacked by any animal, without even taking into account the shear terror that must come when that animal turns out to be a bear.

Though, like any psychological conditions, it is difficult to quantify exactly how these axes will influence the psychological stress response of any one human. Though it may seem like nothing more than one long digression when compared to the science of the biological response, we still needed to explore these psychological variables.

Immediately upon encountering the bear, the body would respond in the same way as it does to any stressor - corticotropin-releasing hormone is excreted from the hypothalamus stimulating the pituitary gland which responds seconds later by adrenocorticotropic hormone. A matter of minutes into the bear attack, this pathway causes a glucocortocoid steroid hormone (which takes the form of cortisol in humans) to be released from the adrenal gland.

While this is happening, my sympathetic nervous system would trigger a release of epinephrine (also from the adreneal gland) and norepinephrine in all of my organs, priming my body for action. The parasympathetic nervous system, on the other hand, is inhibited.

Endorphins, prolactin, vasopressin, and glucagon are released in response to stress, together acting to halt costly biological functions like pain reception, reproductive physiology, renal function, and carbohydrate trafficking. Because of parasympathetic nervous system inhibition, GnRH, LH, FSH, and the gonadal steroids are also inhibited, further inhibiting reproductive physiology. They act to ensure the body has the energy needed to survive a stressful situation. Existing energy stores are broken down and storage is inhibited - survival is king.

The second component of the biological response to an acute stressor is the raiding of existing energy stores and the conversion of this energy into a usable form. Amino acids are recovered from proteins, glucose from glycogen, and fatty acids and glycerol from triglycerides. Inhibition of insulin effectively halts the storage of these biological building blocks, setting them free so that they can be turned into glucose by way of gluconeogenesis and transported to active muscles, providing me the energy necessary to run, dodge, fight back, scream, etc.

The increase in glucose levels in the blood from all of this biological stress preparation results in the stress response which we're all familiar with: an increase in breathing rate to transport glucose and oxygen to the muscles. Cardiovascular tone, blood pressure, and heart rate all rise. Blood volume also rises due to an increase in water retention. Digestion halts. Interestingly, depending on the length of the attack, release of growth hormone could actually be stimulated slightly by stress. Something I mentioned before, the perception of pain and inflammation of injuries, also decreases, a fact for which I can be very thankful when the bear lands his first paw on me.

Thankfully, I escape without suffering too many injuries. The initial stress response has done its intended job, aiding in my flight from bear-induced pain, and I can rest easy and wait for rescue.