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How We Learn about the Brain: Teaching the Infant Brain

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Introduction

This unit is intended to be taught in a high school human anatomy and physiology class. At first glance it may seem to be an odd way to teach about the brain to high school students, but my students are special. All of my students are pregnant or parenting teenagers and have or will have the experience of caring for an infant. Because these infants will grow up to become students in our district school, it is wise to help their mothers prepare the infants for their eventual entrance into the primary grades. Thus, this unit is intended to help the young mothers in my classroom learn enough about the brain, in particular the infant and young child's brain, to be able to prepare their children in the best way possible for their entrance into school.

The unit is structured to follow the development of the brain and nervous system of a child from just after conception through about age five. This time period covers most of the more interesting developments in brain structure and function. The timeline allows for an organized way to study a very complex set of structures.

Objectives

As stated in the introduction, the purpose of this unit is to help young mothers prepare their children for eventual entry into preschool and kindergarten. However, as noble as that goal is, the unit still has to fit into the anatomy and physiology curriculum. This unit will address the part of the curriculum on the central nervous system. It will also touch on some aspects of the peripheral nervous system.

A brief review of embryology [1]

Before any discussion can begin about the development of the brain, a general understanding of embryology is essential. Because the brain and, more generally, the nervous system are some of the earliest components to emerge in an embryo, the two stories are inevitably linked. This is how I plan to begin teaching this curriculum unit, so I present here a very abbreviated version of the stages of human reproduction.

Fertilization and the Zygote

When sperm penetrates an oocyte (the human egg), fertilization occurs and the fertilized egg, now called a zygote, is formed, a single cell with a full compliment of chromosomes. The zygote divides through the process of mitosis, producing two blastomeres. About every 20 hours the cells of the zygote divide again. When the ball of cells has reached about 16 cells, it is called a morula. The cells of the morula continue to divide and continue to make their way through the fallopian tube into the uterus. After about 4 days and at about 100 cells, the morula develops a cavity in the center of the ball and a disk of cells at one side of the ball. The cells that form the disk are called the embryoblast, the future embryo; the cells that form the walls of the rest of the cavity are the trophoblast, the future placenta and fetal membranes. The entire structure is now called a blastocyst (or blastula).

Blastocyst

The blastocyst enters the uterus at about day 6. Within a day or two the trophoblast begins burrowing into the lining of the uterus, destroying cells and stimulating capillary production. The capillaries will become the beginning of the maternal part of the placenta.

By about 13 days, the placenta and umbilical cord have begun to form and the embryoblast has three layers: the ectoderm, the medoderm, and the endoderm. At about 16 days the ectoderm begins to form the neural crest, which is the first stage in the formation of the nervous system. This is also about when a woman will notice that she has not had her period.

Embryo

Shortly after the neural plate forms, cell migrations alter the shape of the embryo, forming bumps and grooves along the length of the neural crest. These cell migrations are a sign of differentiation. Differentiation is the process that leads to the development of the specialized tissues that make up the human body. It is during this period that the fetus is most sensitive to agents causing birth defects; although this sensitivity will continue to some extent throughout the pregnancy. By about three weeks, the circulatory system and the heart begin to form. The cells which form the beginnings of the heart begin to pulse in a rhythm which will become a heartbeat. By about 5 weeks limb buds appear, the beginnings of the digestive and urinary systems also appear. By about 7 weeks, the ossification of the skeletal system begins, the kidneys begin to produce urine, the heart is mostly formed, the arms and legs, hands and feet are forming. Shortly thereafter, the sex of the embryo can be seen by the presence or absence of testes; however, these gonads are very small and not readily visible on ultrasound at this stage.

Fetus

At about 10 weeks, the embryo is considered a fetus. By this time, all of the body systems have begun to develop. The brain still has a smooth surface, but the fissures will begin to form soon. The heart is pumping blood through a primitive circulatory system. The kidneys are processing urine. The digestive organs are largely formed and are practicing their functions. The lungs have formed and begin to inhale and exhale, moving small amounts of amniotic fluid in and out of the lungs. The skeleton has begun to ossify and many muscles are capable of twitching. The skin has formed and some hair follicles are forming, too.

Over the next few months, the body systems continue to develop, grow and become more functional. The development at this point is like a sketch of a masterpiece. All the parts are in place and are proportional; now, all that is needed are the intricate details and coloration that will bring the piece to life. More to the point for this unit, the parts of the brain are sketched in, but the detailed connections that will make it a functional unit have yet to be connected. The detailed connections will come "online" as they get built over the next twenty years and will be continually modified over the lifetime of the owner. Most of the growth occurs before the age of 3, but much modification to a lesser extent continues into adolescence and early adulthood. The details of this development, the subject of this unit, follow.

Because of the unique nature of my students, this section will probably have a greater weight in my teaching than it may in a regular classroom. However, as most anatomy and physiology curricula cover reproduction as well as the brain, this section may be useful as a part of another unit when taught in a more usual classroom setting. It is for that purpose that I include how I plan to teach this section. There are three major concepts I want my students to understand when the complete this part of the unit. First, the students should be able to break the process up into the commonly recognized stages of development from fertilization through birth. Second, my students should have some idea of what is happening during each of the stages. Third, my students should be able to correctly identify the order of the stages that occur. The lesson I suggest for this stage of the unit is a small project. The teacher should break up the process of development into recognizable stages; the ones I have used above would work through the first trimester. The names of the stages should go on squares with enough room for a written description of the stage to be included as well. When I tried this with my class, as I was writing this unit, I printed out the squares with the stage names on a piece of paper and had the students take notes using them during a lecture, but, in future, I might have the students describe the stages based on their own observations from readings in the text book and from the visible embryo website. At any rate, the students should describe the growth that occurs during the stages in their own words in the space left on the square. As the students are exploring what is occurring during the stage, they should also be thinking about what embryo looks like because the next stage of the project is to illustrate the squares. The illustrations could be actually pictures of what a developing embryo looks like, or they could be a visual metaphor for what is happening. The final stage of the project is to have the students create a poster using their squares and illustrations. The poster should tell the story of the process of the formation of the embryo.

First Trimester

The first trimester is a very important period of time for the developing neurological system. The nervous system is the first major system to begin forming. As the nervous system is essential for life, it is somewhat unfortunate that the formation begins before most women even suspect they may be pregnant. As stated above, the neural plate begins forming about 16 days after fertilization, or about the time when a woman may notice that she has missed her period. This means that the system begins to form without benefit of the extra care many women will take when they realize they are pregnant.

The nervous system begins with the formation of the neural plate, a thickening of the ectoderm on what will be the back of the embryo. The neural tube develops as a groove that soon rounds into a tube. Eventually, the tube develops ventricles, or small chambers, which will become the three sections of the brain. This stage is called encephalization. The remainder of the tube will become most of the spinal cord. The first two events are described in the next two sections.

Neural Tube

At about 16 days past fertilization, a special tissue forms in the developing embryo called the ectoderm. The ectoderm is one of three layers in the developing embryo at this point. It will eventually form into most of the exterior parts of the human body, forming tissues such as skin hair, nails, mammary glands, and the entire nervous system. A line of cells (the notochord) forms in the mesoderm. [2] Above the notochord, the ectoderm thickens into a structure called the neural plate. A line in the neural plate just above the notochord develops into the neural groove. The edges of the groove rise and meet in the midline at about 3 weeks, forming the neural tube. The side begin meeting at the center of the length of the tube at the site of the future neck and continue towards both ends. This neural tube will eventually become the brain and spinal cord. The entire process resembles a person rolling their tongue into a tube.

Encephalization [3]

Once the neural tube has closed, encephalization begins. Encephalization is the process of forming the major structures found in the brain. During this stage the head region of the neural tube divides into three chambers: the prosencephalon, most of which will become the cerebrum; the mesencephalon, which will become the midbrain; and the rhombencephalon, which will become the lower part of the brain, including the cerebellum.

The prosencephalon is the vesicle or chamber that is closest to the rostral end (or the end that will become the head) of the neural tube. The prosencephalon divides into three sections. The rostral end produces two vesicles that emerge laterally from the main axis of the neural tube. These two sections together are called the telencephalon and will later become the two cerebral hemispheres of the brain. In later life, these two hemispheres of the brain will process most of the information coming into the brain from the senses as well as controlling movement, reasoning and thought. The remainder of the prosencephalon becomes the diencephalons, which eventually becomes thalamus, hypothalamus, pituitary gland, the pineal gland, and, interestingly, the retina of the eye. Most of these sections are essential for running the involuntary systems of the body, like thirst, hunger, digestion, and sleeping. The thalamus is also an essential relay stage for messages from many of the senses; it routes the message to the correct area of the brain for further processing.

The mesencephalon does not divide into additional vesicles, the way the prosencephalon does. Instead, it develops into the midbrain. The midbrain comprises a complex set of structures related to movement, coordination, mood, pleasure and pain, and visual and auditory reflexes.

The rhombencephalon divides into two vesicles: the metencephalon and the myencephalon. The metencephalon will later become the pons and the cerebellum. The myencephalon will become the medulla oblongata. The cerebellum is essential for coordinated movements; it regulates muscle movement, but it also controls the muscle tone necessary to maintain balance and posture. The pons, as its name suggests, acts as a bridge; it is a relay station between the medulla oblongata and the cerebellum. It is also required for breathing. The medulla oblongata is the first stop in the brain for many messages coming up the spinal cord. It is responsible for many of the autonomic functions of the body like breathing, coughing and swallowing.

Inevitably in every curriculum unit, the question of "how do I teach this" arises. For this unit, there are three major concepts that my students need to understand. The first is a basic question of vocabulary. This is written for an anatomy class, so the names of the parts of the brain are an essential part of the curriculum, particularly as my students will never have seen the material before. The second concept my students need to know refers to the physiology part of the class; they need to know what the parts do. The third concept is a bit more abstract in that it requires both anatomy and physiology to understand. My students need to understand how all of the parts and pieces fit together and work together. The text book that I generally use for my class includes a workbook with black and white illustrations to be colored and labeled to help students learn the names of the various parts of the body. While this approach works very well for many of the body systems, the central nervous system is one where this approach breaks down because of the fundamental three-dimensionality of the brain. So, I suggest a slightly different approach to teaching this section. As part of the preparation for writing this unit, I tried out this section of the unit with my class. The most complex concept from this section is the three dimensional structure of the brain. As most of us do not have access to a world class anatomy lab with actual human brains to study, I suggest building a three-dimensional model of the brain. In my class we built one out of a very popular children's modeling clay. It worked pretty well to convey the general shape of the various parts of the brain, however, because it is extremely malleable, our model tended to be somewhat floppy. I would suggest using a slightly stiffer material like a professional grade modeling clay or polymer clay for this project.

For this project, the students should work on building a model brain. In my class each student worked on a section, and we put all the pieces together. In a larger class, the class could be broken into smaller teams to work on several brains, possibly the brain at different stages of growth. I think it is important that each student be required to build sections of the brain rather than having teams of students each build a section. The structures are complex enough that the students should have as much experience manipulating and forming the brain sections as possible. Once the brain sections are forms, and tested to make sure they fit together, they should be labeled with the name of the part of the brain and the function that the brain part serves.

Second Trimester

Gliogenesis

Gliogenesis seems to foreshadow neurogenesis in some ways. The glia, for example, are formed from cells located in the same region that produces neurons. According to some research, some glial precursor cells can also form neurons under the right circumstances. (Lee, et all, 2000)

Neuronal genesis

Almost all neurons are made in the second trimester. Neuronal genesis is a truly fascinating process. The creation of neurons is much like the creation of other cell in that they are produced through mitosis, but the fascinating thing about neurons is what happens next. When neurons divide in the fetal brain, they divide near central part of the neural tube, close to the ventricles. If all the dividing neurons remained where they were created the brain would simply be a ball of cells, but clearly it is not. Because the brain is differentiated into different sections with different functions and is often arranged in layers, the neurons must migrate according to the proscribed pattern. The daughter neurons move, or rather one daughter cell of each divided pair, climbs to a new location following glial cell fibers initially, and later following the pathway of previously moved (pioneer) neurons. The neurons appear to be following a chemical gradient along the glial cells, which act as a sort of scaffold. The neurons continue to be made and spread out throughout the brain, but rather than starting from the outside and filling in, the brain is built from the inside to the outside. It is almost as if the newer neurons are extruded out along the pathway made by the older neurons. The process is similar to what one sees when a volcano builds new land. Once in place, the neurons begin to send out axonal and dendritic projections along the chemical gradients which suggest the presence of other neurons. Most of the projections, however, are not sent out until after birth. In this way, the brain at birth is similar to a house that has its wiring roughed in, but the detail connections for plugs and light sockets have not yet been made.

Texturing the brain: major fissures

The brain hemispheres separated when the telencephalon formed, but the brain is still fairly smooth until the gyri form. The first set of major fissures form in the brain, creating the major lobes of the cerebrum. There are four major lobes on each side of the brain. While they may look symmetrical, each side generally serves a unique, although sometimes related function, in the adult brain. For example, when looking at a pattern, an adult will use the left side of their brain to look at the details of the pattern and the identical structure on the right side to look at the pattern at a global or big picture level. A child, however, will frequently use both sides of the brain to look at the pattern both locally and globally. In children with damage to one side of the brain, the brain frequently adapts by using the other side for both sorts of functions. Unfortunately, the same is not generally true in adult brains. (Nelson, et al, 2006, pg 103)

The major lobes of the cerebrum, four in each hemisphere are the frontal lobe, the temporal lobe, the parietal lobe, and the occipital lobe. The lobes are located beneath the skull bones bearing the same names. Not surprisingly, the frontal lobe is in the front part of the brain, above the eyes. It is the last part of the brain to mature and does not become fully myelinated until about thirty years old. This part of the brain is responsible for reasoning, conscious evaluation, the logical parts of language, emotion, movement and problem solving. The temporal lobe can be found medial to the ears. This part of the brain contains structures responsible for auditory processing, memory, and some of the auditory component of speech recognition. Interestingly, the pattern recognition aspects required for language comprehension, for both auditory language and for sign language, are processed in the temporal lobe regardless of whether or not there is an auditory component to the language. (Nelson, et al, 2006, pg 106) The occipital lobe is located about where a head hits the pillow when a person lies down on his or her back. It is responsible for processing visual input, including some aspects of pattern recognition. It is the first of the lobes to begin maturation, beginning even before birth. The parietal lobe is located about where a woman wears a high pony tail. It is responsible for processing input mainly from the epidermis, and evaluates sensations like, temperature, pressure, pain, and pleasure.

The lobes of the cerebrum form by differentiating from the original mass of the telencephalon. The temporal lobe is the first to begin differentiation in about the 4th month when the lateral cerebral fossa begins to form a groove that will become the lateral cerebral sulcus, separating the temporal lobe from the frontal lobe. The groove that will become the sulcus deepens as the frontal and temporal lobes grow larger. At about six months other groves begin to appear on the surface of the cerebrum which will grow into the other major sulci, including the central sulcus dividing the frontal and parietal lobes and the occipital sulcus, dividing the parietal and occipital lobes, by about eight months. Again, the sulci appear to deepen as the brain tissue expands around the groove without filling it in.

Third Trimester

Texturing the brain: secondary and tertiary sulci

As the larger fissures finish forming, shallower grooves begin to form within the major lobes. These shallower groves will form secondary and later tertiary sulci. These valleys between the ridges of the brain provide further differentiation of the cerebral tissue and allow for further specialization of function within the more generalized lobes of the brain. These basic structural features of the brain are fully complete by the time an individual is born.

The major structures of the brain, like the sulci separating the major lobes of the brain and most of the secondary sulci, do not vary between individuals, the more detailed, tertiary sulci, do vary between individuals. (Larsen, 1997, ch. 13) This difference between individuals may account in part for the varied abilities we see in our students.

Neuronal organization and myelination

With approximately 100 billion neurons, a baby's brain would get very messy, and probably become dysfunctional without organization, so shortly before birth the neurons are organized into various groups. Each group of neurons performs a different set of tasks. Myelination effectively insulates neurons and improves their functionality. Neurons become significantly more functional as they are myelinated, so the pattern of myelination mirrors the functionality of various parts of the nervous system during development. This section will include a description of a typical neuron, a review of the brain's organization, and a description of the development of the functional aspects of the nervous system.

Myelination starts with the parts of the brain which appear to be most necessary for life. The life support systems like breathing, heart beat regulation, swallowing and digestion, temperature regulation, and the olfactory, vision and hearing reflexes. The control circuitry for most of these life support systems are all located in the brain stem and are all fairly close to each other. As discussed earlier myelination makes conduction along the axons more efficient, so by myelinating the neurons involved in life support systems early, the infant has a better chance of survival. However, even with the amount of myelination that occurs in a healthy full-term infant, most of these systems are not fully functional at birth. This is evident when one considers an infants inability to regulate it body temperature and the trouble some infants have in swallowing and digesting sustenance.

It is interesting to note that while much of the brain, including most of the cortex is not very functional at birth, two systems, vision and hearing, actually appear to begin functioning before birth. There is some evidence that the fetal brain reacts to light shining through the uterus. At birth, the infant brain immediately begins to react to face-like patterns event before it can distinguish the details of the face. There is also evidence that the fetal brain reacts to sounds beginning at about 26 weeks. The infant brain reacts to speech patterns from birth and appears to recognize speech patterns regardless of the language spoken and regardless of whether the language is the one heard during gestation. (Nelson et al, 2006, Ch. 4) These two brain functions seem to be a bit of an extravagance given that the neonatal brain isn't very good at things like breathing and swallowing, but they make sense in the context of the importance of socialization, speech and facial expression, in human culture.

Infant

The newborn human infant is an amazingly complex, yet vulnerable, creature. It has the potential to become the next Einstein or Newton, but at the same time, it isn't even very good at breathing and eating yet and can not so much as hold its head up. Even so, within the three years, the human child can walk and talk and do basic math with more proficiency than our most closely related cousins in the animal kingdom. Clearly, much change must take place between these two states, and most of that change originates in the brain.

Brain growth

The neonatal brain grows amazingly fast. The amazing pace of growth generally starts before birth, in the last month of gestation, but it increases after birth. Most of the growth, however, is not the creation of new neurons as one might expect in the brain. Most of the neurons an adult has are present at birth. Instead, the growth is primarily in the form of dendritic and axonal projections and support cells (glial) for the brain. By support cells I mean glial cells such as astrocytes and oligodendrocytes which help the neurons function by insulating their electrical circuitry.

Sensory refinement [4]

Several of the senses begin to function before birth. As was mentioned earlier, the vision and hearing systems are somewhat functional in the third trimester. Hearing is more completely functional than vision, in that the eye responds to light by closing the pupil. Infants have to develop control the fine muscles of the eye that contract the pupil according to the amount of light entering the eye as well as the muscles which control the curvature of the eye allowing the eye to focus light onto the retina and the muscled which control movement of the eye within the eye socket.

Sight

In the third trimester, fetus will instinctively turn towards light, indicating that the brain registers the difference between light and dark. At birth, infants are drawn to faces, particularly faces with eyes. They do not, however, seem to be able to distinguish details of individual faces. This is likely because the eye muscles required for minute focus are not fully developed yet. Additionally, the brain structures for recognizing details in patterns require experience to develop.

Hearing

The third trimester also ushers in the ability to hear. Because the brain develops gradually, stimuli have varying ability to produce reliable brain responses. Hearing is a good example. By about 26 weeks, a fetus will respond to loud noises some of the time. By 28 weeks, fetal response to sound is more reliable. By 33 weeks, auditory stimuli produce responses in the auditory cortex. In part this may be explained by the fact that much of the brainstem receiving the immediate stimulus only begins to form connections to the cortex at about 26 weeks. As more connections are made, more of the stimulus will be able to be passed on to the cortex. At birth an infant is able to recognize speech patterns. The infant brain reacts differently to human speech, any human speech, whether it is their Mother's language or not, differently than it reacts to other noises. By about 12 months, an infant will react differently to its native language than to a non-native language.

Smell

The sense of smell is not possible to measure in utero because the fetus is surrounded by amniotic fluid. However, tests done on preterm infants indicate that there is some response to olfactory stimulation from about 29 weeks. There may be olfactory response before that because the nose opens at about 20 weeks, but preterm infants that are that young generally do not survive out of the uterus. Most infants respond favorably to smells that are familiar, like amniotic fluid and their mother, and to food, like colostrum. This phenomenon explains why infants are soothed by having something nearby, a blanket or piece of clothing that smells like their mother. Infants may also use the sense of smell to find the nipple.

Touch

Surprisingly, a prenatal response to pain can actually be elicited. Many years ago studies were performed on therapeutically and spontaneously aborted fetuses. By about 19 weeks fetus withdraw from painful stimuli such as poking. The responses described may actually be spinal reflexes rather than responses elicited from the brain. It is possible that fetal response to pain is limited, however, because of their exposure to several anesthetics produced by the placenta. (Lagercrantz et al, 2009, pg 258) Furthermore, the fetus probably does not experience pain in the way that we do because the somatosensory pathways in its brain are not fully connected until the third trimester. In preterm infants as young as 25 weeks, a response to pain is noted in the somatosensory cortex when blood is drawn. Infants, however, respond to sensations other than simply pain. They are certainly soothed by being held and rocked, which may have more to do with the motion or proximity of a heartbeat. But, they are frequently soothed simply by being touched as well. They respond with crying to cold and to heat.

Taste

The tongue develops from two different types of tissue. The outer part of the tongue develops from ectoderm tissue in the pharynx. The internal parts of the tongue develop from muscle precursor tissue cells called myocytes. The derivation from the two different tissue types explains why the tongue, unlike so many other sensory organs in the head, requires two cranial nerves rather than just one. The tongue forms beginning in the 4th week, so presumably as soon as the nerves connecting the ectodermal tissue to the brain are functions, the tongue is able to taste. (Larsen, 1997, pg 349)

Birth to School

Most of the skills that a child will need to succeed in school are actually learned before he or she enters the classroom. School builds upon these skills, enhances, refines and expands them, but the classroom does not lay the groundwork, which must come before a child enters the classroom. At least that is how the system is supposed to work. Because my students are all young mothers and because most of their children will enter the New Haven school system, it is incumbent on our school to make sure that the young mothers are able to teach their children the skills needed to be ready for Kindergarten. That preparation is the goal of this section of the unit.

In teaching this section, the goal will be for the students to put together a book to be used with their children. The students will be asked to select a target age for the audience of their book. The students will, then, figure out what the skills the brain is ready to explore at the age. Those skills will form the basis of the topic of the book, which will be designed to teach those skills to a child. In a paper that will accompany the book, the students will have to explain the skills they are trying to teach and explain how their book teaches those skills. They will also have to explain what other skills might be appropriate for their chosen target age, what skills would have been learned before and what skills might build on those they are trying to teach.

Another possible assessment strategy for this section might be to have students come up with a developmental timeline of skills a child should have as they grow. I would be somewhat reluctant to do this particular activity with my own students simply because I would hate for them to become unduly concerned about their child's development if it is a bit slower than the norm; however, I think this activity would probably work quite well in a regular classroom setting.

Motor Skills

Motor skills develop early in life and are among the first tested to measure infant development. Some early milestones include suckling, pupil dilation and contraction, grasping objects, lifting and turning of the head, sitting, manipulating objects, crawling, standing, and walking. The use of muscles becomes refined throughout life. Anyone who has seen the difference between a toddler's gait and an adult's can see that there is great improvement in muscle control that happens between the two stages. (Cools et al, 2009)

However, muscle control goes beyond simply movement. Fine muscle control is necessary for much of a child's later education. Writing, for example, is essential for education. The difference between kindergarten handwriting and high school hand writing illustrates the gradual improvement in fine motor control that occurs between the ages of five and eighteen. Many of the muscles used for suckling are later used to form words or playing wind instruments. The regions of the brain that are used by toddlers to manipulate objects are later used by children, and in some cases adults, to mentally rotate objects as one might do for geometrical or architectural problems. (Nelson, et al, 2006) As a child develops, the gross or more generalized movements become more refined with use as the muscles become specialized for various tasks. So, while a kindergartener might be expected to write his or her name, they could not do so without the basic gross motor skills needed to hold the writing implement.

Since, my students are preparing their children for our future kindergarten classes, my goal is to focus on some of the basic motor skills a preschool child ought be have accomplished before school. The skill that tend to be tested on the movement assessment tests included in Cools et al include locomotion, stability and balance, object manipulation, including throwing, rolling, catching, and hitting balls, reflexes, fine motor skills, grasping objects, bilateral coordination, and strength. Most early childhood development texts will elaborate on these skills, as well. (Cools et al, 2009)

One way for students to introduce these skills in a book might be to ask the child to point at objects in illustrations. For example, the text might read, "the dog is playing with a ball, can you point to the ball?" The child could then point to the ball in the picture. Alternatively, hook and loop closures over pictures, spinning dial, buttons, and other interactive features can be used to enhance motor skills. It might be a good idea to look at some children's books with the students to analyze what features might be adapted into their own creations and which adaptations are appropriate for various age groups.

Language [5]

Language is an essential part of human culture. Every human culture uses a language of some sort. While other animals such as elephants and cetaceans certainly communicate using auditory pathways, no other animal appears to communicate with the degree of complexity that we do. As language is so essential to being human, it is not surprising that many of the prerequisites for language, such as hearing, seeing, and auditory pattern recognition are present even before birth. Language is also quite complex in that it requires the use of several parts of the brain to function. As noted above, the muscles that are first used for suckling are later used to form words in speech. However, children learn to speak by imitating what they hear, so auditory pathways are also essential for language.

Infants, even before they are 6 months old react to the sound patterns in language. They react to sound patterns in all languages, not just the one that is predominantly spoken around them. However, as they grow accustomed to one predominant language, their ability to recognize speech narrows to focus on the patterns in the predominant language so that by 12 months infant focus on the sound patterns in their predominant language. By 2-3 months children can differentiate between speech going forward and speech going backward. This is not to say that children can not learn other languages, it just means that it takes a bit longer for children to learn the new language patterns. For example, 3-6 year old children can learn to recognize speech patterns in a non-native language after 2 months of training. The brain appears to treat sign language as it does spoken languages. Finally, language appears to be most easily acquired before adolescence. So, in guiding students working on their books, I would recommend focusing on language in the books which would emphasize repeated sounds, so rhymes and alliteration might be good concepts to introduce with the language component of this unit. (Nelson, et al, 2006, Ch. 4)

As it appears from the cognitive development books that children learn language by learning sound patterns, sound patterns are probably a good way to teach language. As the students write their books, it will be important to consider the words that are used in the text. Word sets with repeating sounds, such as alliterative language or rhyming words would be a good place to start. This may one reason why so many nursery rhymes and children's songs have been used to introduce language to children.

Mathematics [6]

The field of mathematics is composed primarily of spatial awareness (and the observation of objects in space) and logic. These two skills seem to develop much later in life than the language skills do. However, there are aspects of these two fields that do begin to develop in young children.

Children as young as 8 months appear to begin to recognize patterns, such as general face shapes. However, they do not yet appear to be able to distinguish between faces. This is not to say, however, that they do not distinguish between people. From my own observation of the infants in our school's daycare, children as young as 3 months will show a distinct preference for people they recognize. However, they may be using non-pattern based cues like scent to differentiate between people. By four years old, however, children can reproduce patterns, with both local and general features. This ability is a necessary prerequisite for learning to write, both letters and numbers. It is also necessary for learning to recognize geometric shapes and to count objects.

While children, even as young as 4 years old can recognize and reproduce patterns, their brains do not process patterns in the same way as an adult brain. Children tend to process patterns on both sides of their brains rather than processing in a more specialized region as adults do. The do not process patterns in a fully adult manner until about age 14; although as young as 7, they do begin to process global patterns in a more adult-like manner.

Spatial cognition is not limited to patterns, and mathematics, particularly advanced mathematics like geometry, tend to rely on the ability to rotate object mentally. This is a skill that most children do not acquire until about age 10-12 years. Even then, children tend to use the parietal lobe to process the information while adults tend to use the frontal lobe. Occasionally, the motor cortex is used by both groups as well.

In teaching this section to students and presenting information for use in their books, I would recommend focusing on pattern recognition, but mostly for older (closer to kindergarten) children. Faces work very well for young children, as human children seem to be instinctively drawn to faces, even from a very young age. Older children may also be able to begin counting simple objects.

Finally, because logic tends to be processed in the frontal lobe, it is one of the last skills to develop. The frontal lobe is not fully myelinated, hence not fully functional, until about the age of 30. That puts most of the increase and improvement in logic toward the end of high school and into college and the early years of a career, hence, beyond the scope of this unit.

Other skills

Most other skills need for school are built upon math and language skills. Even the social skills needed for appropriate social interactions are built upon pattern recognition needed to identify positive and negative reactions to a particular action, linguistic cues, and an understanding of the logic of the rules of a society. No skills acquisition would be possible, however, without memory. Memory appears to function, at least short term memory, from birth or possibly even shortly before birth. However, it is difficult to test in very young infants because they lack the motor skills needed to respond to stimuli.

In teaching this to my students, I plan to remind them again, and again, that memory is most strongly built upon repetition, so if they wish their children to acquire and retain a skill, the skill will have to be taught and practiced. This concept, of course, also holds true for our students, too. Good luck!

Resources

Books

Teachers

Johnson, M. H. (2005). Developmental cognitive neuroscience: An introduction, 2nd ed.. Malden, MA: Blackwell Publishing.

Nelson, C. A., de Hann, M., & Thomas, K. M. (2006). Neuroscience of cognitive development: The role of experience and the developing brain. Hoboken, New Jersey: John Wiley & Sons, Inc.

Both of the cognitive neuroscience books are written by prominent members of the field of cognitive neuroscience. They contain similar information and are reasonably accessible once one has an understanding of basic brain anatomy and physiology.

Larsen, W. J. (1997). Human Embryology, 2nd ed.. New York, NY: Churchill Livingstone. This is a standard text in embryology and is well complimented by the visible embryo website.

Students

Bloom, F. E. (2007). Best of the brain from Scientific American. New York, NY: Dana Press. This book is an edited collection of recent articles on the brain and brain science collected from Scientific American magazine. It is accessible to high school students reading at an 8 th grade reading level or higher.

Healy, J. M. (2004). Your child's growing mind: Brain development and learning from birth to adolescence, 3rd ed.. New York, NY: Broadway Books. This book would be appropriate for students, but I would recommend finding the most applicable excerpts for class readings.

Journal Articles

Teachers

Cools, W, De Martelaer, K, Samaey, C, & Andries, C (2009). Movement skills assessment of typical developing preschool children: A review of seven movement skill assessment tools. Journal of Sports science and medicine, 8, 154-168. Article reviewing muscle development tests.

Lagercrantz, Hugo, & Changeux, J (2009). The emergence of Human Consciousness: From Fetal to Neonatal Life. Pediatric Research. 65, 225-260. Very useful, readily accessible article reviewing brain development.

Lee, J. C., Mayer-Proschel, M., & Rao, M. S. (2000). Gliogenesis in the central nervous system. Glia, 30, 105-121. This article will be more easily accessible with a background in neural anatomy.

Lenroot, R, & Giedd, J. N. (2006). Brain Development in children and adolescents: Insights from anatomical magnetic resonance imaging. Neuroscience and Biobehavioral Reviews. 30, 718-729.

Rhawn, J (1999).Fetal brain and cognitive development. Developemental Review. 20, 81-98. Good for historical context. Lagercrantz, et al offers more recent information.

Websites

Teachers

Insel, T. R. (2000). The development of brain and behavior. Retrieved April 6, 2009, from The development of brain and behavior Web site: http://www.acnp.org/g4/GN401000066/CH066.html

Johnson, K. A., Becker, J. A. (1999). The whole brain atlas. Retrieved July 27, 2009, from The whole brain atlas Web site: http://www.med.harvard.edu/AANLIB/home.html

Larsen, P. D., & Stensaas, S. S. (2007, September). PediNeuroLogic Exam. Retrieved April 4, 2009, from PediNeuroLogic Exam website Web site: http://library.med.utah.edu/pedineurologicexam. Good basic website.

Students

Chudler, E. H. (2008). Neuroscience for kids - Explore the nervous system. Retrieved April 4, 2009, from Neuroscience for kids Web site: http://faculty.washington.edu/chudler/introb.html

Conlin, T Sushi. Retrieved July 27, 2009, from J-Quest Web site: http://ix.cs.uoregon.edu/~tomc/jquest/ . Very nice pictures of the brain.

Dubuc, B (2002, September). The brain from top to bottom. Retrieved April 4, 2009, from The brain from top to bottom Web site: http://thebrain.mcgill.ca/flash/index_i.html . Good basic information.

Goldberg, J (2009, July 27). The Dana foundation. Retrieved July 27, 2009, from The Dana foundation Web site: http://www.dana.org/resources/brainweb/detail.aspx?id=5110

Human brain map. Retrieved July 27, 2009, from BBC - Science and Nature- Human body and mind - body - brain map Web site: http://www.bbc.co.uk/science/humanbody/body/interactives/organs/brainmap/index.shtml

Office of Communications and Public Liaison, (2007, May 1). Brain Basics: know your brain. Retrieved July 27, 2009, from National Institute of Neurological Disorder and Stroke Web site: http://www.ninds.nih.gov/disorders/brain_basics/know_your_brain.htm

PBS, The secret life of the brain. Retrieved April 4, 2009, from The baby's brain Web site: http://www.pbs.org/wnet/brain/episode1/index.html. companion website to the video series, which is worthwhile also.

(1998). Probe the brain. Retrieved July 27, 2009, from A Science Odessey Web site: http://www.pbs.org/wgbh/aso/tryit/brain/#

Schoenwolf, G the visible embryo. Retrieved July 27, 2009, from The visible embryo Web site: http://www.visembryo.com/baby/index.html

Appendix: Standards

There appear to be very few standards that have been published either by the State of Connecticut's department of education or by the city of New Haven. In my own teaching I try to cover the major body systems found in the human body. The closest published standards that I have found which cover the brain and nervous system are for biology and are as follows:

Connecticut State Science Core Framework, page 34

"The nervous system mediates communication between different parts of the body and the body's interactions with the environment."

"The neurons transmit electrochemical impulses."

"Sensory neurons, interneurons and motor neurons all have a role in sensation, thought and response."

Notes

[1] This information can be found in far more detail with some beautiful pictures at http://www.visembryo.com/baby/index.html. It is also found in Larsen (1997)

[2] This line of cells is called the notochord and makes us chordates, according to biological taxonomy.

[3] Most of the information in this section comes from this McGill University website http://thebrain.mcgill.ca/flash/i/i_09/i_09_cr/i_09_cr_dev/i_09_cr_dev.html

[4] The information in this section comes in part from Lagercrantz's article and in part from the cognitive development books.

[5] Information in this section can be found in both Neuroscience of cognitive development and in Developmental cognitive Neuroscience

[6] Information in this section can be found in both Neuroscience of cognitive development and in Developmental cognitive Neuroscience