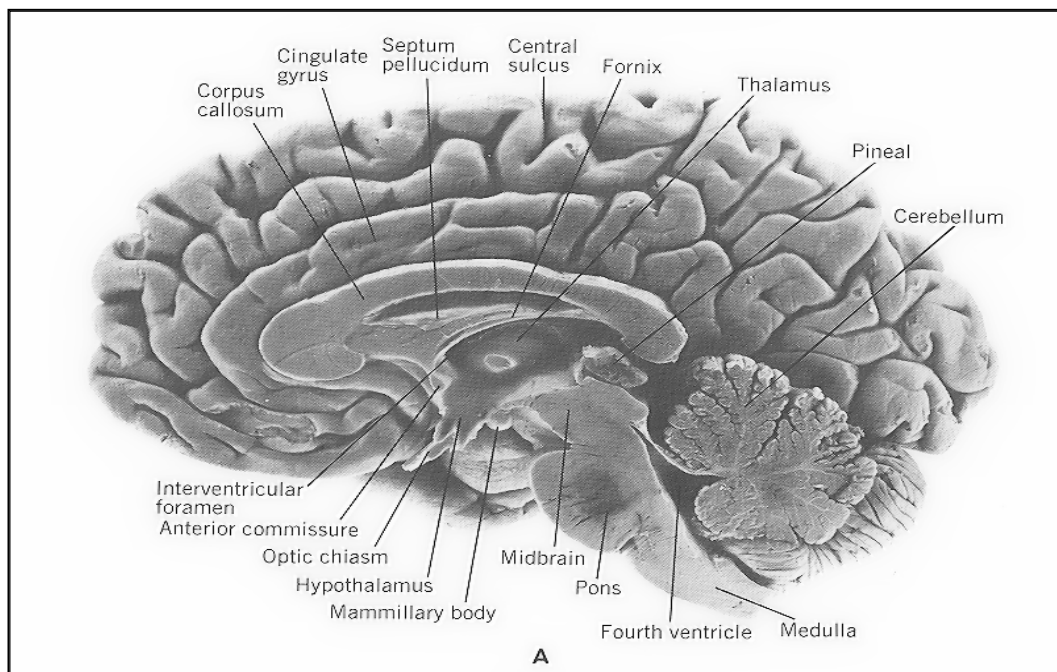




Video Series 1

UNDERSTANDING TRAUMATIZED AND MALTREATED CHILDREN:
THE CORE CONCEPTS

The Amazing Human Brain



Bruce D. Perry, M.D., Ph.D.

This chapter is designed as supplemental material for The ChildTrauma Academy's video/DVD series *Understanding Traumatized and Maltreated Children: The Core Concepts*. These materials have been developed by the ChildTrauma Academy to assist parents, caregivers, teachers and various professionals working with maltreated and traumatized children. Continuing Education credits can be given for reviewing these materials. Please refer to the Introductory materials for more information about additional supplemental materials and CEU credits.

TRAIN-THE-TRAINER SERIES
Edited by B. D. Perry

Introduction

The adult brain weighs about three pounds. This three pounds of, primarily, water and fat, allows us to walk, talk, and touch; to laugh and cry; to love and hate; to create and destroy. Everything we do, everything we think, everything we feel, every wish, dream, regret and hope is mediated by our brain. Our brain guides us through our lives. By sensing the world around us, storing some fragment of each unique moment, cataloguing, sorting, organizing and acting on our experiences, our brain defines us. It is the brain that allows us to be connected to each other in the present. It is the brain that links us to the past as our language, religion, economies, technologies - essentially all of our cultural practices - reflect the distilled experiences of thousands of generations of our ancestors. And it is the brain that connects us to the future as we pass elements of our life experience to the next generations. It is the brain that allowed humankind to create humanity.

The purpose of this course is to provide background information about the brain's structure and function that create the framework for understanding the impact that maltreatment or trauma may have on the developing child. The majority of professionals working with maltreated children do not have a background in biology or the neurosciences. This chapter is targeted at the wide group of non-neuroscientists working with maltreated children. Understanding of the rudiments of human brain function and brain development can provide very useful and practical insight to the, all-too-often, puzzling emotional, behavioral, cognitive, social and physical problems faced when working with maltreated children.

Course Objectives:

- *Present an overview of the basic structure, organization, and functioning of the human brain*
- *Discuss the brain's role in the survival of the species as well as the individual*
- *Provide the foundations of a neurodevelopmental approach to understanding human behavior and, consequently, the impact of child maltreatment*

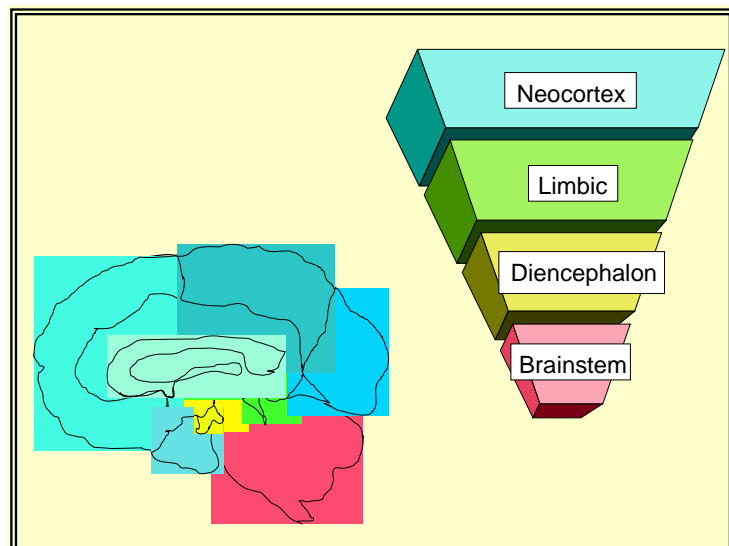
Section 1 - Key Points:

- *The “prime directives” of the brain and how these underlie and/or motivate human behavior at the most basic level*
- *The key actions of the brain (i.e., sensing, processing, storing, and acting) and how they enable the brain to accomplish its prime directives*
- *The brain’s (and the body’s) response to new information and novel stimuli; how this can impact human interactions and responses to situations*

The Prime Directives of the Brain

Sharks sense blood in water, dogs hear very high pitched sounds, bears detect scents from miles away, geese navigate thousand mile migrations somehow sensing magnetic fields of the earth, hawks see the movement of prey from hundreds of feet in the air and snakes “sense” body heat. Each of these unique capabilities is mediated by the animal’s brain. Their brain’s capacities to sense, process and act are designed to help keep them alive - to find food, to avoid threat, to procreate and keep the species going. It is, in many regards, the same for us. We need a brain to keep our species going. Without the unique properties of the brain, humankind would have long ago become extinct. Our brain helps keep us alive and thriving while we develop. And then, once mature, our brain allows us to create, protect, nurture and teach the next generation. Our brain is designed to help us survive, procreate and become caregivers.

The brains of the animals described above have sensory and brain-mediated capabilities that are specialized for the challenges and threats of the ecosystems in which they evolved - the climates, predators, prey, and geography that thousands of generations of their species faced. Again, it is the same for us. Our brain has special capabilities that helped promote survival in the environmental conditions - the ecosystems and social systems - facing thousands of generations of our human and pre-human ancestors. This is important. This means that the human brain, our brains, have structural and functional capabilities that



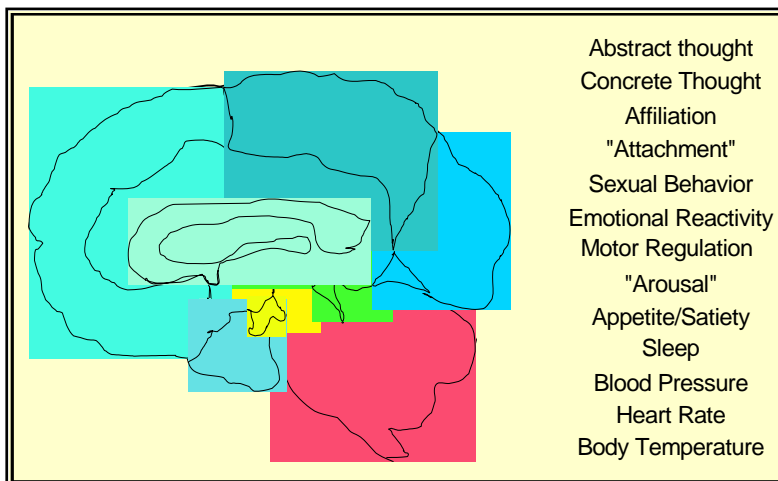
The Human Brain. The brain can be divided into four interconnected areas: brainstem, diencephalons, limbic and neocortex. The complexity of structure, cellular organization and function increases from the lower, most simple area, the brainstem to the most complex, the neocortex.

were selected to promote survival in "primitive" hunter-gatherer bands of about forty people. For 99 percent of the time we have been homo sapiens, our ancestors lived in these small groups where their lives were characterized by nomadic migration, cooperative hunting of large game, and foraging for non-cultivated fruits and grains. The social structures, economies, communications, technologies and manifestations of abstract creativity that now characterize human life were not present when the human brain was evolving. In many ways, the complexities of the modern world (a distilled reflection of the creativity of thousands of human brains) pose tremendous and unfamiliar challenges to a human brain designed for a different world.

It is in these historical roots that the brain's key capabilities were evolved, modified and refined to allow the survival of the species. The key elements of brain functioning work together to ensure that the three prime directives of the human brain allow the survival of the species. It is our brain that ensures that we survive, mate and procreate, and protect and nurture our young. Without the brain-mediated capabilities to do any of these, our species could not have survived.

The Key Actions of the Brain

Despite its complexity, the brain has some key actions. The brain senses, processes incoming signals, stores elements of this information, and acts on the incoming input.



Hierarchy of Brain Function: The human brain is organized from the most simple (e.g., fewest cells: brainstem) to most complex (e.g., most cells and most synapses: frontal cortex). The various functions of the brain, from most simple and reflexive (e.g., regulation of body temperature) to most complex (e.g., abstract thought) are mediated in parallel with these various areas. These areas organize during development and change in the mature brain in a 'use-dependent' fashion. The more a certain neural system is activated, the more it will 'build in' this neural state -- creating an internal representation of the experience corresponding to this neural activation. This use-dependent capacity to make internal representations of the external or internal world is the basis for learning and memory.

Sense: In order to keep us alive, the brain has a set of sensory organs (eyes, ears, nose, taste, touch) to tell us what is going on in the outside world. Remember, we can't hear like a dog, smell like a bear or see like a hawk. Our ears hear sound within a certain range, we see "light" in the visual range not infrared or ultraviolet, the perception of touch requires a certain level of pressure, we smell only when the scent is powerful or close. But, with the senses we have, our brain can integrate the information from these different senses and create an internal representation of the external world.

All experience is filtered by our senses. All

sensory signals (e.g., sound, sight, taste, touch), in turn, initiate a cascade of cellular and molecular processes in the brain that alter neuronal neurochemistry, cytoarchitecture and, ultimately, brain structure and function. This process of creating some internal representation of the external world (i.e., information) depends upon the pattern, intensity and frequency of neuronal activity produced by *sensing, processing and storing* signals.

The more frequently a certain pattern of neural activation occurs, the more indelible the internal representation- the more indelible the 'memory.' Experience thus creates a processing template through which all new input is filtered. All living organisms have mechanisms to sense and respond to changes in their environments. These environments - external as 'sensed' by our five senses and internal as 'sensed' by a set of specialized neurons throughout the body (e.g., glucose or sodium sensitive neurons) - are always changing. A continuous, dynamic process of modulation, regulation, compensation and activation characterizes our neurophysiology - all designed to keep our body's systems in some state of equilibrium or homeostasis. Each of our many complex physiological systems has a rhythm of activity that regulates key functions; when blood sugar falls below a certain level, a set of compensatory physiological actions are activated. When tissue oxygen is low from exertion, when an individual is dehydrated, sleepy or threatened by a predator, still other regulating activities will be turned on to respond to the specific need. For each of these systems there are 'basal' or homeostatic patterns of activity within which the majority of environmental challenges can be sustained.

We have other sensory mechanisms to tell the brain what is going on in the internal world - the physiological milieu of the body. For example, we have special sensory apparatus that tell the brain the concentration of oxygen in the blood; others sense the concentration of salts (too high and we become thirsty), or gases such as CO₂. These internal sensory apparatus, like the five senses for the external world, help the brain continuously monitor and act to keep us alive.

Process: Once our sensory apparatus has translated physical or chemical information from the outside (or inside) world into neuronal activity, this set of signals travels up into the brain to be processed. Sensory information from the external environment (visual, auditory, tactile, olfactory, gustatory) and the internal environment (e.g., blood glucose, arterial pressure, CO₂ levels) enters the central nervous system at the level of the brain stem and midbrain. As this primary sensory input comes into the brain stem and midbrain, it is matched against previously stored patterns of activation and, if unknown or if associated with previous threat, the brain will activate a set of responses that are designed to help promote survival. This alarm response is at the heart of the post-traumatic symptoms seen in so many maltreated children (see other ChildTrauma Academy booklets).

Throughout life, the brain is sensing, processing and storing patterns of neuronal activation (i.e., making memories) that correspond to various sights, sounds, smells, tastes, movements. Using various modes of memory (e.g., cognitive, emotional, motor), the brain stores these patterns, makes associations between the

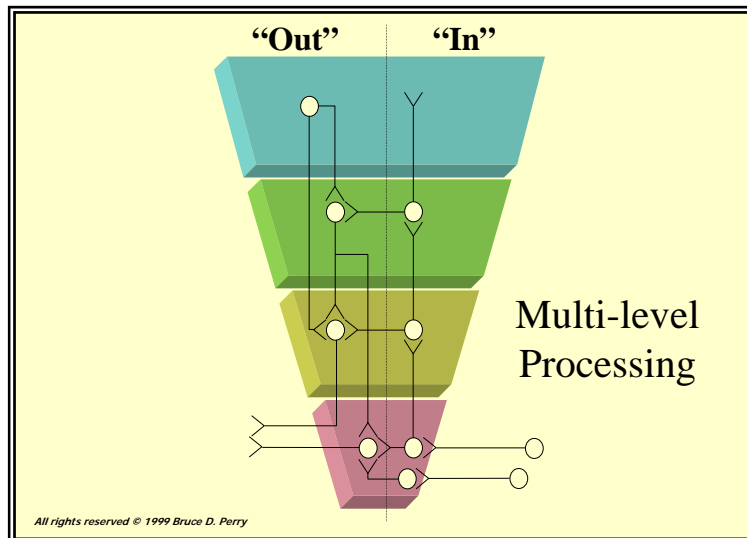
multiple sensory stimuli that co-occur, and creates templates of experience against which all future experience is matched.

In this regard, the brain is a conservative organ. It does not like to be surprised. All unknown or unfamiliar environmental cues are judged to be 'threatening' until proven otherwise. Novel stimuli focus attention, increase arousal and induce an alarm response until they can be proven neutral or safe. New patterns and cues that do not match the stored 'memories' of previous experience prime the stress-response systems in the brain. Once categorized as neutral, safe or threatening, these stored 'memories' are added to the catalogue of patterns, cues and associations against which subsequent environmental cues are matched.

What is safe and comfortable becomes so through experience; something in the present moment matches the associated, stored 'memories' of previous safe, pleasing or rewarding experiences. In contrast, when the environment, internal or external, matches with stored neuronal patterns associated with a previous threatening experience, the brain's stress-response systems will be activated. Key signs and symptoms of trauma-related neuropsychiatric disorders result from these memories of 'fear' - storing elements of traumatic experience, making associations, generalizing and, later, triggering complex, multi-system responses (i.e., cognitive, emotional, motor, 'state') reflecting these 'memories'. This process of creating memories of fear occurs at multiple levels in the brain's hierarchical systems.

As the neural signals from primary sensory systems (i.e., vision, hearing, taste, touch, and smell) come into the brainstem, a process of integrating the signals begins. At each level of the brain, further integration takes place so that by the time the signals from an event reach the thalamic nuclei, there has been an integration that allows a more complex "internal" representation. Sensory integration--putting the sight, sound, smell and feel of an event together--is a crucial step in healthy development. There can be disruption of this capacity by even minor timing errors. If the signals coming from the neural systems responsible for hearing do not get into the thalamus and cortex in a synchronous way, there can be confusion, disorganization and abnormal functions. A tiny glimpse into this dysynchrony can be illustrated by the feeling you get when you watch a poorly dubbed foreign film - or if you watch TV with a tiny sound delay. The movements don't match with the sound - it is disorienting. Again, this can happen when fear alters the processing of incoming information - time seems suspended, sounds fade or accentuate, movement can seem in slow motion (anyone who has driven on ice and watched as their car slips towards someone else's bumper knows this feeling).

At each level of brain organization, the incoming afferent signal is categorized. By comparing the incoming signal with previously stored patterns, the brain can help categorize the incoming information. Sometimes this results in mistakes. For the Vietnam Vet, a loud firecracker can induce a startle response and anxiety even though he knows it is only a firecracker. That is because the incoming loud sound is categorized in the brainstem as being previously associated with threat and danger; there is an immediate response-- even before the signal can get to the cortex. At



Sequential Processing. All incoming sensory information first enters the CNS at the level of the spinal cord or brainstem. This means that the first place where patterns of activation are matched against previously stored templates is in these primitive areas. Indeed, the spinal cord and brainstem may process and act on incoming information before the integrated and interpreted signals even get up to the cortex (e.g., reflex withdrawal of a finger from fire).

each level of processing that takes place, there is a categorization process. This immediate, localized processing and acting can be crucial for survival. Your brainstem and spinal cord will tell you to withdraw your hand from a fire even before your cortex knows that you have been burned.

Another key step in processing experience is in organizing information. Because the brain cannot possibly create a unique neural imprint or pattern of change to store every element of every experience, the brain stores 'template' patterns based upon the first set of organizing experiences. All future incoming input is matched against these stored templates and, if sufficiently different

from the original pattern, the brain will make neural changes (i.e., create a memory) that reflects that tiny difference. Take the visual image of mother's face, for example. To the infant, if no other face has ever been seen, the infant's brain will create some neural templates of basic facial features--eyes, nose, mouth, expressions, etc. And when baby first sees father, the neural templates for face are in place--only minor modifications need be stored.

Store: Inherent in the processing of information coming into the brain is the capacity to store elements of these incoming signals. At the heart of our survival neurobiology is the capacity to make and store internal representations of the external world--memory. The ability of the brain to create memories is due to the capacity of neurons and neural systems to change from one 'homeostatic' state to another. In response to a set of stimuli-induced (e.g., sensations) alterations in activity, neurons undergo molecular changes that reflect this activity. In a very real sense, unless the homeostatic dynamic of a neural system is altered by "use", it will not change - it will not make internal representations of the experience--it will not make memories. Neurons and neural systems change in a "use-dependent" fashion. Therefore, when neural systems that have a homeostatic patterns of activation influenced by new or extreme patterns corresponding to new or extreme environmental situations, they will change their molecular neurophysiology, creating "memories."

This has important implications for understanding how we 'create' memories of traumatic experiences. For adults, most experiences have only a small component

that is 'new' or unique. Typically, the majority of places, faces, words, sounds, smells, tastes in any given moment are familiar - the brain has sensed, processed and stored these patterns before. In these situations only some portions of the brain are 'activated' and processing outside of their homeostatic range. In the classroom, for example, a lecture may result in cortical activation but will cause little new emotional, motor or arousal activity. The result, hopefully, is new cognitive memories - storing the information from the lecture. Similarly, practicing piano may result in new cerebellar-basal ganglia-motor cortex activity and create 'motor' memories but have little effect on emotional or state-regulation areas of the brain.

Act: Finally, the brain mediates and controls the actions of the human body. By regulating and directing the actions of the neuromuscular, autonomic, endocrine, and immune systems, the brain controls the actions of the human being. The neuronal pathways sending signals into a brain area are called afferent and those sending signals out are called efferent. The efferent pathways regulate the actions resulting from the process of sensing, processing and storage of incoming signals. Now this simple (and somewhat misleading) linear process is only a crude approximation of the key actions of the brain. Indeed, there are hundreds if not thousands of local and regional feedback loops in an open and interactive dynamic system (well beyond any mathematical models of complex systems yet developed).

Section 2 - Key Points:

- *Models for describing the structure, organization, and functioning of the brain*
- *The orderly manner in which the brain develops and organizes*
- *The component "parts" of the brain, their roles, and the ways in which they function*

Brain Organization and Function

In order to carry out all of these key actions, the brain has evolved a wonderful and highly functional structure. The brain is not just one homogeneous mass of tissue. The brain has a complex and hierarchical organization. Multiple parallel systems exist that mediate various distinct functions. In general, the complexity of brain structure and the functions that these different structures mediate are organized in a bottom to top organization (see Figures above)

The bottom line is that the brain has lots of parts. For our purposes, the brain will be divided into four major areas: brainstem, diencephalon, limbic and neocortical. This, of course, is not the only way to divide up the brain. The organization of the brain can be described from several perspectives. This is not surprising considering how complex it is. Several ways to think about the organization of the brain are listed below.

One common and important way to think about brain organization is to literally look at it. There are two major approaches to “looking” at the brain; what is visible to the un-aided eye (gross anatomy) and what is visible when using magnifying aids (neurohistology). The combination of the different areas determined from neurohistology and from neuroanatomy has defined many constituent parts of the brain (see table below). From these constituent parts, certain larger regions can be

<p align="center">Maclean’s Triune Brain A Paleoevolutionary View of Human Brain Structure and Function</p>
<p align="center"><i>Neomammalian</i> (Neocortex and key thalamic nuclei)</p>
<p align="center"><i>Paleomammalian</i> (Limbic cortex and associated limbic system including amygdala and hippocampus)</p>
<p align="center"><i>Protoreptilian or R-complex</i> (Caudate nucleus, putamen, globus pallidus and associated brainstem inputs)</p>

defined. In one of the most original and useful ways of understanding the human brain, Paul Maclean, a pioneer of modern neuroscience, has defined three distinct systems within the brain that correspond to key evolutionary systems that have evolved across various species. This Triune Brain model defines the lower, less complex areas of the brain as being similar in structure and function to the reptilian brain - hence his term the R-complex. Maclean identifies the limbic and associated areas as the paleomammalian system.

Finally, the neomammalian systems are those that are in the neocortex and associated sensory integration nuclei in the thalamus. These areas are uniquely organized in primates. In other Academy booklets examining the impact of abuse, neglect or trauma on the brain, we will return to this useful model.

The more common approaches to division of the human brain are outlined in the table below. In the most simple, there are three divisions: hindbrain, midbrain and forebrain. The developmental style of dividing is based upon the developmental heritage of the given constituent parts. The four-part division used in this booklet is on the left hand column.

The key observation in organizational process is that the brain has a hierarchical organization, from bottom to top, becoming more complex. The most complex part of the brain is the cortex when 50% of all neurons in the brain are within the outer ¼ inch of the surface of the cortex. When examining genetic homology across species, the frontal cortex (part of the neocortex) is the most “uniquely” human with only about 94% homology with non-human primates while other cortical areas are 96 to 98% homologous. It should be no surprise then that the cortex, especially, the frontal cortex, mediates the most unique human properties.

Matching the hierarchical structure is a hierarchy of function. The simplest regulatory functions are mediated by the lower brainstem areas and the most complex by the neocortex (see Figures). The key to remember is that different brain areas and systems mediate different functions. This will be important when trying to

understand the changes in emotional, behavioral and cognitive functioning that take place when someone is threatened.

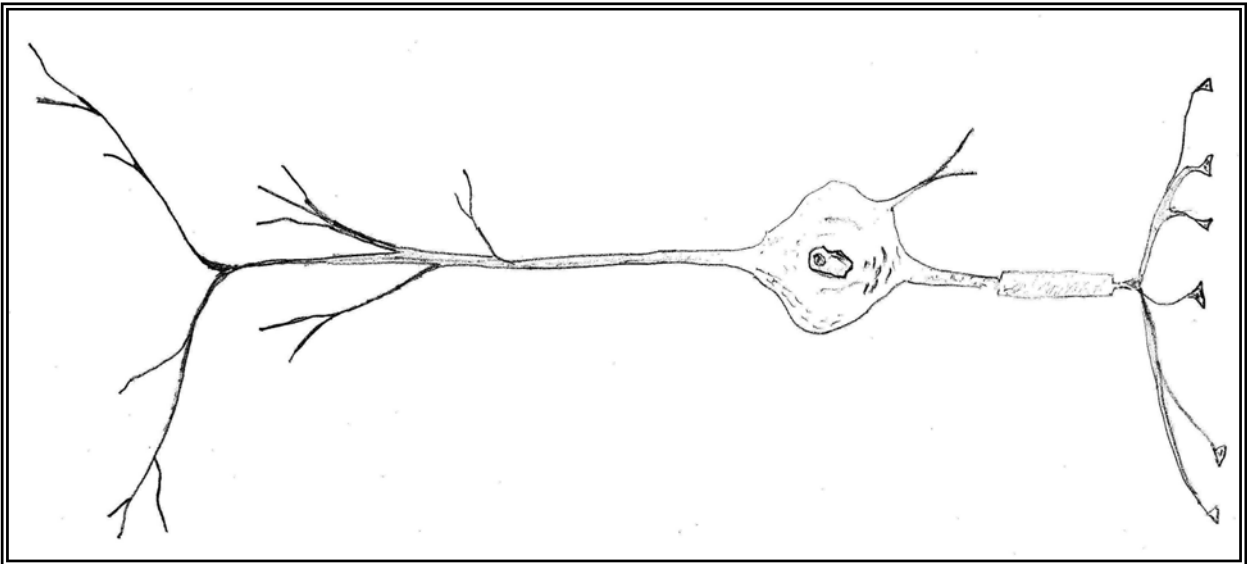
Functional Division	Constituent Parts	Developmental Division	Primary Division	
Neocortex	Cerebral cortex <i>Frontal Lobes</i> <i>Temporal Lobes</i> <i>Parietal Lobes</i> <i>Occipital Lobes</i> <i>Corpus Callosum</i>	Telencephalon	Cerebral Hemispheres	Forebrain
	Amygdala			
	Hippocampus			
Limbic <i>Cingulate Cortex</i> <i>Amygdala</i> <i>Hippocampus</i> <i>Septum</i>	Basal ganglia <i>Caudate Nucleus</i> <i>Putamen</i> <i>Globus Pallidus</i>			
	Thalamus	Diencephalon	Diencephalon	
	Hypothalamus			
Brainstem	Midbrain <i>Superior Colliculus</i> <i>Inferior Colliculus</i>	Mesencephalon	Brainstem	Midbrain
	Cerebellum	Metencephalon		Hindbrain
	Pons			
	Medulla Oblongata	Myelencephalon		
Spinal Cord	Spinal Cord		Spinal Cord	

The Brain's Building Blocks

The brain is an amazingly complex organ. Indeed, it is the most complex biological organ in the known universe. It is comprised of trillions of "moving parts" - the cells of the nervous system.

Neurons: The basic structural units of the human brain are cells. The brain is comprised of two major types of specialized cells, neurons and glial cells. Each cell has a cell wall, a membrane that separates the inside (intracellular) components of the cell from the outside (extracellular) environment of the cell (Fig. below). Inside each of these 100 billion neurons and 1 trillion glial cells is the exact same genetic material, the same genes. Yet, each of these 1.1 trillion cells is expressing only a portion of this genetic material. More astounding, each of these cells is expressing a unique pattern of gene activation that is a reflection of the cell's history and current environment. Neurons are cells specialized to receive, store and transmit information--the business of neurons is communication. All neurons have special structural features that allow neurons to 'communicate'--to receive, process, store and send 'information' that comes from their outside (extracellular) world (sound familiar?). Specialized structural and biochemical properties allow to receive a stream of chemical signals from other neurons, process these incoming 'messages', change their chemical interior in response to these signals (and thereby, store important 'information'), and then transmit the summed signals to other neurons. Chains of neurons embraced in continuous dialogue, continuous communication,

create functional systems that allow the brain to mediate and control a host of remarkable activities. Neurons come in a variety of shapes and sizes. Most of them have a long process called an axon that conducts information away from the neuronal



The Neuron. Neurons come in a variety of shapes and sizes. Most of them have a long process called an axon (right half of figure) that conducts information away from the neuronal cell body (soma) and a series of smaller processes called dendrites (left half) that receive information from other nerve cells through synaptic connections (synapses). The vast majority of human neurons are multipolar; that is, there are multiple dendritic projections from the cell body and almost always an axon as well.

cell body (soma) and a series of smaller processes called dendrites that receive information from other nerve cells through synaptic connections (synapses). The vast majority of human neurons are multipolar; that is, there are multiple dendritic projections from the cell body and almost always an axon as well. Some are also unipolar or bipolar, having one or two processes, respectively.

There are hundreds of "types" of neurons. They can be classified by unique structural properties or by unique functional properties. Neurons that are directly involved in the transduction of physical or chemical signals from sense organs are called sensory neurons. Sensory neurons are either directly sensitive to various stimuli (i.e. touch or temperature changes) or else receives direct connections from non-neuronal receptor cells. Motor neurons end directly on muscles or glands. Interneurons interconnect other neurons. For the most part, the CNS is composed almost entirely of interneurons. In some areas of the brain, neurons are densely packed while in others they are distant. Most neurons form their connections with neighboring neurons that are physically adjacent. Through short axonal connections, these "intrinsic" neurons interact with and modify brain activity in their local areas. Other neurons, however, send axons to other neurons in distant areas of the brain. These are called extrinsic neurons. Extrinsic neurons tend to form groups or clusters called nuclei. The nucleus of cells then sends a group of axonal connections to various distant brain areas. One extrinsic neuron may send axonal projections to several

widely separate brain areas. The fact that one neuron or one group of neurons can send simultaneous signals to many areas suggests that these nuclei will play important roles in orchestrating and coordination of communication and functioning of the brain.

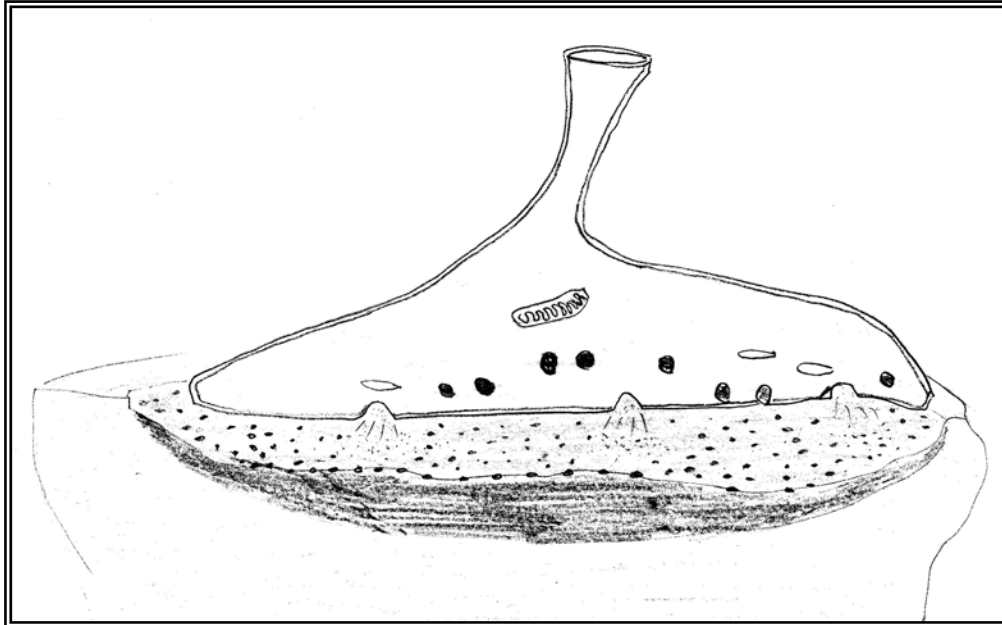
Glial Cells: Glia get a bad rap. Despite being 90% of the cells in the brain, we don't have "gliologists" or "the gliosciences"--we have neurologists and the neurosciences. Make no mistake, neurons are the major functional cells in cross-regional communication. Recent studies suggest that glial cells also play an important role in communication. Many glial cells have receptors for neurotransmitters and may play a role in the co-release of various classical and non-classical neurotransmitters or neuromodulators.

The major functions of glial cells, however, appear to be "supportive" of the communication functions of neurons. To do so, there are several types of glial cells in the CNS. Some of them (oligodendroglia in the CNS and Schwann Cells in the periphery) form myelin sheaths, which are fat wrappings--like insulation--around axons that allow the axons to conduct information more rapidly. Other types of glial cells regulate the composition of extracellular fluids, complement neurons in certain metabolic activities, and participate in various humoral functions within the CNS. Glial cells provide crucial 'support' functions for neurons (e.g., guiding developing neurons to the 'right' places in the brain, storing extra energy for active neurons).

How Neurons Communicate

Synaptic transmission: Neurons and glial cells are the 'building blocks' of brain structure, while neuron-to-neuron communication is the basic unit of brain function. It is quite astonishing to think that, somehow, the memory of a loved one's face or the capacity to create a new loving bond with another person is created by some dynamic pattern of synaptic activation. Yet, based upon what is known about brain functioning, this must be the case. We have so much yet to learn, but one essential element of this process is neuron-to-neuron communication.

The major biochemical mechanism for this neuron-to-neuron communication is 'receptor-mediated' synaptic neurotransmission at unique areas where neurons come in close proximity. These areas of close proximity are called synapses. In the synapse, the distance between neurons is very short. A chemical (classified as a neurotransmitter or neuromodulator) released from one neuron makes its way across an extra-cellular space and binds to a specialized protein called a receptor. By occupying the binding site, the neurotransmitter helps change the shape of this receptor which helps it then catalyze a secondary set of chemical interactions INSIDE the neuron that create second messengers.



The Synapse: The neurotransmitter is stored in the vesicles, which will fuse with the pre-synaptic neuron's membrane and release the neurotransmitter into the synaptic cleft. The neurotransmitter diffuses across this space and occupies receptors on the post-synaptic neuron, initiating a cascade of chemical communication central to all nervous tissue functioning.

The second messengers such as cyclic AMP, inositol phosphate and calcium will then shift the intracellular dynamic of other chemicals which may even influence the activity of specific genes. This cascade of intracellular chemical responses can then influence the activity of that cell and may change the rate of firing - hence the rate of release of neurotransmitter.

A continuous dynamic of synaptic neurotransmission regulates the activity and functional properties of the chains of neuronal systems that allows the brain to do all of its remarkable activities.

The Remarkable Human Brain

The brain and its constituent parts are the most complex system in the known universe. With one trillion separate cells, each one in a continuous process of changing in response to chemical signals. From the moment of conception to the moment of death, the biology of the individual is changing. The greatest changes take place in the brain. Each of its trillion cells has the very same genes - the very same genetic potential. Yet, through the long process of development, the history of each cell's progenitors and its individual history of micro-environmental history (i.e., the timing, pattern, quality and nature of activation) have determined that at any given moment only a fraction of the genome is expressed. Each cell is expressing a different combination of the genome. Each cell is unique. Some cells become glia,

some neurons. Some neurons (noradrenergic) use norepinephrine as a neurotransmitter, some serotonin. Some noradrenergic neurons are in the locus coeruleus, some are in the pons. Some locus coeruleus noradrenergic neurons project to the hippocampus, others to the cortex and amygdala. And on and on.

It is in this complexity that our species has found the capability to store the accumulated experience of thousands of generations - to create human culture. Our language, religions, governments, childrearing practices, technologies, economies - are all man-made; yet all depend upon the remarkable capacity of the brain to make internal representations of the external world. It is the amazing plasticity and malleability of the human brain that allows humanity.

Section 3 - Key Points:

- *The human fear response and the parts of the brain involved in it*
- *The biological basis of communication and interpersonal connection*
- *Cortical Modulation and the reason this is critical for humans*
- *"Change-ability" of the brain*
- *The challenges the traumatized or neglected child faces in learning*

The Neurobiology of Trauma and Maltreatment

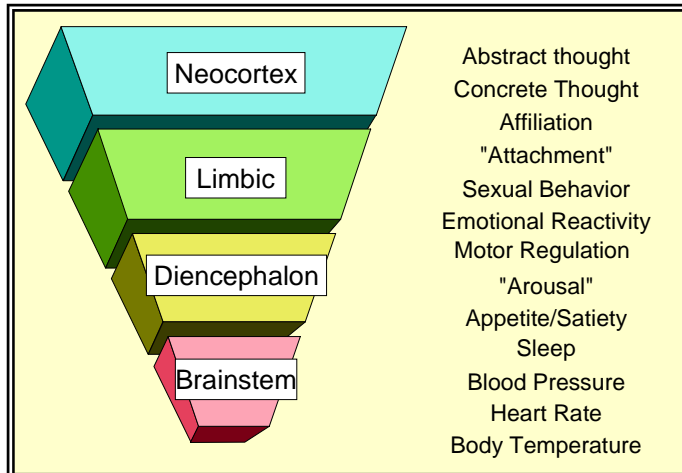
In order to understand the traumatized child we must understand the fear response. The human brain has a very elaborate and important set of neural systems involved in the response to threat. Indeed, it is the abnormal persisting activation of these systems that appears to lead to many of the symptoms seen in maltreated children. The next section will provide an overview of the key brain systems regulating the stress response.

Neural Systems Involved in Threat, Fear and Trauma

There are many neurotransmitters involved in the stress response. Some of the most important are clusters of intrinsic neurons that use the monoamine neurotransmitters epinephrine, norepinephrine, dopamine and serotonergic. These systems, despite comprising only a minor fraction of the brain's neurons, have disproportionate "power" to regulate human behavior, emotional functioning and cognition. This is because these systems originate in the brainstem and have connections in virtually all brain areas. Collectively, the brainstem monoamines regulate and mediate hundreds of crucial functions--including the complexities of the stress response.

The Reticular Activating System

Brainstem: The network of ascending arousal-related neural systems in the brain consisting of locus coeruleus noradrenergic neurons, dorsal raphe serotonin neurons, cholinergic neurons from the lateral dorsal tegmentum, mesolimbic and mesocortical



Hierarchy of Brain Function: The human brain is organized from the most simple (e.g., fewest cells: brainstem) to most complex (e.g., most cells and most synapses: frontal cortex). The various functions of the brain, from most simple and reflexive (e.g., regulation of body temperature) to most complex (e.g., abstract thought) are mediated in parallel with these various areas. These areas organize during development and change in the mature brain in a 'use-dependent' fashion. The more a certain neural system is activated, the more it will 'build in' this neural state -- creating an internal representation of the experience corresponding to this neural activation. This use-dependent capacity to make internal representations of the external or internal world is the basis for learning and memory.

dopaminergic neurons, among others, form the reticular activating system (RAS). A great deal of the original research on arousal, fear, response to stress and threat was carried out using various lesion models of the RAS. The RAS plays a major role in arousal, anxiety and modulation of limbic and cortical processing. These brainstem and midbrain monoamine systems, working together, provide the flexible and diverse functions necessary to modulate the variety of functions related to anxiety regulation.

Locus Coeruleus: A critical brain stem nuclei involved in initiating, maintaining, and mobilizing the total body response to threat is the locus coeruleus (LC). This bilateral grouping of norepinephrine-containing neurons originates in the pons and sends diverse axonal projections to virtually all major brain regions, enabling its function as a general regulator of noradrenergic tone and activity. The LC plays a major role in

determining the 'valence' or value of incoming sensory information, increasing in activity if the information is novel or potentially threatening. The ventral tegmental nucleus (VTN) also plays a part in regulating the sympathetic nuclei in the pons/medulla. Acute stress results in an increase in LC and VTN activity and release of norepinephrine that influences the brain and the rest of the body. These brainstem catecholamine systems (LC and VTN) play a critical role in regulating arousal, vigilance, affect, behavioral irritability, locomotion, attention, the response to stress, sleep and the startle response.

Hippocampus: The hippocampus is a crucial brain formation located at the interface between the cortex and the lower diencephalic areas. It plays a major role in memory including what we call episodic, declarative and spatial learning and

memory. In addition it plays a key role in various activities of the autonomic nervous and neuroendocrine systems. Stress hormones and stress-related neurotransmitter systems (i.e., those from the locus coeruleus and other key brainstem nuclei) have the hippocampus as a target. Various hormones (e.g., cortisol) appear to alter hippocampus synapse formation and dendritic structure, thereby causing actual changes in gross structure and hippocampal volume as defined using various brain imaging techniques. Repeated stress appears to inhibit the development of neurons in the dentate gyrus (part of the hippocampus) and atrophy of dendrites in the CA3 region of the hippocampus. These neurobiological changes are likely related to some of the observed functional problems with memory and learning that accompany stress-related neuropsychiatric syndromes, including Post-traumatic Stress Disorder (PTSD: see Academy Volume 2, Number 4).

Amygdala: In the recent past, the amygdala has emerged as the key brain region in the processing, interpreting and integration of emotional functioning. In the same fashion that the LC plays the central role in orchestrating arousal, the amygdala plays the central role in the CNS in processing afferent and efferent connections related to emotional functioning. The amygdala receives input directly from sensory thalamus, hippocampus (via multiple projections), entorhinal cortex, sensory association areas of cortex, polymodal sensory association areas of cortex, and from various midbrain and brainstem arousal systems via the RAS. The amygdala processes and determines the emotional value of simple sensory input, complex multisensory perceptions and complex cognitive abstractions, even responding specifically to complex, socially relevant stimuli. In turn, the amygdala orchestrates the response to this emotional information by sending projections to brain areas involved in motor (behavioral), autonomic nervous system and neuroendocrine area of the CNS. In a series of landmark studies, LeDoux and colleagues have demonstrated the key role of amygdala in 'emotional' memory. Animals, including humans, store information other than cognitive, and the storage of emotional information is critically important in normal and abnormal regulation of anxiety. The 'site' of perception of anxiety is likely to be the amygdala. It is in these limbic areas that the patterns of neuronal activity associated with threat, and mediated by the monoamine neurotransmitters systems of the reticular activating system, become an emotion.

Cortex: The quality and intensity of any emotion, including anxiety, is dependent upon subjective interpretation or cognitive appraisal of the given situation. Most theories addressing the etiology of anxiety disorders discuss the process of 'mislabeling' of stimuli as being 'threat'-related, thereby inducing a fear-response and anxiety in situations where no true threat exists. How an individual cortically-'interprets' the limbic-mediated activity (i.e, their internal state) associated with arousal plays a major role in the subjective sense of anxiety. Kluver-Bucy syndrome, resulting from damage or surgical ablation of temporal lobes results in loss of fear for current and previously threatening cues. The general disinhibition of this syndrome suggests a loss of the capacity to recall cortically-stored information related to previous threat, or to efficiently store threat-related cues from new experience.

Other areas of the cortex play a role in threat, primary among these are the primary and multimodal association areas which have direct connection to the amygdala. Important neurotransmitters in cortical, as well as other regions involved in threat are GABA and glycine. The capacity of benzodiazepines to alter arousal and sensitivity to threat has long been known. Indeed in humans, primary pharmacological treatment for many anxiety disorders involves benzodiazepine treatment, targeting GABA receptor complexes. While the GABA binding sites are ubiquitous in the CNS, the specific primary region for the therapeutic effects of benzodiazepines is unknown. It is likely that therapeutic effects are the result of action in multiple areas of the brain, including the cortex.

Fundamental to understanding the fear response is appreciating the essential role of relationships in human living groups. The neurobiology of the fear response is profoundly influenced by the presence and nature of other human beings. Human beings are designed to be interdependent.

Communication and Attachment

Communication between one human and another is the hallmark of our species. Communication was the critical capacity required for survival during the thousands of generations of our evolution. Naked, slow, weak and without biological armor or weapons, humans survived by living and hunting in groups. Interdependent individuals created a strong, flexible and adaptive 'whole' - the band, the clan, the tribe.

While physically separate and self-aware, individual humans are linked by the invisible, yet biological, bonds of sensation, perception and communication into larger biological units--collections of individuals--groups. One individual may belong to many groups--a couple, a family, a working group--each with unique and dynamic properties. Each group has a set of tasks and a set of rewards for the individual and, as a whole, the integrity and function of the group is formed, maintained and changed by social interaction.

Central to the invisible biological processes that allow social interaction is communication -- the capacity to perceive and understand others and to express meaning and intention to others. As might be expected, after thousands of generations, the human brain developed remarkable biological apparatus dedicated specifically to 'social' perception and communication, verbal and non-verbal. These underlying biological properties are continually 'at play' in all human interactions - sensing, processing, perceiving, storing and acting on signals from other humans. All human interactions are governed by core principles of communication that, in turn, are the product of neurobiological processes shaped by thousands of years of evolutionary pressures.

During the thousands of generations of the early history of our species, we lived in small bands--twenty to fifty members. Individual survival depended upon cooperation and communication. The remarkable expressive communication capacity of the face was further refined. Facial expression becomes the most important of all

social communication 'instruments.' Facial expressions have the capacity to reflect the internal emotional state of the individual, and elicit a specific emotional and social response from an individual - smile, frown, glare, snarl, ignore, stare, come hither, get lost. The face expresses pain, ecstasy, anger, fear, doubt, confidence and threat.

Socio-emotional communication: Central to the invisible biological processes that allow social interaction is communication -- the capacity to perceive and understand others and to express meaning and intention to others. As might be expected, after thousands of generations, the human brain developed remarkable biological apparatus dedicated specifically to 'social' perception and communication, verbal and non-verbal. Just as there are parts of the brain responsible for moving, others for seeing or hearing, there are systems in our brains that are dedicated to social-affiliation and communication. These parts of the human brain are organized, in part, by the somatosensory experiences of early life. Eye contact, rocking, cooing, smiling – all are translated by the sensory organs into patterns of neural activity. In turn these patterns are processed in lower parts of the brain and the organized, categorized patterns of activity converge in various sub-cortical and cortical areas (e.g., supraorbital prefrontal cortex, cingulate gyrus) where these waves of neuronal signals help organize these brain areas.

During development, each person creates a catalogue of familiar faces, the faces of the family and the band, and stores these as templates as familiar/safe. And in these familiar faces, the infant and child learn the non-verbal language of the group - as surely as they learn the verbal language. An unfamiliar face will elicit a low-level alarm response in any individual--all new faces are judged to be threatening until proven otherwise. This is due to two main factors. The first is that, in general, the brain's information matching process is very conservative. All novel situations and new information are judged to be

threatening until proven otherwise. The second and most powerful, specific reason that new faces elicit a low level alarm is that the human brain evolved in a world where for thousands of generations, the major threats to any individual were other humans - humans from other clans. A new person, a new face in the typical interaction from 100,000 years ago to 5,000 years ago meant that there were other humans around - competing for the same water, fruits, game, and cave. This new person was as likely to attack you, drive you away, steal your camping site, take the young and rape the women of your band, as they were to decide to affiliate or cooperate. Across generations, wariness to new individuals, new groups and new ideas was selected and built into the circuits of the human brain's alarm-response.

Over hundreds of thousands of years, proto-hominids and human beings lived in hunter-gatherer bands with thirty to forty members. Thus, the biological 'capacity' for the number of familiar/safe faces was quite small. And these template faces and facial features of 'same'/safe/familiar, like all other templates for emotional, behavioral and social functioning, are set during childhood. This tendency to have an alarm response when exposed to an unfamiliar face or mismatched facial features is the root of many human behaviors. For example, despite very minor (millimeter) differences in where facial features are placed, almost all people can immediately recognize the difference in a Down's syndrome child. This matching against previous

template faces is at the root of racism (and a strong argument why children of different races should be together in school and play - allowing them to build in diverse set of internal templates of what is same/safe/familiar).

This capacity to match diverse information against previous templates of multi-sensorial input is also at the root of recognition of deceit. When words do not match with body movement, facial expression, the tone of voice, the brain 'senses' a multi-sensory mismatch ('usually when some says "I love you", there are accompanying non-verbal signals eye contact, facial, body movement—or when someone is 'telling the truth'). This is, of course, why children raised with caregivers who talk the talk but don't walk the walk (e.g., domestic violence, multiple foster homes) internalize patterns of communication and interaction which are very distorted and often destructive (talk about association of intimacy, power, violence, threat,). And why, so often, children raised in these deceitful settings, can so easily lie without detection - they have not internalized the same non-verbal templates associated with deceit. For these children, the development of sociopathic characteristics is merely an adaptation to the deceitful, inconsistent and unrewarding world their caregivers have created for them.

Through these thousands of generations of evolutionary selection, the brain developed the capacity to read non-verbal cues - many of which are communicated via changes in facial expression. The brain has special face and expression recognition capabilities - and through a process of 'matching' expressions and faces with previous known faces and expressions, makes decisions about the familiarity and intentionality of the specific interaction.

Because we have a limited capacity for categorizing and matching specific faces and facial expressions, the brain uses other body movements, postures, and other symbolic trappings of recognition (e.g., clothes, uniforms, style of hair cut), to make secondary decisions about recognition. You may not recognize the face but the haircut, clothes, manner of interaction can readily identify someone as "familiar/good" or as "familiar/bad." This categorizing tendency, of course, is the basis for a host of well-described and common phenomenon in human interaction--including first impressions or using 'known' celebrities to sell products or ideas. A classic example of this in the mental health field is transference. This phenomenon involves attaching multiple attributes of a past relationship to a current relationship when only one of those attributes may truly be present (e.g., reacting to a male therapist with the intensity that was present in a paternal relationship).

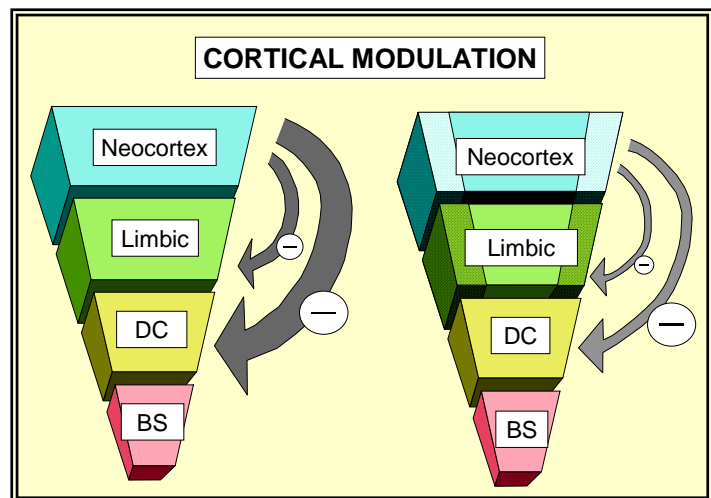
The Power of the Human Cortex

The human brain works, largely, through inhibitory mechanisms. The structural organization and functional capabilities of the mature brain develop throughout life; the majority of structural organization takes place in childhood. This development is characterized by 1) sequential development and 'sensitivity'--from the brainstem to the cortex and 2) 'use-dependent' organization of these various brain areas. As the brain grows and organizes from the "inside-out" and the "bottom-up" the higher,

more complex areas begin to control and modulate the more reactive, primitive functioning of the lower parts of the brain. The person becomes less reactive, less impulsive, more 'thoughtful.' The brain's impulse-mediating capacity is related to the ratio between the excitatory activity of the lower, more-primitive portions of the brain and the modulating activity of higher, sub-cortical and cortical areas. Any factors which increase the activity or reactivity of the brainstem (e.g., chronic traumatic stress) or decrease the moderating capacity of the limbic or cortical areas (e.g., neglect, brain injury, mental retardation, Alzheimer's, alcohol intoxication) will increase an individual's aggression, impulsivity and capacity to be violent (see below). A key neurodevelopmental factor that plays a major role in determining this moderating capacity is the brain's amazing capacity to organize and change in a 'use-dependent' fashion.

The capacity to moderate frustration, impulsivity, aggression and violent behavior is age-related. With a set of sufficient motor, sensory, emotional, cognitive and social experiences during infancy and childhood, the mature brain develops--in a use-dependent fashion--a mature, humane capacity to tolerate frustration, contain impulsivity and channel aggressive urges.

A frustrated three-year-old (with a relatively unorganized cortex) will have a difficult time modulating the reactive, brainstem-mediated state of arousal and will scream, kick, bite, throw and hit. However, the older child when frustrated may feel like kicking, biting and spiting, but has 'built in' the capacity to modulate and inhibit those urges. All theoretical frameworks in developmental psychology describe this sequential development of ego-functions and super-ego which are, simply, cortically-mediated, inhibitory capabilities which modulate the more primitive, less mature, reactive impulses of the human brain. Loss of cortical function through any variety of pathological process (e.g., stroke, dementia) results in 'regression' -- simply, a loss of cortical modulation of arousal, impulsivity, motor hyperactivity, and aggression -- all mediated by lower portions of the central nervous system (brainstem, midbrain). Conversely, any deprivation of optimal developmental experiences which leads to underdevelopment of cortical, sub-cortical and limbic areas will necessarily result in

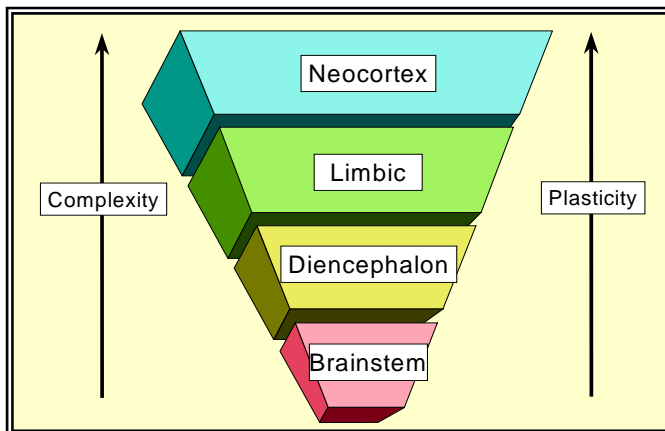


Cortical Modulation: As the brain develops in this sequential and hierarchical fashion, and the more complex limbic, sub-cortical and cortical areas organize, they begin to modulate, moderate and 'control' the more primitive and 'reactive' lower portions of the brain (Figure 2). These various brain areas develop, organize and become fully functional at different times during childhood. At birth, for example, the brainstem areas responsible for regulating cardiovascular and respiratory function must be intact while the cortical areas responsible for abstract cognition have years before they will be fully-functional.

persistence of primitive, immature behavioral reactivity and, predispose to violent behavior.

The Plasticity and Malleability of the Human Brain

The human brain is very plastic--meaning that it is capable of changing in response to patterned, repetitive activation (e.g., reading or hearing a new language, learning a new motor skill such as typing). Recalling, however, that the brain is not



just "one" large mass of equivalent tissue; recalling that the brain has a hierarchical and complex organization and that different systems mediate different functions, it stands to reason that not all parts of the brain--once developed--are as easy to modify or change with experience. Simply stated, not all parts of the brain are equally plastic.

The malleability of specific human brain areas is different. The most complex area of the brain - the cortex - is the most plastic. We can modify some cortex-related functions throughout life with minimal "effort." For example, even a 90-year-old person can learn a new phone number. The lower parts of the brain - those mediating core regulatory functions - are not very plastic. And that is for good reason. It would be very destructive for these basic and life-sustaining functions to be easily modified by experience once they were organized. A lesion that kills one million neurons in the cortex can be overcome - people recover language and motor skills following a stroke. A lesion in the brainstem that killed as many cells would result in death.

The degree of brain plasticity is related to two main factors - the stage of development and the area or system of the brain. Once an area of the brain is organized, it is much less responsive to the environment - it is less plastic. For some brain areas such as the cortex, however, significant plasticity remains throughout life, such that experiences can continue to alter, easily, neurophysiological organization and functioning. A critical concept related to memory and brain plasticity is the differential plasticity of various brain systems. Not all parts of the brain are as plastic as others. Once the brain has organized (i.e., after age three), experience-dependent modifications of the regulatory system are much less likely than experience-dependent modifications of cortically-mediated functions such as language development.

State-dependent Storage and Recall

As described above, the brain changes in a use-dependent fashion. All parts of the brain can modify their functioning in response to specific patterns of activation -- or to chronic activation. These use-dependent changes in the brain result in changes in cognition (this, of course, is the basis for cognitive learning), emotional functioning (social learning), motor-vestibular functioning (e.g., the ability to write, type, ride a bike) and state-regulation capacity (e.g., resting heart rate). No part of the brain can change without being activated -- you can't teach someone French while they are asleep or teach a child to ride a bike by talking with them.

Mismatch between modality of teaching and the 'receptive' portions of a specific child's brain occur frequently. This is particularly true when considering the learning experiences of the traumatized child--sitting in a classroom in a persisting state of arousal and anxiety--or in a state of dissociation. In either case, this child is essentially unavailable to process efficiently the complex cognitive information being conveyed by the teacher. This principle, of course, extends to other kinds of 'learning'--social and emotional. The traumatized child frequently has significant impairment in social and emotional functioning. These capabilities develop in response to experience -- experiences that these children often lack -- or fail at. Indeed, hypervigilant children frequently develop remarkable non-verbal skills in proportion to their verbal skills (street smarts). Indeed, often they over-read (misinterpret) non-verbal cues -- eye contact means threat, a friendly touch is interpreted as an antecedent to seduction and rape -- accurate in the world they came from but now, hopefully, out of context. During development, these children spent so much time in a low-level state of fear (mediated by brainstem and midbrain areas) that they were focusing consistently on non-verbal cues. In our clinic population, children raised in chronically traumatic environments demonstrate a prominent V-P split on IQ testing (n = 108; WISC Verbal = 8.2; WISC Performance = 10.4, Perry, in preparation).

This is consistent with the clinical observations of teachers that these children are really smart but can't learn easily. Often these children are labeled as learning disabled. These difficulties with cognitive organization contribute to a more primitive, less mature style of problem-solving -- with violence often being employed as a "tool."

This principle is critically important in understanding why a traumatized child--in a persisting state of arousal--can sit in a classroom and not learn. The brain of this child has different areas activated; different parts of the brain 'controlling' his functioning. The capacity to internalize new verbal cognitive information depends upon having portions of the frontal and related cortical areas being activated -- which, in turn, requires a state of attentive calm. A state the traumatized child rarely achieves.

Children in a state of fear retrieve information from the world differently than children that feel calm (see Figures). We all are familiar with 'test' anxiety. Imagine

what life would be like if all experiences invoked the persisting emotion of anxiety. If a child has information stored in cortical areas but in the specific moment is very fearful, this information is inaccessible. In this regard, cognitively stored information does little good in the life-threatening moment. Simple didactic conflict-resolution models are doomed to fail unless they involve elements of role-playing. Imagine how much you would trust an Army that went through combat training by sitting in classroom--or the E.R. physician about to run her first code after only leaning how to do that by reading a book. In the midst of most threatening experiences--situations where violence often takes place -- the 'problem-solving' information in the cortex is not easily accessed. It is of interest to note that information learned in song, rhyme or rap is more easily recalled when in a state of high arousal. This is due, of course, to the fact that this information is stored in a different fashion than traditional verbal cognitive information.

Ages	30 ← 15	15 ← 8	8 ← 3	3 ← 1	1 ← 0
Developmental Stage	Adult Adolescent	Adolescent Child	Child Toddler	Toddler Infant	Infant Newborn
Primary secondary Brain Areas	NEOCORTEX Subcortex	SUBCORTEX Limbic	LIMBIC Midbrain	MIDBRAIN Brainstem	BRAINSTEM Autonomic
Cognition	Abstract	Concrete	"Emotional"	Reactive	Reflexive
Mental State	CALM	AROUSAL	ALARM	FEAR	TERROR

When threatened, a child is likely to act in an 'immature' fashion. Regression, a 'retreat' to a less mature style of functioning and behavior, is commonly observed in all of us when we are physically ill, sleep-deprived, hungry, fatigued or threatened. As we 'regress', in response to the real or perceived threat, our behaviors are mediated (primarily) by less-complex brain areas. If a child has been raised in an environment of persisting threat, the child will have an altered baseline such that the internal state of calm is rarely obtained (or only artificially obtained via EtOH or drugs). In addition, the traumatized child will have a 'sensitized' alarm response, over-reading verbal and non-verbal cues as threatening. This increased reactivity will result in dramatic changes in behavior in the face of seemingly minor provocative cues. All too often, this over-reading of threat will lead to a 'fight' or 'flight' reaction -- and impulsive violence. The child will view their violent actions as defensive.

Children exposed to significant threat will "re-set" their baseline state of arousal such that even at baseline -- when no external threats or demands are present, they will be in a physiological state of persisting alarm. As external stressors are introduced (e.g., a complicated task at school, a disagreement with a peer) the traumatized child will be more 'reactive' -- moving into a state of fear or terror in the presence of even minor stressors. The cognition and behavior of the child will reflect their state of arousal. This increased baseline level of arousal and increased reactivity in response to a perceived threat plays a major role in the associated behavioral and cognitive problems associated with traumatized children.

Glossary:

Action potential: This is an electrical charge that travels down the axon of a neuron to the synaptic terminal where it can increase or decrease the probability that hundreds of intracellular vesicles filled with neurotransmitter will fuse with the pre-synaptic membrane of that neuron and release the neurotransmitter into the synaptic cleft. The action potential occurs when the neuron has been activated and temporarily reverses the electric polarity of the interior membrane from negative to positive.

Amygdala: This is a structure in the forebrain. It is part of the limbic system and plays a major role in emotional memory and the response to threat.

Axon: This is the tiny fibrous extension of the neuron away from the cell body to other target cells (neurons, muscles, glands).

Autonomic Nervous System: The ANS is that part of the nervous system responsible for regulating the activity of the body's other organs (e.g., skin, muscle, circulatory, digestive and endocrine system).

Central Nervous System: This is the portion of the nervous system comprised of the spinal cord and brain.

Cerebellum: This is a large cauliflower-looking structure on the top of the brainstem. This structure is very important in motor movement and motor-vestibular memory and learning.

Cerebral Cortex: This is the outer most layer of the cerebral hemisphere of the brain. The cortex mediates all conscious activity including planning, problem solving, language and speech. It is also involved in perception and voluntary motor activity.

Cognition: This refers to the mental process by which we become aware of the world and use that information to problem solve and make sense out of the world. It is somewhat oversimplified but cognition refers to thinking and all of the mental processes related to thinking.

Glia: These are specialized cells that nourish, support and complement the activity of neurons in the brain. Astrocytes are the most common and appear to play a key role in regulating the amount of neurotransmitter in the synapse by taking up excess neurotransmitter. Oligodendrocytes are glial cells which specialize to form the myelin sheath around many axonal projections.

Hippocampus: This is a thin structure in the sub-cortex shaped like a seahorse. It is an important part of the limbic systems and plays a major role in learning, memory and emotional regulation.

Homeostasis: This is the tendency of a physiological system (i.e., a neuron, neural system or the body as a whole) to maintain its internal environment in a stable equilibrium

Hypothalamus: This is a group of important nuclei that mediate many important functions. It is located at the base of the brain and connected to the pituitary by a network of specialized blood vessels. The hypothalamic nuclei are involved in regulating many of the body's internal organs via hormonal communication. The hypothalamus is a key part of the hypothalamic-pituitary-adrenal (HPA) axis that is so important in the stress response.

Limbic System: This is a group of functionally and developmentally linked structures in the brain (including the amygdala, cingulate cortex, hippocampus, septum and basal ganglia). The limbic system is involved in regulation of emotion, memory and processing complex socio-emotional communication.

Neuron: A cell specialized for receiving and transmitting information. While neurons have tremendous heterogeneity in structure, they all have some form of dendritic projections that receive incoming information and axonal projections that communicate to other cells.

Neurotransmitter: A chemical that is release from a neuron that can relay information to another cell by binding to a receptor on the membrane of the target cell.

Synapse: This is the specialized space between two neurons that is involved in information transfer. Neurotransmitter is released from one neuron enters the synaptic cleft (space) and sends a 'signal' to the post-synaptic neuron by occupying that receptor's receptors.

Thalamus: This is a paired structure of two tiny egg-shaped structures in the diencephalon. This structure is a crucial area for integrating and organizing sensory information that comes into the brain. In the thalamus, this information is processed and forwarded to the key cortical areas where more processing and integrating will take place.

Use-dependent: This refers to the specific changes in neurons and neural systems following activation. Repetitive, patterned stimulation alters the organization and functioning of neurons and neural systems and, thereby, the brain.

About the Author

Bruce D. Perry, M.D., Ph.D.

Dr. Perry is the Senior Fellow of the ChildTrauma Academy. Dr. Perry served as the Thomas S. Trammell Research Professor of Child Psychiatry at Baylor College of Medicine and Chief of Psychiatry at Texas Children's Hospital in Houston, Texas from 1992 to 2001. In addition he has served as the Director of Provincial Programs in Children's Mental Health for Alberta, Canada, and is the author of more than 200 scientific articles and chapters. He is the recipient of dozens of awards and honors and is an internationally recognized authority in the area of child maltreatment and the impact of trauma and neglect on the developing brain.

About The ChildTrauma Academy

The ChildTrauma Academy, a not-for-profit organization based in Houston, TX, is a unique collaborative of individuals and organizations working to improve the lives of high-risk children through direct service, research and education. These efforts are in partnership with the public and private systems that are mandated to protect, heal and educate children. The work of the Academy has been supported, in part, by grants from Texas Department of Protective and Regulatory Services, the Children's Justice Act, the Court Improvement Act and through innovative partnerships with academic and corporate partners such as Powered, Inc., Scholastic, Inc., Linkletter Media and Digital Consulting and Software Services.

The mission of the ChildTrauma Academy is to foster the creation of innovations in practice, programs and policy related to traumatized and maltreated children. To support this mission, the Academy has two main activities; 1) Program development and consultation and 2) Specialized education and training services.

For more information or to direct donations:

Jana Rubenstein, M.Ed., LPC
Director, ChildTrauma Academy
5161 San Felipe, Suite 320
ChildTrauma Academy
Houston, TX 77056
jlrcata@aol.com

Web Resources:

www.ChildTrauma.org
www.ChildTraumaAcademy.com