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Grand Central:

EARLY BRAIN ANATOMY AND VIOLENCE

"But, I don't understand you," said Dorothy, in bewilderment. "How was it that you appeared to me as a great head?"

"That was one of my tricks," answered Oz. "Step this way and I will tell you all about it."

He led the way to a small chamber in the rear of the Throne Room, and they all followed him. He pointed to one corner, in which lay the Great Head, made out of many thicknesses of paper, and with a carefully painted face.

"This I hung from the ceiling by a wire," said Oz; "I stood behind the screen and pulled a thread, to make the eyes move and the mouth open."

—L. FRANK BAUM
The Wizard of Oz

THE HUMPTY DUMPTY YEARS

Like the Wizard of Oz manipulating the show of sounds and lights for Dorothy, the human brain lies at the seat of control of all human behavior. Until very recently we had limited opportunities to look inside at this mysterious three-pound wizard nestled inside the human skull. Because of ethical considerations the primary research methodologies have historically been limited to studies on animals and the rare human specimens available through autopsy. But with new technologies like the Positron Emission Topography (PET) scan and Magnetic Resonance Imaging (MRI), we can now look inside the living human brain with noninvasive techniques that produce graphic images of what is going on. The "wizard", while becoming less mysterious, is inspiring even more awe as we begin to comprehend the complex machinations that take place to produce even the simplest behaviors.

Seemingly normal at birth, Chelsea was born more than forty years ago in a small coastal town in the Pacific Northwest. But unknown to her parents—and to a host of doctors who by school age evaluated her as retarded—Chelsea was deaf. She was isolated in school, where she was classified as being of low intelligence. It wasn't until she was thirty-one years old that a neurologist recognized her real disability and had her fitted with a hearing aid. Now Chelsea is an active member of her community. She works in a veterinary clinic. The only problem is that after fifteen years of therapy and with normal intelligence, she still cannot speak intelligibly. Chelsea is living testimony to the lesson that in human brain development, there is a critical period for spoken language. Because her brain was deprived of the sounds she needed to hear at a crucial time, the physical connections necessary for organizing speech in coherent sentences have forever been lost to her. Chelsea will never master normal sentence construction.[1]

Ryan was born to an unmarried college student who decided that the best future for her baby would be secured by placing him with married parents through adoption. However, the adoption agency,

unaware at that time of the importance of earliest attachment, was concerned about Ryan's irregular heartbeat. A response to anesthesia his mother had received for her cesarean delivery, the arrhythmia disappeared fairly quickly. But since medical assurances were paramount to the agency, it placed Ryan in a private foster home where, without the social worker's knowledge, the foster mother was taking care of nine other children under age three.

Ryan lay in a crib day after day. He drank cold milk from bottles that were propped to feed him. He heard the sounds of the other children, but he rarely saw an adult face. He was handled infrequently; his diapers went unchanged for most of the day. He developed a full-body rash, a bleeding diaper rash, cradle cap, ear infections in both ears, and, most fearsome, an unwillingness to be held or to look at an adult face. At nine weeks, when Ryan was finally placed in his adoptive home, he would turn away from efforts to engage him, staring instead at a bright light or a shining object. He had gained weight normally and, in spite of his rash, was a handsome, red-haired baby. But he did not want to be touched. If he cried, he preferred to lie on a flat space, where he would comfort himself. Ryan was not autistic. He was twice separated from major caregivers and severely neglected. What his brain had missed was touch, trust, and reciprocal contact with a parent. Now twenty-five years old, Ryan looks normal. He is a college student and works full-time. But he is still somewhat withdrawn, and his relationships with people, while improving each year, are superficial and lack spontaneity. Trust is still precarious for Ryan. Touch is still measured.

Neither Chelsea nor Ryan is a violent individual in spite of early losses. Both were raised in loving homes and environments that were protective and prosocial. But Chelsea and Ryan remind us that there are "critical periods" and sensitive periods for several key aspects of human development, including the ability to trust or to feel connected to other people. While we might like to believe that given sufficient opportunity we can reverse any damage done to children, the research tells us that the effects of some early experiences cannot be undone.

The most amazing result of all has been the portrait that emerges of the brain itself. Far from the preset, isolated, and independently functioning organ pictured in our biology texts of a decade ago, the brain is, in fact, a dynamic organism that is constantly reflecting and adjusting to the environment the individual is experiencing. While genetics do set the broad parameters, actual matter in the brain is built—or not—by sound, sight, smell, touch, and movement from the outside environment. By the eighteenth week of gestation, when the brain is still primitive, the fetus has developed all of the one hundred to two hundred billion basic brain cells or neurons that it will ever have in a lifetime. But by birth, connecting structures (dendrites and synapses) between those nerve cells have just started to form. Those connections now depend on the outside environment for completion. Stimulation from the baby's world actually generates the building of the corresponding systems to process that stimulation in the baby's brain. Seeing people and objects, for example, generates the building of dendritic and synaptic growth in the visual cortex; hearing sounds builds the auditory cortex; and so forth.

Both the matter of the brain and to some degree the function this matter performs are generated by exposure to stimulation. Because we are each different genetically and because each of our environments is different, no two brains are exactly alike. Babies who are talked to and read to or who are exposed to more than one language are building a different set of connections than those who are receiving primarily large-muscle stimulation—patty-cake, prewalking games, etc. While there are scientists such as Dr. Frank Kiel of Cornell University who believe that the brain comes prewired with some concepts, such as a preference for a human face over inanimate objects, there is general agreement in the scientific community that even before birth the brain is shaped by stimulation from the environment. After birth, development is an interactive process between the baby's physiology and his or her environment.

The dependence of the human brain on the environment for its growth begins to make sense when one considers the purpose of the

brain in all organisms. The primary goal of the brain is to enable the organism to survive. The key to survival and to human dominance on the planet is our ability to adapt to the kind of environment in which we find ourselves. Live video photographs can now show us that both the organic matter and the chemistry of the human brain change in response to our environments to allow us to cope with variables in our worlds. The parts of the brain that grow and the parts that don't depend on the baby's experience. Dr. Bruce Perry calls this phenomenon "use-dependent development."

So the genes provide the blueprints and lay down the basic framework of the brain. But the shaping and finishing within that framework is facilitated by the environment. As Ronald Kotulak said in his Pulitzer Prize–winning series on brain development published in 1993 in the *Chicago Tribune:*

> They work in tandem, with genes providing the building blocks, and the environment acting like an on-the-job foreman, providing instructions for final construction. . . . Sounds, sights, smells, touch—like little carpenters—all can quickly change the architecture of the brain, and sometimes they can turn into vandals. . . . The discovery that the outside world is indeed the brain's real food is truly intriguing. The brain gobbles up its external environment in bits and chunks through its sensory system: vision, hearing, smell, touch and taste. . . . The digested world is reassembled in the form of trillions of cells that are constantly growing or dying, or becoming stronger or weaker, depending on the richness of the banquet.

Our familiar global measures of children's systematic development, like head circumference and behavioral milestones such as crawling, walking, and talking, are now validated and enhanced by new graphic, computer-generated techniques that enable us to view precise functions in the developing brain. What we are now able to see is the physiology that accompanies and shapes these behavioral milestones. The newly achieved behaviors in turn catalyze the next round of physiological to fade after about three years, Ramey makes a strong case for beginning earlier, in the first months of life, when the neurological circuits for learning words and sound are being built. He began his Abecedarian project in 1972 as an experiment to test whether mental retardation coming from inadequate environments could be prevented. The interventions included intensive high-quality preschool programs combined with medical and nutritional supports beginning shortly after birth and continuing until children entered kindergarten. The researchers assigned children from 120 impoverished families into one of four groups: intensive early education in a day care center from age four months to eight years; from four months to five years; from five to eight years; and none (control group).

Among these families, all of whom were poor, the researchers discovered that the factors that most placed children at risk of cognitive delays or mental retardation had to do with the parents' educational histories and their intellectual and language abilities. The single strongest predictor of all is the mother's tested level of intelligence. In the Abecedarian project, of the control-group children, all of whom had mothers with IQs less than seventy, all but one child emerged in grade school retarded or of borderline intelligence. In the intervention groups, children who, beginning at four months, participated in the program five days a week, fifty weeks a year, all tested within the normal range by age three—an average of twenty points higher than children in the control group. When children did not receive intervention until after age five, 86 percent tested below an IQ of eighty-five. Ramey's research has conclusively shown that interventions that begin at birth and are provided during the preschool years, but not later, have a measurable impact on children's development, which is sustained to age fifteen. In a recent follow-up study with Dr. Frances Campbell, Ramey reported that children who were enrolled early in the Abecedarian project still scored higher in reading and in math by five points at age fifteen than did children who did not receive intervention. Ramey believes that early enrollment in the enriched day care is key to these enduring gains. Children enrolled

after the age of five showed no sustained gains in IQ or academic performance. In an interview reported by Ronald Kotulak in his *Chicago Tribune* brain development series, Ramey stated:

> The quality of the environment and the kind of experiences children have may affect brain structure and function so profoundly that they may not be correctable after age five. If we had a comparable level of knowledge with respect to a particular form of cancer or hypertension or some other illness that affected adults, you can be sure we would be in action with great vigor.

Neurobiologists studying how the brain develops give us insight into how Ramey's observations occur biologically. Dr. Charles Nelson of the University of Minnesota studies how the brain changes from experience. As mentioned earlier dendritic and synaptic nerve connections are overproduced and the brain "prunes" those not properly reinforced by stimulation. Nelson refers to this process of overproduction, selective stimulation, and pruning as an "information capture mechanism." This learning process allows the organism to shape itself in accordance with the variables consistently occurring in the environment and to specialize its responses accordingly. If the information is distorted, so is the development.

Dr. Greenough explains critical periods—such as that for vision—in terms of Nelson's information capture mechanisms. The critical period occurs because the cells for capturing certain information are there on a time-limited basis before they are pruned or used elsewhere. Greenough postulates that information capture mechanisms may also be set in place neurologically to allow the animal to adapt and incorporate the responses appropriate to specific social environments. He believes that if inappropriate experiences (e.g. abuse) occur or if appropriate experiences do not occur—especially when these are combined with biological factors such as attention-deficit/hyperactivity disorder—later behavior is likely to reflect this early programmed distortion on a sustained basis. Dr. H. F. Harlow's classic work with tional strategies, including interventions to stem emotional and cognitive disabilities that can undermine learning from the time of birth.

In a recent television interview on *Prime Time Live,* Diane Sawyer discussed the subject of critical periods in brain development with Dr. Michael Phelps, who co-invented the brain-imaging technique called the PET scan. Phelps was quoted by Sawyer as saying: "The development years are not just a chance to educate, they're actually your obligation to form a brain and if you miss these opportunities then, you've missed them—forever." The program concluded with poignant images of caged songbirds while in voiceover Sawyer said: "At Rockefeller University there is a birdcage and it's quiet. The scientists tell us that they've learned that when baby songbirds like these don't hear a parent singing, when they grow up, they will never learn to sing."[8]

FROM THE BOTTOM UP

Anatomically, the brain can be divided into four basic parts: the brainstem, the midbrain, the limbic brain, and the cortex. These parts develop in a hierarchical progression starting with simple and gradually moving to more complex functions. This development begins with the brain stem, which controls the basic and most essential functions necessary to sustain life, including involuntary functions like blood pressure, heart rate, and body temperature. Next to develop is the midbrain, which controls appetite and sleep, among other things. Then comes the limbic brain, which is the seat of emotion and impulse. And, finally, the cortex, where logic, planning, and cognition—the executive functions—take place, is developed. Each of these parts of the brain is responsive to the environment, or use-dependent, according to Dr. Perry, and will be shaped by the individual's unique experience of his or her surroundings.

When we seek to understand violent behavior from the perspective of brain anatomy, we find some surprising realities. First of all, violent impulses are generated in the lower parts of the brain, par-

ticularly the limbic system. Under conditions of extreme threat or rage, when the brain is flooded with stress hormones, the "fight or flight" human is not under the governance of the analytical cortex, the seat of rationality and wisdom. Under those extreme conditions, it is the limbic brain and midbrain which are quickest to respond to mobilize the individual. This biological process is well understood by the army. The constant drill and practice in boot camp to prepare for combat is deliberately directed at the limbic brain. The training of new recruits for war conditions, where instantaneous and precise action is called for must bypass the analytical and time-consuming cortical functions. Even those of us who have never served in the military have our own experiences with the body's response to emergency or threat and can recall moments of freezing or running when normal rational thoughts were totally unavailable to us until fear or fury subsided. Dr. Perry succinctly explains that our ability to think before we act is related to the ratio between the excitatory activity of the primitive areas of the brain and the moderating efforts of the cortical or higher areas:

> Any factors which increase the activity or reactivity of the brainstem (e.g. chronic stress) or decrease the moderating capacity of the limbic or cortical areas (e.g. neglect) will increase an individual's aggressivity, impulsivity and capacity to display violence.[9]

This understanding of the stress response system and its impact on brain development has huge implications for working with people with attentional or impulsive disabilities. For children with developmental disabilities or damage (e.g., attention-deficit/hyperactivity disorder or post-traumatic stress disorder), cognitively based therapies may be an exercise in futility. To be effective, interventions need to be directed at the limbic and midbrain levels.

Violent behavior is most likely to occur when a young child's experiences result in lack of adequate stimulation to the cortex—the system for modulation and control—together with overstimulation of

Researchers, including Dr. Frank Wood of Wake Forest University in Chapel Hill, North Carolina, and Dr. Adrian Raine of the University of Southern California, assert that they can see a characteristic pattern of underactivation of the prefrontal lobe together with excessive activity in the region of the limbic system in the brains of impulsive killers. Emotionally charged memories may be stored in the limbic system and may be restimulated—often years later. The neural alarm system is often imprecise or out of date, and, since it acts without rational (cortical) screening, behavior may appear totally out of context in the present circumstances.

There is a great deal of speculation about the possible causes of this kind of brain abnormality. The hypotheses range from injury to the prefrontal lobes to genetic causes. What we know is that children with early discernible impulse-control problems, such as attention-deficit/hyperactivity disorder (ADHD), are at considerably higher risk of later violent behavior when the problem is left untreated, or is treated only by stimulant medication. Negative outcomes for these children are greatly increased when ADHD is exacerbated by familial or environmental factors such as maternal rejection, child abuse, or the modeling of violent solutions to everyday problems.

THE MIND BODY SYNTHESIZER: THE ORBITOFRONTAL CORTEX

An area of the brain that is receiving increasing attention in relation to infant development is the orbitofrontal cortex. This part of the brain connects the cortex to the limbic system and is critically involved in the regulation of emotions. Here sensory input of all kinds—vision, hearing, touch, taste, and smell—is connected with our visceral body sensations. This is the area responsible for our "gut reactions" to people and events—our earliest associations between experiences in the outside world and our internal physical responses. Dr. Allan Schore, of the Department of Psychiatry and Biobehavioral Sciences at the UCLA School of Medicine, views the orbitofrontal cortex as

the key area involved in both infant attachment and emotional regulation, the failure of which can result in impulsive violence.

The orbitofrontal cortex (so called because it sits just above the orbit of the eyes) is positioned at the undersurface and between the two cerebral hemispheres.[12] This area represents a central point of convergence of the cortex and subcortex. Because of its unique anatomical location, it receives both sensory stimulation (vision, touch, sound, smell) from the external social environment, and visceral information concerning the body's internal environment, so that interpersonal experiences can be associated with emotional and motivational states.

According to Schore, all of the connections between the cortex and the subcortex are regulated by this particular area. As a result, sensory information from the environment, such as the expression on the mother's face and the tone of her voice, is associated in the baby's experience with the physical sensations the baby is simultaneously experiencing, such as intense pleasure and excitement or fear and discomfort. When this goes awry, for example, when a baby "fails to thrive" or fails to gain weight, stops growing, and seems to lose interest in living, this is the area of the brain responsible for the linkages between sensual and emotional deprivation and the physical symptoms that result.

The orbitofrontal areas contain neurons that are especially sensitive to the emotional expressions on the human face, which is a primary source of information sent and received in social situations. The orbitofrontal cortex is particularly expanded in the right hemisphere, which connects deeply into the limbic system, where positive and negative emotions are generated. In fact, this part of the cortex sends direct connections to all the lower limbic areas, including the amygdala. Because it is the only part of the cortex that projects directly to the hypothalamus and autonomic centers deep in the brain stem, the orbital frontal cortex acts as a central control center over both the sympathetic and the parasympathetic nervous systems, which generate the bodily components of emotional behavior.

with strong emotion, can and do remain an influence throughout our lives. Memory, as it turns out, is not just a matter of rational or even verbal recall. We also have a nonverbal, essentially emotional memory, particularly for experiences, events, and people that carry a strong emotional valence.

Sensual experience (auditory, visual, tactile, and olfactory) typically travels first to the neocortex for analysis. But when perceptions are accompanied by strong emotional impact, particularly those perceived as life threatening, they may bypass the neocortex and send a message directly to the amygdala, which mobilizes the organism for fight or flight. All of this can happen in an instant—and without input from rational processing by the neocortex.

Studies done by Dr. LeDoux in 1989 that exposed rats to fear-inducing visual stimuli provide strong evidence that the amygdala matures very early in life, so that emotional messages can be processed before cognition. In addition, LeDoux found that these fear-based associations experienced early were difficult to erase, even when the sensory cortex was later completely severed. According to LeDoux, early experienced precognitive emotions continue to play out in later life even though the individual may have no conscious memory of the association.[15]

Dr. George Engel documented this process at work in a thirty-year longitudinal study of "Monica."[16] Monica was a child born with congenital atresia of the esophagus, a condition that precluded her being fed by mouth. For the first two days after birth she choked and regurgitated her feedings. On the third day a feeding tube was inserted into her stomach. For two years she was fed through the tube while lying flat on her back without holding or contact of any kind. She was in fact frequently fed "while crying, fussing or playing" and did not participate in the process. A tube placed in her neck to continuously drain the saliva limited how Monica could be held. Her mother subsequently became depressed and withdrew from her baby. Monica became unresponsive and for a while showed a failure to thrive.

At age two, Monica was hospitalized for nine months while her esophagus was reconstructed. She began to receive oral feedings either lying flat on her back or propped in her crib. Her mother and the nurses still rarely held her. After she returned home, she was able to eat normally. She grew up with no conscious memories of her early tube feedings; she was told by her mother much later that she had been fed by a tube in her abdomen as a baby.

Engel and his associates continued to observe Monica as she grew. As a little girl she fed her dolls in the exact position she herself had experienced, flat on their backs without holding or contact of any kind. Engel also noted that her conversations with the dolls indicated preconscious memories of her earlier experiences. She would place the dolls down on the bed and stand at their side. At four years of age she said to one, "Poor baby, you ain't got a mouth." She also talked about the dolls "leaking at the neck," where she herself had experienced the early drainage tube.

When Monica babysat as a teenager, she fed her charges in the same strange way. When she had children of her own, in spite of having observed her mother feeding her younger siblings normally, Monica seldom, if ever, held their bottles during their feedings. Her mother, husband, and a sister all coached her to hold her babies enfolded in a face-to-face position. Although she was generally compliant with requests from others, she consistently refused close body or face-to-face contact with her babies while feeding them. Instead, clearly acting from early and enduring preverbal memory, she lay them flat across her lap and replicated her own experience.

Infant memory is the subject of much current research at several universities, including the University of Massachusetts. Drs. Rachel Clifton and Nancy Myers, both psychologists, have successfully documented the capacity of two-and-a-half-year-old children to exhibit learning they experienced at age six months.[17] Originally researching motor and hearing skills, Dr. Clifton placed sixteen six-month-old babies in a pitch dark room with objects that made different sounds and used infrared cameras to capture how and when infants reached during sleep. The balance between the two is the key to normal function. For most of us, there is a balance, enabling us to react in reasonable ways. But, as with the McGill students, our functional levels can be altered, at least temporarily. Alcohol and extremely stressful environments can have similar effects to the students' initial drink of amino acids. When these exposures occur to a developing fetus or infant, the levels of serotonin and noradrenaline are just being built, shaping lifetime patterns.

Violent behavior is roughly of two types: impulsive and premeditated. Most acts of violence are impulsive. "Cold-blooded" or premeditated acts are far less common and are typically enacted by a very different personality than the "hot-blooded" crime. When environmental experiences early in life cause noradrenaline levels to be too high and serotonin levels too low, the result, in the presence of later emotional triggers, may be impulsive violence. Conversely, very low levels of noradrenaline together with low levels of serotonin result in underarousal, which may generate an appetite for high-risk behaviors to achieve arousal, setting the stage for predatory violence or premeditated crimes. Interestingly, very high levels of serotonin are not a means of counteracting this effect. Excessively high serotonin levels result not in well-being, but in rigidity or obsessive-compulsive behavior, like Lady MacBeth's repetitive hand washing. The balance of neurochemicals in either scenario is thought to be set primarily by early experience.[21] When babies develop in an atmosphere of terror or trauma, these neurochemicals can be called upon to enable them to survive. But that which enables survival may also create permanent and lethal imbalances.

Low levels of serotonin may be the result of a genetic error. A single gene inherited by some people from their fathers results in an inability to adequately convert tryptophan from common foods into serotonin. The individual inheriting this gene may have no problem unless there is an additional stressor, primarily alcohol. In affected individuals, alcohol briefly raises, then drastically lowers, serotonin levels. At the latter point, the individual is prone to acting out

aggressively. This gene is common—affecting 40 percent of the Swedish population tested at random.[22] With 48 percent of the homicides in the United States committed under the influence of alcohol, the role of this interaction is clearly of concern.

Normal serotonin and noradrenaline levels are extremely important to balanced functioning. Without realizing it, our culture is creating more and more individuals with an imbalance in this delicate equation in the brain. Alcohol, drugs, and other toxic exposures such as lead are being implicated in damage to the genes responsible for these neurochemicals. So are conditions after birth such as abusive, terrifying, or war-torn environments, in which impulsive or reactive behaviors are essential to survival. Researchers suspect that conditions of child neglect, child abuse, gang warfare, and domestic violence are—without our awareness—biologically, as well as socially, feeding the cycle of violent crime. As Ron Kotulak stated in his series on the brain:

> Underlying the scientific quest, which has revealed genetic and environmental links to abnormal brain chemistry, is the growing suspicion that society may unwittingly be feeding the nation's epidemic of murder, rape and other criminal acts by making childhood more dangerous than ever.[23]

Abuse and neglect in the first years of life have a particularly pervasive impact. Prenatal development and the first two years are the time when the genetic, organic, and neurochemical foundations for impulse control are being created. It is also the time when the capacities for rational thinking and sensitivity to other people are being rooted—or not—in the child's personality.