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How the Brain Learns

Inherent Differences Between Boys and Girls

> Boys and girls are different, and that's the truth. When I was a young teacher this thing started of saying they weren't different, and I kept my mouth shut, but I raised three kids of my own and I taught hundreds and I just didn't believe what I was hearing. Now I'm so glad we're all talking about the differences between boys and girls again.
>
> —NANCY LYNN, TEACHER FOR ALMOST FORTY YEARS

NANCY LYNN TAUGHT NEARLY EVERY GRADE IN HER THIRTY-EIGHT-YEAR CAREER. We met her when she was a "retired" volunteer ("I'm retired but busier at school than ever!"), providing reading tutorials and co-teaching learning disabled students. She was a small, thin woman of sixty-nine whom the kids called "Mrs. Lynn," never "Nancy." Though tiny in stature, she commanded respect, and she moved among her students with grace and confidence.

She spoke the words with which this chapter begins at a teacher training. "I'm not too old to keep learning," she told us. Nancy was a kind of leader at the training. She told us some poignant stories.

She told us about a boy who just couldn't sit still. To help him stop getting in constant trouble for his fidgeting, she decided to ask him to run errands for her. This gave him something to do. She told us about another boy whom she could barely manage in fourth grade. He was

overly aggressive and often angry. One day on the playground, the class discovered a dead squirrel. This boy bent to the squirrel, held it a moment, and looked (untypically for him) very tender. Nancy let him hold it; she talked to him and asked him to lead the burial service.

"He was so different after that day," she recalled. "He felt so bad for the squirrel. I think he understood life better after that and became a better boy. He just needed to see how things really were in the world around him. He needed to see what that aggression, which he sure had a lot of, really does in the world. My role was not just to teach him reading, writing, and 'rithmetic. My job was to help teach the boy in him how to be a good young man."

She told us about a seventh-grade girl whose father had died during the summer. The girl, though very bright, was underachieving. In Nancy's words: "She was just sort of disappearing into herself, not participating anymore, letting her grades fall." Nancy decided one day to drive the girl home from school herself and try to become close. Nancy ended up becoming a friend of the family and helping the girl not only achieve again but also work through her grief. Nancy was practicing an intuitive, early version of what we now refer to as raising a child's self-esteem and making sure a girl doesn't lose her voice. In Nancy's words, "Sometimes girls are very fragile and need a special kind of attention. Girl attention."

Coming from someone with so much experience, these stories opened the door to other comments at the training. Some of the parents and teachers who had not wanted to talk openly about male-female difference felt more courage to do so.

"Boys and girls are so different," said a parent of four. "They just come out of the womb that way. I had two of each, and I started out thinking they'd be the same. They weren't."

"I've taught twenty years," said another teacher, "and if I've learned anything it's that while boys and girls are the same in lots of ways, they are definitely different. Every year I change the way I teach just to accommodate that one fact."

Parents and teachers like these have seen the whole gamut of changing theories in education. Teachers like Nancy Lynn are a joy

to talk to, for many reasons. They carry the very energy and history of our culture in their hearts, minds, and memories, reminding us that education has always held out to us a vast banquet of possibilities. Nancy inspired the workshop by reminding us that educators do not have to limit their thinking to be effective.

For more than a decade, I have been asking these two questions at teacher trainings and seminars: "When you were being trained to be a teacher, how many of you were offered a class in the *actual development of the student's brain?*" and "How many of you were offered a class in the *developmental differences* between the way a *boy's brain* works and a *girl's brain* works?"

Generally, about 10–20 percent of the attendees raise their hands in answer to the first question. To the second, only a few hands may go up. As the day of training proceeds, all of us come to agree that for too many decades, biological information about the development of a child's brain, as well as the crucial differences between male and female brain development, has been fragmentary, incomplete, and sometimes nonexistent. This state of educational training has brought real harm to our educational culture. We are walking into classrooms unprepared to do our jobs. We are putting boys and girls together in classrooms and a system of education that is unprepared to deal with who these children really are.

In this chapter, we present some of the newest and freshest research into the brain, brain similarities, and male-female brain differences. As you read much of this information, you will probably say to yourself, "Oh yeah, I guess I knew that." But a lot of it will startle you; then, when you sit back and notice the ideas and facts at work among your students, we hope you will say, "Aha, so that's why such-and-such happens" or "OK, so now I see how to make my classroom even better."

The Wide Spectrum of Gender in the Brain

As you master this material, we hope you will check the research by keeping your own journal of observations. For a month or so, mark

down "gender experiences" you see in your classroom, or home, or wherever it is that you are a teacher of children ("Today Jimmy did such-and-such" or "Today Heather said something that . . ."). A detailed journal generally corroborates most of the brain-based research that we lay out in this chapter, and it leads to new insights into how you can interact with these male and female brains.

At the same time, you will discover many exceptions to what we say. Brain development is best understood as a spectrum of development rather than two poles, female and male. Many of the children you have contact with lean toward the female on their brain development spectrum, many others toward the male. Mainly, your girls lean toward the female and boys toward the male, but you may also notice a number of "bridge brains." These are boys and girls who possess nearly equal qualities of both the male and female brains. They are, in a sense, the bridge between male and female cultures because their brains are the most "bi-gender."

The material of this chapter should not be used to stereotype or limit males and females, because each child is an individual. Rather, it should be used to *add* wisdom to the individuality already assumed in every human. Of course, difference is not evidence of gender superiority or inferiority in general. There are some things that boys tend to be better at than girls, and vice versa. There is a skill superiority already built into general male and female brain development. But this in no way means there is an inherent male or female superiority in moral or social terms. Unfortunately, when it was discovered a hundred years ago that the male brain was 10 percent larger physically than the female, some neuroscientists of that time proclaimed, "You see, this corroborates what we've said all along: men are smarter than women." Interpretations like this can make all of us a little afraid of saying that boys and girls learn differently because their brains are different.

Nonetheless, we certainly hope this chapter helps you become fearless in pursuit of the wisdom inherent in brain difference. Camilla Benbow, a researcher at the University of Iowa, has studied more than a million schoolchildren to determine the reliability of the early findings on the reality of brain differences. She discovered marked,

sex-different approaches and attitudes to learning and living between boys and girls for which she had initially sought explanation in one or more overriding cultural events or social experiences. Benbow, and most researchers like her, started doing their research twenty years ago, when searching for sociological reasons for male-female difference was the accepted practice. Benbow ended up with this result: "After fifteen years of looking for an environmental explanation and getting zero results, I gave up." The differences, she discovered, were in the brain, with culture playing an important part but not the defining role that many people have wished to believe.

Other researchers, notably Laurie Allen at UCLA, have discovered actual structural differences in the brain. Still others, such as Ruben Gur at the University of Pennsylvania, have discovered functional differences using positronic emission tomography (PET) scans. Their research has been corroborated all over the world. The best primary text we know of for getting a whole picture (on a worldwide scale) of brain-based gender differences is *Brain Sex*, by Anne Moir and David Jessel.

In the end, what all of us in this field have found is that once brain difference becomes real for those who teach children, a number of doors to better education open. Let's open some of them now and walk through. True equality of education occurs, we will discover, as each teacher embraces the fact that we need to know more about how the brain in general learns, and how boys' and girls' brains learn differently.

How the Brain Works

How does the brain actually work? Our answer to this question is far more extensive than it was two decades ago, but it is a long way from complete. One might just as well attempt to fully describe how the planet works, how our solar system works, or how the universe works, for the brain is no less complex, fascinating, and mysterious than these. In describing and graphically illustrating the workings of the brain, we must leave out more than we put in. For the purposes of this book,

we strive to include all the areas where there is, ultimately, some difference between male and female brains.

Science has estimated that the adult brain has around one hundred billion neurons and an even larger number of glial cells. An adult human brain is between 2.25 and 3.5 pounds of dense matter in three major layers: the cerebral cortex at the top; the limbic system in the middle; and the brain stem at the bottom, connecting with the spinal cord. Historically, for more than two million years, the brain has grown from the bottom up, the upper limbic system and the four lobes of the cerebral cortex developing later than the lower limbic and the brain stem.

In general, the three layers of the brain are known for distinct functions (though all functioning areas of the brain constantly interact). The brain stem is where fight-or-flight responses are harbored. When we're in an immediate crisis, we often feel our instincts take over. This happens in the brain stem, the most primitive part of our brain and essential for our survival.

Our limbic system is generally where emotion is processed. A sensory stimulant comes into the brain through our eyes, ears, skin, or other organs, and we experience an emotive response to it; the immediate sensual and emotive response resides, to a great extent, in the limbic system in the middle of the brain. Although some aggressive responses are brain-stem responses, others come from the limbic system as well—specifically from the amygdala, which lies at the bottom of the limbic system, just above the brain stem.

The four lobes at the top of the brain are generally where thinking occurs. In each lobe, different sensory stimulants are processed. Certain cortices in the top of the brain (for instance, the prefrontal cortex) handle the majority of our moral and other kinds of decision making. The brain is divided into the left and the right hemispheres. The left is primarily associated with verbal skills—speaking, reading, and writing—and the right is primarily associated with spatial skills, such as measuring, perceiving direction, and working with blocks or other objects.

When we are teaching a child the higher-order content of a novel, or how to do math, we are generally speaking to the top of

the brain, though emotional responses often mix in, especially if the student has an emotional reaction to the content of a book or lesson. In this way, the neocortex and the limbic system work together.

An example of an emotional reaction is "I feel sympathy for Hester Prynne" or, less obviously, "I can't do this, it's too hard." Either way, the emotive response in the limbic system can slow down or shut off most thinking in the top of the brain, depending on how tough the emotional moment is. In neurological terms, a child who thinks she can't do it might fulfill her own thinking: during the crisis of self-esteem her blood flow remains heavily in the middle of the brain, not moving up to the thinking centers. When we tell a child to "think before you act," we are actually saying, "Redirect your blood flow from the limbic system, and even from the brain stem, to the top of the brain before you act."

We may never understand all of the machinations, functions, and potentials of our brain. It is not our purpose here to try. Our goal should be to look at what we *do* know about how the brain learns and what we are discovering about the important differences in how male and female brains operate. By taking these first, tentative steps toward understanding, we can help our children become comfortably and fully themselves—accepting their differences, celebrating their natural strengths, and aiding them in compensating for their natural weaknesses. Table 1.1 shows the similarities and differences between the male and female brain.

How Boys' and Girls' Minds Are Different

There are a number of categories of male-female difference to consider. We present some of these expositionally, while including two tables by which to make an even deeper comparison. There are many differences we could present, but we have preselected those that seem most essential to learning strategies. You'll find that each category contains mainly highlights of what appears in the tables.

TABLE 1.1

BRAIN GENDER DIFFERENCES

PART OF BRAIN	FUNCTION	SIMILARITIES AND DIFFERENCES	IMPACT
Amygdala	Part of limbic system involved in emotional processing, especially anger and fear.	Tends to be larger in males.	May make males more aggressive.
Arcuate fasciculus	Curving bundle of nerve fibers in the central nervous system.	Likely develops earlier in girls as evidenced by their earlier speech capabilities.	Females tend to speak in sentences earlier than males do.
Basal ganglia	Control movement sequences when necessary, such as in walking.	Likely to engage more quickly in male brain—when required.	Males generally quicker to respond to attention demands in physical environment.
Brain stem	Connects brain to spinal cord; handles primitive drives such as "fight or flight."	Male brain at rest here to a greater extent.	May make males more likely to respond with a physical response when they feel threatened or emotionally charged.
Broca's area	Motor area for speech; processes grammatical structures and word production.	Tends to be more highly active in females.	Improved verbal communication skill tendencies in females.
Cerebellum	This is the "doing center"—a region of the brain that plays an important role in the integration of sensory perception, coordination, and motor control.	Tends to be larger in the male brain.	Coupled with the higher levels of spinal fluid in the male system, messages between the brain and body tend to move more quickly and with less impulse control in males.

PART OF BRAIN	FUNCTION	SIMILARITIES AND DIFFERENCES	IMPACT
Cerebral cortex	Contains neurons that promote higher intellectual functions and memory, and interprets sensory impulses.	Female brain tends to have more connections between neurons and increased blood flow in this area.	Increased processing speed in the female brain may help girls respond to classroom information faster than males, making transitions and multitasking easier.
Corpus callosum	Connects the left and right hemispheres of the brain.	Tends to be denser in the female brain, containing more neural connections between hemispheres.	Tends to allow the female brain to process more information more quickly between the two hemispheres, connecting language and emotion processing centers more efficiently.
Dopamine	A neurotransmitter that stimulates motivation and pleasure centers in the brains of both males and females. Critical to the way our brain controls body movements and flow of information within the brain.	Male and female brain can stimulate dopamine in different ways.	Not enough dopamine and we have trouble controlling movements. Too much dopamine can lead to uncontrolled or subconscious movement, such as repetitive tapping, jerking, and so on.
Estrogens	A group of female sex hormones that cause estrus and promote development of secondary sex characteristics; shapes female brain.	Significantly higher in females than males.	In females can tend to lower aggression, competitiveness, self-assertion, self-reliance.

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PART OF BRAIN	FUNCTION	SIMILARITIES AND DIFFERENCES	IMPACT
Frontal lobe	Facilitates speech, thought, and emotion; produces neurons for skilled movement.	Matures earlier and tends to have increased blood flow in the female brain.	May lead to improved verbal communication skills and less risk taking in females.
Hippocampus	Key player in converting information from working memory into long-term or permanent memory; crucial for learning to have meaning, and for retention.	Tends to be larger in females; number and speed of neuron transmissions higher in females.	Increased memory storage in females can allow them to access more information for recall.
Hypothalamus	Controls automatic body processes (heart beat, breathing, temperature); also controls differences in sexuality.	Female and male cell structures and patterns significantly different—denser in males, less dense in females.	Males tend to have greater and more constant sex drive.
Limbic system	Contains a number of structures (including the amygdale and hippocampus) that play a key role in how boys and girls learn and perform differently.	Female brain tends to rest here to a greater extent. There tend to be more neural connections between the female limbic system and verbal processing areas.	Females tend to be able to respond verbally to stressful and emotion-laden experiences more quickly than males. Females also tend to have more access to emotively descriptive language in written assignments.
Medulla oblongata	Widening continuation of the spinal cord, forming the lowest part of the brain and containing nerve centers that control breathing and circulation.	Likely increase in male brain-stem functioning implies stronger relationship to connections between medulla oblongata and resting male brain.	Possible increase in SIDS death in males could be explained by this relationship; may lead to increased male aggression.

PART OF BRAIN	FUNCTION	SIMILARITIES AND DIFFERENCES	IMPACT
Gray matter and white matter	Brain tissue is divided into two types: gray matter and white matter. Gray matter is made up of the cell bodies of nerve cells. White matter is made up of the long filaments that extend from the cell bodies—the "telephone wires" of the neuronal network, transmitting the electrical signals that carry the messages between neurons.	Male brains tend to have more grey matter; female brains tend to have more white matter.	Female brains tend to move information more quickly from one processing area to another in the brain, often making females more efficient multitaskers. Males tend to learn more effectively through task and project focus.
Occipital lobe	Detects and interprets visual images.	Differences evident in divergent responses to light sensitivity.	Females tend to see better in low light; males tend to see better in bright light.
Oxytocin	Often referred to as the "tend and befriend" hormone, related to social recognition and bonding. Promotes development and maintenance of relationships.	Much more functionally present in females than males.	Likely involved in the increase of mother-child bonding capacity at birth. Girls are often more motivated biologically to please parents, teachers, and peers as they strive to establish and maintain relationships.
Parietal lobe	Perceives and interprets bodily sensations such as touch, pressure, pain, and temperature.	In females, more data move through than in males; male brain better at "zoning out."	Females tend to have more tactile sensitivity.

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PART OF BRAIN	FUNCTION	SIMILARITIES AND DIFFERENCES	IMPACT
Cortisol	Usually referred to as the "stress hormone" as it is involved in response to stress and anxiety. It increases blood pressure and blood sugar, and reduces immune responses.	Males and females both tend to have increased cortisol levels as a result of stress, but once the stressor is removed male cortisol levels tend to decrease more quickly than females, who may tend to "stress" about things longer.	Low cortisol levels lead to feelings of euphoria; high cortisol levels can lead to despair; laughing and the experience of humor can lower cortisol levels; caffeine and sleep deprivation increases cortisol levels.
Progesterone	Steroid hormone of the corpus luteum, active in preparing the uterus for fertilized ovum.	Much more functional and present in females.	Females may have reduced susceptibility to traumatic brain injury and this protective effect has been hypothesized to be caused by increased circulating levels of estrogen and progesterone in females.
Serotonin	A neurotransmitter known as the "feel good" chemical. It affects mood and anxiety, helps individuals relax and cool off during times of conflict.	Research indicates that the male brain has 52 percent more serotonin than the female brain, but may not process it as efficiently.	Depression can occur in some women because of low serotonin in combination with fluctuating estrogen levels.
Testosterone	Male sex and aggression hormone; responsible for architecture of the male brain and body in utero.	Much more present and functional in males; levels tend to rise when males "win" and decline when they "lose"—female levels tend to remain constant and not as subject to fluctuations in response to winning or losing.	Tends to result in more aggression, competitiveness, self-assertion, and self-reliance in males; healthy competition in a classroom may help motivate boys (and some girls!).

PART OF BRAIN	FUNCTION	SIMILARITIES AND DIFFERENCES	IMPACT
Thalamus	Regulates emotional life and physical safety; processes incoming sensory information; tells us what's going on outside body.	Processes data faster in females, especially at certain times in menstrual cycle.	Greater stress and activity in female thalamus at varying times during menstruation.
Vasopressin	Hormone secreted by posterior lobe of pituitary gland; increases blood pressure by constricting arterioles.	Involved in water retention, blood pressure, and memory; supports the pair-bond between sexual partners.	Vasopressin can be a factor in inducing the male to become aggressive toward other males.
Wernicke's area	Links language and thought; enhances word comprehension.	Likely more highly active in females.	Improved verbal communication skills in females.

Developmental and Structural Differences

In most cases, and in most aspects of developmental chronology, girls' brains mature earlier than boys' brains. An example is in the myelination of the brain. One of the last steps in the brain's growth to adulthood occurs as the nerves that spiral around the shaft of other nerves of the brain, like vines around a tree, are coated.

This coating is myelin, which allows electrical impulses to travel down a nerve quickly and efficiently. A ten-year-old is generally a more developed human than a toddler, and an adult more so than a ten-year-old, in large part because of myelination. Myelination continues in the brain until physical maturity is reached: in females the brain tends to mature in the early twenties, in males this occurs later, closer to age thirty.

This is a maturity difference at the tail end of childhood, but the differing maturity occurs at the beginning as well. Girls, for instance, can acquire their complex verbal skills as much as a year earlier than boys. Thus, quite often a preschool girl reads faster and with a larger vocabulary than a peer boy does, and she speaks with better grammar. In general, female brains develop more quickly than male brains. Brain development in infants is often most pronounced in the right hemisphere and gradually moves to the left. In females, the movement to the left starts earlier than in males.

Perhaps the most familiar structural difference in the brain is the corpus callosum, the bundle of nerves that connects the right and left hemispheres. In females it tends to be larger (meaning generally having more neural connections) than in males, giving girls more cross-talk between the hemispheres of the brain. There is more (and quicker) development in females than males in the prefrontal lobes, where affect regulation finds its executive decision making, and the occipital lobes, where sensory processing often occurs.

Girls tend to absorb more sensory data than boys. On average, they hear better, smell better, and take in more information through fingertips and skin. Females tend to be better than males at controlling impulsive behavior. They often are able to self-monitor high-risk and immoral conduct better than boys (on average)—especially if the boys and the girls are equally untrained in ethics or impulse control. In other words, girls are by nature less likely to take moral risks than boys. Boys are more likely to physically show natural aggression.

Girls' verbal abilities tend to develop earlier so they rely more heavily on verbal communication; boys often rely heavily on nonverbal communication, and are less able to verbalize feelings and responses as quickly as girls. This has immense ramifications in our present culture, which relies so heavily on talk, conversation, words. We are all far better trained at listening to words than at watching silent cues, which often makes communication with a male difficult.

Males tend to have more development in certain areas of the right hemisphere, which provides them with better spatial abilities such

as measuring, mechanical design, and geography and map reading. Lynn S. Liben, of Pennsylvania State University, recently reviewed data from the 1999 National Geography Bee, a geography-based contest hosted by Alex Trebek that has attracted five million participants. Of those millions, forty-five times more boys than girls are likely to be finalists.

Like many researchers, Liben and the coauthors of her study concluded that although to some extent the boy-girl gap can be accounted for by cultural factors, the lion's share of the gap stems from better cognitive spatials in the male brain. "There really are some differences biologically," she said; "I feel I have to say this as a woman."

Chemical Differences

Males and females have a differing amount of most of the brain chemicals. Serotonin, often called the "feel good" chemical, is a neurotransmitter. Less effective processing of serotonin may make males more impulsive in general, as well as more fidgety. Differences in vasopressin and oxytocin are also substantial. For instance, the crying of a child may stimulate secretion of oxytocin in the female brain to a greater degree than in the male brain. Oxytocin is just one of the brain chemicals that, being more constantly stimulated in females, make the female capable of quick and immediate empathic responses to others' pain and needs.

Hormonal Differences

Although males and females both possess all the human hormones, degree of dominance differs. Females are dominated by estrogen and progesterone, males by testosterone. These hormones are contrasting in their effects. Progesterone, for instance, is a female growth hormone and also a bonding hormone. Testosterone is the male growth hormone, and also the sex-drive and aggression hormone.

Whereas a girl may be likely to bond first and ask questions later, a boy might be aggressive first and ask questions later. A girl is likely to try to manage social bonds in a group situation through egalitarian alliances, but a boy tends to manage social energy by striving for dominance or pecking order.

Human behavior is far more driven by hormones than we have wanted to admit. Despite the plethora of research on testosterone and premenstrual syndrome, we tend to avoid acknowledging the importance of hormonal differences. Yet male and female mood are very dependent on the interplay of hormones and the brain. Beginning in prepuberty, generally around ten years old, males often receive as many as seven to ten "spikes" or "surges" of testosterone every day. During the spiking, hormonal flow can make their moods vacillate between aggressive and withdrawn.

Females' estrogen and progesterone levels rise and fall with their hormonal cycle, making their moods swing as well. These hormones affect in-class emotive functioning, of course, because of mood, but they also influence learning performance. For instance, when female estrogen is high, girls may score higher on both standardized and in-class tests than when it is low. When male testosterone is high, the boy may perform better on spatial exams, like math tests, but worse on verbal tests.

There is great variety among boys and girls in their own hormonal levels. Some boys are high-testosterone: very aggressive, socially ambitious, striving for dominance, heavy in muscle mass, or a combination of these conditions. Some boys are low-testosterone, more sensitive, softer in appearance and manner. By adulthood, males can end up with twenty times more testosterone than females, but possibly also only five or six times as much. Female hormone levels vary, of course, with the time of the month and other circumstances (such as hearing a child cry, seeing another person suffer, becoming pregnant, or even competing). When both males and females compete, their testosterone levels go up (females included), but males obviously have a much higher testosterone baseline; this makes males on average more aggressively competitive than females.

Functional Differences

How the brain uses its cell and blood activity differs considerably in males and females. Boys tend to use the right hemisphere more; girls tend to use the left. Boys tend to process emotive information from the limbic system to the brain stem (where fight-or-flight responses are stored); girls tend to process more of it in the upper brain, where complex thought occurs. Ruben Gur, at the University of Pennsylvania, has used PET scans, magnetic resonance imaging (MRI), and other brain imaging techniques to show that the resting female brain is as active as the activated male brain. In his words, "There is more going on in a resting female brain than in a resting male brain." There are benefits to both ways of processing information. However, the female brain, never truly at rest, may have a learning advantage by being more consistently engaged, even when bored.

Quite often a girl's response to a situation is more complex than a boy's. Males tend to manage stimulants with more of what is called "task focus." Because the male brain is not as activated in as many places, it becomes overwhelmed by stimulation more quickly than the female, causing it to decide on the importance of stimulants for their necessity to a task at hand. A lot goes untouched by the male brain because it does not attend to those things, preferring to manage stimulation by "sticking to a plan." The advantage in this is a quick, direct route to a goal. A disadvantage is that if the task goes badly or failure emerges, the male may have fewer resources to redirect himself.

Two areas of greater functioning in the female are memory and sensory intake. Comparable greater functioning in the male is in spatial tasks and abstract reasoning. The male brain gives boys the edge in dealing with spatial relationships (such as objects and theorems); the female brain responds more quickly to greater quantities of sensory information, connecting it with the primacy of personal relationships and communication. Cultural factors certainly reinforce these tendencies, but the differences are innate, centered in brain functioning.

Some teachers discover, over the years, the power that comes from using their voices appropriately. Because girls and women tend to hear better than boys and men, sometimes a louder voice is needed for boys.

This fact makes an interesting basis for keeping boys near the front of the classroom or for arranging the room so that each student has an equal opportunity to see and hear.

Another intriguing difference applies to teaching music, especially choir. Six times as many girls can sing in tune as boys. Males and females even see things differently, with females generally far better at seeing in a darkened room. On the other hand, males see better than women in bright light. This suggests a biological rationale for how teachers should arrange their students in terms of distance or closeness to visual learning aids.

The differences between male and female students go beyond just hearing and seeing. Females react acutely and quickly to pain, although their overall resistance to long-term discomfort is stronger than in males. There is even rather strong evidence that males and females taste things differently. Generally, females are sensitive to bitter flavors and prefer high concentrations of sweet things. Males are attracted to salty flavors. The female nose and palate are more sensitive than the male. Interestingly, a superior olfactory sensitivity also increases in males just before females ovulate; and at this critical time of her menstrual cycle, the biology of a woman makes her even more sensitive to a male's biology.

Gender difference has been noted in the memory ability of males and females. Girls can store a greater quantity of seemingly random information, especially if it is linked to an emotional or relational experience they had. Boys tend to store information well when it is organized into clear, logical form or has specific importance to them, such as sports trivia.

Whereas girls fare better at sensory data and varied memory, boys fare better at spatial skills in general. We heard a wonderful example of male-brain spatial development from Jeff Knight, a teacher at Balboa Elementary School in Spokane, Washington, who gave his students a stick figure grid to recopy in three-dimensional space. Nearly all the boys could do it, but many of the girls couldn't. The boys also mastered the task more quickly.

Differences in Processing Emotion

Perhaps the least understood area of brain difference is emotive processing. We educators may give it too little credence because we have been taught to think of it as nonessential to learning. In fact, brain-based research shows us it is crucial.

This is an area where boys are generally more at risk for missed learning and processing opportunities. The female brain processes more emotive stimulants, through more senses, and more completely than the male brain. It also verbalizes emotive information quickly. Boys can sometimes take hours to process emotively (and manage the same information as girls). This lesser emotive ability makes males more emotionally fragile than we tend to think. A boy who has had a crisis at home in the morning may come to school with a higher cortisol (stress hormone) level than, say, his sister because he has held in, or not processed, the emotional stress of the crisis at home. He may be unable to learn for much of the morning, whereas his sister may quickly process and even talk out the hard edges of the stress so that she can learn efficiently the very same morning. The male is thus often intrinsically fragile because he cannot guide his own emotions toward processing and verbalization as quickly as a female does, and his fragility may extend to his ability to learn that day.

Both females and males must be equally understood and protected emotionally. So any brain research pointing out ways in which boys are more emotionally fragile than girls is not offered to take attention away from girls' emotional needs. It is offered to inspire us to a new vision of males. Males are simply not as tough as we think; often females are emotionally tougher (though it doesn't appear so when they overtly show distress in tears and in talk more than do boys).

Simultaneously, we have all intuited how girls often take things personally; this is a way in which they are fragile. Girls process more emotive information than boys; whereas male emotional fragility comes from having fewer cortical areas available to process emotional

information, girls' emotional fragility often comes from having so many emotive functions that they become overwhelmed by the emotional input.

One brain difference related to emotive processing is potentially of great interest, and even startling. Present brain technologies such as PET scans and MRIs are just beginning to show us that when sensory information laden with emotive content (let us again use the example of the sibling students experiencing a crisis with a parent before school) comes into the female limbic system, brain activity may be moving quickly to the top of the female brain—into those four lobes where thinking occurs—more than in the male brain. The boy's brain, on the other hand, seems to have a tendency to move information quickly toward the bottom of the limbic system (that is, the amygdala) and the brain stem. In simple terms, this makes a female more likely to process the pain or hurt and get help from others to talk about it, because more of her activity moves up to the hemispheres that verbalize and reason over the crisis; by contrast, the male is likely to become physically aggressive (fight) or withdrawn (flight).

So a male's aggression-and-withdrawal response short-circuits intellectual and academic learning because his emotive processing is taking longer and involves less reasoning; in addition, less of his emotional crisis-response neural firing is in the top of the brain, where learning is occurring. He's more occupied in the lower brain.

It is important to say that there are many exceptions to this scenario. Many girls become aggressive and shut down after a crisis at home or a humiliation at school; many boys learn better during and after a crisis because they can shut off their emotions and get to work. Many things are going on in each brain and personality that can outweigh gender difference.

Even given these exceptions, however, it's essential for us to watch how the mind is coping with an emotional crisis or outburst. If we see a girl or boy moving the emotive information downward rather than upward (becoming violent or withdrawn rather than moving through the emotions verbally or with other strategies), we must intervene as needed to help it move up. In Part Two, we give you innovative ways to

do so. Because many children can stay on their academic tasks even despite emotive pressure and pain, we come to notice that our innovations are generally directed to the girls and boys who cannot stay on task—those who are having trouble learning because they do not have the brain baseline emotive skills to process feelings quickly, or have not found in their schools and classrooms the structures they need to help them process emotions in healthy ways. Many of these structures end up not being just talk oriented, as emotionality is only partially about "using words." More on this later.

The gender differences I have just outlined are only the tip of the iceberg. We have collected more for you in Table 1.2.

TABLE 1.2

DEVELOPMENTAL GENDER DIFFERENCES AND TENDENCIES

MALE	FEMALE
PREBIRTH	
• Develops testosterone	• Develops estrogen
• Same structural brain first six weeks after conception	• Same structural brain first six weeks after conception
• "Set"*male* brain immune to *female* hormones	• "Set"*female* brain immune to *male* hormones
• Fetus generally more active, restless	• Fetus generally less active in womb
• *Male* cortex develops slower	• *Female* cortex develops faster
• At six weeks in utero sexual identity begins to develop, and brain changes	• Normal template of human brain appears to be female
• At six weeks large dose of male hormone changes brain permanently	• Lack of testosterone impact allows brain structure to remain female
• Brain is more lateral than female's	• Brain is less lateral than male's
• Less flexible	• More flexible
• Less internalized	• Less externalized
• Greater idling in brain stem (reptilian brain)	• Greater idling in cingulate gyrus (limbic system)
• Brain 10 percent larger (mass) than girl's	• Brain mass 10 percent smaller in girls
• Corpus callosum smaller	• Corpus callosum larger

(continued)

MALE	FEMALE
INFANCY	
• Prefers mechanical or structural toys • Looks at objects for shorter but more active periods • Gazes at mother half as long as girl does • Motor activity more vigorous than girl's • At one week, cannot distinguish another baby's cry from background noise • At four months of age cannot distinguish faces of known people in photos • Sensitive to salty foods • Less sensitive to physical sensation on skin • More easily angered • Better narrow vision and depth perception • Superior perception at blue end of color spectrum • Takes in less sensory "proximal" data • Left eye dominant • Less bothered by loud noises • Less interested in soft, cooing words and singing • Less able to recognize emotional nuance • 25 percent higher mortality rate than girls	• Prefers soft, cuddly toys • Plays with objects for longer periods, but less actively • Play is more sanguine • At one week, able to distinguish another baby's cry from background noise • At four months of age able to recognize faces of known people in photographs • Sensitive to bitter tastes, prefers sweets • More sensitive to physical sensation on skin • More easily saddened • Better peripheral vision • Superior perception at red end of color spectrum • More attuned to sensory input • Equal visual skill with either eye • Less tolerant of loud noises • More comforted by soft, cooing words and singing • More able to recognize emotional nuance • 25 percent lower mortality rate than boys • Three times better at reading; reading as auditory activity (superior hearing)
TODDLERS	
• Speaks first words later than girls • By age four and a half, 99 percent of speech is comprehensible • Shows greater interest in exploring once standing is mastered • Greater muscle mass already evident by age three • Less able to multitask • Hears better in right ear • Better auditory memory • More likely to ignore voices—even parents' • More physically impulsive	• Develops better vocabulary earlier than boys • By age three, 99 percent of speech is comprehensible • Even after mastering standing, does not roam as freely as boys • Greater concentration of fatty tissue still more evident than muscle at age three • Better ability to multitask • Hears equally well with either ear • Better visual memory • Less likely to ignore voices—especially those familiar

MALE	FEMALE
PRESCHOOL AND KINDERGARTEN	
• One-directional, less cross-talk between hemispheres, more focused • Occupies larger space on playground than girls • Playground activities involve more individual running • Playground games are rough and vigorous, competitive and aggressive • Playing with blocks, builds high structures likely to topple over • Newcomers to group ignored until they prove their worth and value • Stories filled with excitement and action, ignoring victims • Games involve bodily contact, tumbling, continuous flow of action • Primarily interested in objects and things • Saying good-bye to mom takes approximately thirty seconds • Uses dolls for attack weapons and warfare • More speech problems • Picks same-gender peers for friends • Expresses emotions through action • Less sensitive to social and personal context • Less attention span and empathy	• More cross-talk between hemispheres of brain as shown by approach to activities • Congregates in groups of other girls in smaller spaces, often huddling together • Playground games are quieter and less active, more cooperative • Playing with blocks, tends to build low and long structures • Newcomers greeted more warmly • Stories pay attention to human dynamics; particular concern with victim's feelings • Games involve turn taking and indirect competition most of the time • Primarily interested in people and relationships • Saying good-bye to mom takes approximately ninety seconds • Uses dolls for playing out domestic scenes • Fewer speech problems; seems to differentiate sounds better • Picks same-gender peers for friends • Expresses emotions through words • More sensitive to social and personal context • Greater attention span and empathy
GRADES 1–3	
• Takes longer to attain reading mastery • Superior at certain visual tasks in bright light • Better at tests requiring circling of answers • Hypothalamus functions to keep hormonal levels even • Better general math • Better at three-dimensional reasoning • More rule bound than girls • 95 percent of hyperactive children • More able to separate emotion from reason	• Reads better and sooner than boys • Superior at seeing in low light • Superior at hearing • Better at tests requiring listening as questions being read • Hypothalamus functions to fluctuate hormone levels • Better verbal ability • Better at grammar and vocabulary • Less bound by arbitrary rules • Only 5 percent of hyperactive children • Less able to separate emotion from reason

(continued)

MALE	FEMALE
GRADES 4–6	
• Hormones begin to increase at age ten • Primarily focused on action, exploration, and things • More likely than ever to use aggression to resolve differences • Better at reading maps and deciphering directions • Better at chess • More likely to need remedial reading • Solves math problems without talking • Channel surfs on TV	• Affected by hormone changes earlier than boys • Primarily focused on relationships and communication • Unlikely to settle differences with hitting • Better at fine-motor skills and coordination for fine tasks • Better at learning a foreign language • More likely to sing in tune • Solves math problems with language help • Watches one program for longer period
MIDDLE SCHOOL	
• Testosterone develops body at ratio of 40 percent muscle mass to 15 percent fat • Testosterone indisputably an aggression-inducing chemical • When talkative in class, often seeking attention • 50 percent more likely to be held back a grade than eighth-grade girls • Amount of male hormone relates directly to success at traditional male tasks • More likely to be a victim of physical abuse	• Estrogen develops body ratio of 23 percent muscle mass to 25 percent fat • Estrogen generates greater activity in the brain (first phase of menstruation, increased concentration) • When quiet in class, often confident • 50 percent less likely to be held back a grade than eighth-grade boys • Amount of female hormone relates directly to success at traditional female tasks • More likely to be victim of sexual abuse • Hypothalamus functions to fluctuate levels based on a twenty-eight day cycle
HIGH SCHOOL	
• Concentration on things directed at career considerations • Focus on strength and muscularity for sexual attractiveness (fearing weakness) • Social acceptance based on physical strength and athleticism • More likely to be involved in criminal behavior • In one study 69 percent of males suggested "fighting" as best way to resolve conflict	• Concentration on more intimate personal relationships • Focus on slender appearance for sexual attractiveness (fearing obesity) • Social acceptance based on peer relationships and beauty • Less likely to be involved in criminal behavior • In one study 69 percent of females suggested "walking away or talking things out as the best way to resolve conflict"

MALE	FEMALE
• Social hierarchies tend to be stable (boys "know their place") • Pursuit of power a universal male trait • Achieves far greater academic success after puberty • IQ scores rise dramatically between fourteen and sixteen • Boys with XXY chromosomal pattern (an extra female chromosome) do less well at spatial reasoning • Bullies still popular among peers • Athletes slightly more sexually active than male peers • If involved in high school athletics, more likely to get better grades and go to college (also more likely to drink and try drugs) • More likely to succeed at suicide • 85 percent of students in advanced placement computer science classes • Matriculated (graduated) at lower levels than girls in high school and college • Less likely than girls to suffer episode of clinical depression • Performance on writing examinations less affected by biological cycles	• Social hierarchies tend to be fluid • Pursuit of comfortable environment a universal female trait • Higher-than-normal estrogen level produces certain intellectual disadvantages • IQ scores level off or drop during middle school but rise again at high school • Girls with higher-than-normal level of testosterone better at spatial reasoning • Bullies among girls unpopular • Athletes less likely to be sexually active than girl peers • Less likely to become pregnant if involved in school activities • More likely unsuccessful at suicide attempt • 15 percent of students in advanced placement computer science classes female • Matriculation levels higher than boys in recent years in both high school and college • Almost 50 percent of girls in one survey experienced at least one episode of clinical depression within five years of high school graduation • Performance on writing exams drops by as much as 14 percent during menstrual cycle • Outperform men in tests of verbal and communication skills

Why the Brains Are Different

One of the intriguing things about brain-based research is our theoretical understanding of why the differences between female and male brains exist. We now have no problem proving that they exist because MRIs and PET scans show us how certain structures in the brain differ, and how blood flow and neurotransmission varies with gender. But

why? Why the differences that scientific technology has now taken out of the world of speculation and made fact?

We can answer the question in two ways: one involves human and natural history and the other involves hormones in utero and at puberty.

A Brief History of Brain Difference

Evolutionary biologists believe our brains differ by gender because it has been necessary in human evolution for humans to divide up tasks by gender. (If your personal religious convictions make the theory of evolution unacceptable to you, the explanation can be changed to "God created us this way.") From the evolutionary point of view, however, there was indeed some form of mysterious, even divine, inception to humanity, occurring some four million years ago, and gradual evolution of the human brain, beginning around two million years ago. As the brain evolved, its elements (amygdala, two hemispheres, brain stem, limbic system, and so on) diverged in development, to a degree, according to gender.

In order for the human species to survive, this divergence of sex roles was necessary. Until about ten thousand years ago, when the agricultural age arose in many parts of the world, humans were hunter-gatherers. Males were responsible for hunting (a very spatial occupation) and periphery protection and war (very aggressive occupations); females were responsible for gathering roots and other vegetation and most child care (sensory and verbal occupations). Males built most of the large structures, forming large-group teams for their activities. Females did more of the inside work: arranging and managing internal home space, and working in dyads, triads, and smaller groups. Females verbalized in their intimate groups; males tended to carry out action in their larger groups.

Over millions of years, the brain both created and accommodated these circumstances. Females had to be better at verbal skills than males; males had to be better at spatials and more physically aggressive. Females had to care more about small-group consensus; males had to

rely more on pecking-order hierarchies with dominant leadership. Females had to hear, see, and use all the senses and remember variety among things in order to provide the subtle brain development and care a child needs; males had to focus on the single task of providing for and protecting communities of children.

Both the brain and its hormones—which are catalysts for brain activity—came to differ with gender. The differences existed (as they still do) even in utero; for instance, male babies tend to be more active, kicking the mother more. Human environmental socialization was likely to enhance these tendencies in those cultures that required greater difference. Thus, in some small tribal cultures, where competition for resources within a community is not stiff, where everyone works together closely and where there are few if any wars with other tribes, the gender differences are lessened. In cultures with larger populations (like ours) where there is immense competition for resources, where family and care units are increasingly independent from one another, and where conflict with other cultures is constant or imminent, the gender differences shine through more.

It is interesting to note that male and female hormones were not as far apart in their constitution a million years ago as they are now. We know this because testosterone level is directly related to bulking, or muscle mass, and fossil records show us that male and female bodies used to be closer in size than they are now.

Some evolutionary biologists argue that the most important determinant of hormonal gender difference is population growth. The larger the population, the more testosterone is required. Given present human social reality, males have little choice in increasing theirs; they are compelled to compete constantly for resources. Females have some choice; should they choose to attach to a bonding group (an extended family) or an alpha male (a competent male) during the child-raising years, they can avoid being increasingly competitive and thus not need to raise their own testosterone. Females can increase their testosterone by competing more (high-testosterone females will already do so) or by being injected with testosterone (and taking androgenic testosterone-based steroids). Some women have experimented with testosterone

over the last few years; they become more independent, socially ambitious, and aggressive.

Given that both male and female testosterone levels are going up around the world today, the population argument seems valid. The more population we have, the more our brains (and therefore our hormones) anticipate the necessary increase in all the ways we can compete as individuals, communities, and a species, from testosterone-linked aggression to estrogen- and progesterone-linked bonding and consensus building.

It is surely important for social theorists who strive to "androgynize" males and females to know this. Although in some ways boys and girls are definitely becoming more like each other (boys are learning to verbalize feelings better, and girls are learning to compete better on athletic and work teams), they are also becoming ever more different. More males are being born with high testosterone (for example, we are producing taller basketball players and larger athletes, and more males with better engineering and architectural spatial development). More females are being born with higher estrogen and progesterone; that is, we are producing more females who have better verbals and who in fact do not flourish well except in close attachments and relationships with mates and family. Brain-based research and its evolutionary perspective compel us to accept that *both* androgyny and separate-gender traits are increasing. The solution to the problems being experienced in the schools involves helping *both* the androgynous kids and the more gender-different.

The Role of Hormones in the Womb and at Puberty

The historical causation of gender differences in the brain probably goes back to hunter-gatherer society and continues in our high-population culture, but the logistical causation of brain difference lies in how male and female hormones influence development.

All fetuses start out undifferentiated. In the first trimester of pregnancy, surges of testosterone from the mother's ovaries, responding to signals from the fetus's Y chromosome, begin creating a male. One set

of surges compels the genitals to drop and become penis and testicles. Further surges of testosterone wire the brain toward male structure and functioning. Thus, sex hormones change the brain's very architecture to male.

When the surges of testosterone, estrogen, progesterone, prolactin, and other hormones occur at puberty, we have a kind of second-womb or second-birth activity. The brain changes toward increased genderization yet again. For instance, in both sexes, surges of testosterone at puberty swell the amygdala (the part of the limbic system that generates feelings of fear and anger). This change is especially pronounced in boys, which helps explain the rise in aggressiveness seen in both sexes at adolescence, and especially in males who become high risk. The increased level of estrogen at puberty causes sudden growth of the hippocampus, the part of the brain that focuses on memory. A larger hippocampus can mean a better memory. The hippocampus in girls grows larger than it does in boys—one reason girls and women are better than boys and men at remembering some things, such as names and faces in myriad social relationships.

Estrogen and testosterone seem to help flip on neurological switches at puberty, switches that were previously set by hormonal levels way back during fetal development. Once flipped, these switches change a teenager's sex drive, along with a host of other attitudes and behaviors (irritability, aggressiveness, and moodiness, to list just a few).

Researchers have further found that a shift in prenatal hormones can affect us in ways that may not become clear until later in life. Testosterone shapes centers in the brain that process spatial information. In studies of girls with congenital adrenal hyperplasia (CAH), a condition that causes the adrenal glands to make excess androgen (a testosterone-like hormone) during prenatal development, their brains were found to be permanently changed. Sheri Berenbaum, a psychologist at Southern Illinois University Medical School, found that as teenagers, girls with CAH were more aggressive than their sisters and had better spatial skills (such as the ability to rotate objects in their minds, or to imagine how pieces of a puzzle fit together). These girls were also more interested than their sisters in becoming "engineers and pilots."

Why are male and female brains different? The best answer we have now is this: millions of years of human history are inherited in the neural systems of male and female children. This history is then imitated as the child's brain and hormones develop. Though of course with many exceptions, girls and boys develop their internal wiring differently, and the difference has profound effects on how boys and girls act, live, and learn.

In this chapter we've held up an X-ray of the human brain, hormones, and development in order to discover the seat of the differences between boys and girls. Now let's look even more closely at how those natural differences directly relate to the learning process.