It comes down to this, animals have a brain and plants don’t. Biological competence isn’t the issue. The reason plants don’t have a brain is that they’re not going anywhere of their own volition. And if an organism isn’t going anywhere, it doesn’t even need to know where it is. What’s the point?

But if an organism has legs, wings, or fins, it needs a sensory system to inform it about here and there, a decision system to determine if here is better than there or there is better than here, and a motor system to get it to there if that’s the preferred option.

To plan and regulate personal movements, and to predict and respond to the movements of others and of moving objects thus pretty much defines the basic purpose of a brain (and of school for all that).

We can use our leg/foot/toe system to physically move our body; our arm/hand/finger system to grasp, lift, carry, and throw; and our neck/face/tongue system to move food into our body, and ideas from our brain into the brains of others. So speech and song are forms of movement.

We also move between dichotomous states – such as from infancy to elderly, from unemployed to employed, from sad to happy, from healthy to sick. The arts add aesthetic qualities to human mobility by encouraging us to move with style and grace. Sports explore virtuosity and the extent of our movement capabilities. Most technologies supplement the limitations of biological movement.

So to be human is to move in many different ways – from the ritual movements associated with conception at the beginning of life to those associated with burial at the end.

Our life experiences and the stories we tell about them focus principally on movement in time and space. When movement stops, we die.

Teachers who continually ask students to sit still and be quiet thus seem more interested in teaching a grove of trees than a room full of students.

Educational leaders who eliminate recess, and reduce arts and physical education programs seemingly don’t understand the purpose of a brain, and what it takes to develop and maintain one. Perhaps they’re plants, and so don’t quite grasp that
movement is our brain’s definitive property -- and that aesthetic movements add quality to human life.

**Cognitive Neuroscience Developments**

The relatively recent development of neuroimaging technologies escalated the scientific study of our brain and cognition. Psychological researchers study the behavioral (or motor) output of a brain, and educational and sociological researchers study the behavior of groups of brains, but neuroimaging technologies such as fMRI (functional magnetic resonance imagining) have added another important research dimension. Neuroimaging can transform a real brain hidden within a skull into a virtual brain observable in a computer. This transformation has finally allowed scientists to observe how various brain processing systems collaborate when they develop a decision, and then activate the appropriate behavior.

Discovering via neuroimaging that two brains might not identically execute a task doesn’t necessarily tell us if one cognitive strategy is better than the other, or why one person performs better than the other – but not being able to observe such internal processing differences insures that our understanding of brain functions would forever be limited to the behavioral end product of cognition.

Neuroimaging studies of brain processes will thus be integral to future educational theories, policies, and practices. An infant isn’t much more than a wet noisy pet – fascinating, but at least 20 years from a clear sense of what it will become. We carefully observe a child’s capabilities and possibilities -- and the enigmas become speculations become convictions.

The neurosciences are similarly in their infancy – fascinating, but they currently provide only tantalizing glimpses of the profound effect they will eventually have on our profession. Other articles in this issue describe the current state of our profession’s exploration of the educational applications of selected cognitive neuroscience discoveries.

This article will describe seven movement-related areas of cognitive neuroscience research that I believe will play key roles in shifting the current behavioral orientation of our profession to an orientation that also incorporates cognitive neuroscience discoveries. Become acquainted with them and their emerging literature, and begin to informally explore their potential educational applications.

**Mirror Neurons.**

Parental genetic information combines to provide a developing embryo with the necessary bodybuilding directions – how to be. When the child is born, parents and others must provide cultural information about how to behave. They do this principally through language and our brain’s remarkable recently discovered mirror neuron system.

Movement skills must obviously begin to develop almost immediately, and many movement skills (such as how tie shoelaces) can’t be learned solely through verbal directions. Our brain’s mirror neuron system helps to solve that instructional problem, and especially for young children who haven’t developed language skills.

The motor cortex in the frontal lobes regulates conscious movements. The mirror neurons in this region prime movement sequences (such as the sequential actions
involved in grasping an object) but they also automatically activate when we observe someone else carry out that movement. They thus create a mental model of observed movements – simulating, and then often imitating what they observe.

For example, when we observe someone yawn, it activates our brain’s yawning system. Adults typically override the tendency and stifle the yawn – but if we stick out our tongue at an infant who is only a few hours old, it’s probable that she’ll immediately reciprocate, even though she had never before stuck out her tongue. Her observation of our behavior and lack of motor inhibition will automatically activate the mirror neurons that prime the motor neurons that activate her tongue projection movements.

Mirror neurons help to explain how children learn to speak, how empathy develops, what causes such maladies as autism, why observing others engaged in sports and artistic performance is so appealing, the effects of role modeling and electronic media on behavior – and I expect a whole lot more in the years ahead (Sylwester, 2006).

The renowned neuroscientist V. S. Ramachandran (2006) suggested that mirror neurons may provide the same powerful unifying framework for our understanding of teaching and learning that the 1953 discovery of DNA did for our understanding of genetics.

**Neuroplasticity.**

Changes occur in the organization of our brain at the cellular and network levels whenever we learn, remember, and forget. This process of adapting cognitive capabilities to new demands and conditions is called neuroplasticity. For example, the brain region that regulates left hand finger movements becomes more robust in right-handed violin students because of the increased activation of left hand fingers, but such changes don’t occur in the region that regulates the right hand fingers that only hold the bow.

Neuroimaging technologies can now compare the amount of brain space devoted to an activity in those who are proficient in a skill with those who aren’t, and so can determine the physical effects of an intervention. For example, Temple (2003) discovered that 8-12 year old dyslexics not only improved selected language abilities after exposure to a program called Fast ForWord, but also that fMRI brain scans of the related language areas reflected this improvement.

The recent discovery of the genetic mechanism that simplifies learning in children, and makes it more difficult in older people suggests that scientists may be able to eventually manipulate the process to enhance learning in older people, such as to learn a new language, or to recover from a stroke (Devlin, 2006).

Our brain is thus far more plastic than scientists formerly believed. Neuroimaging technology will play an increasing role in diagnosing cognitive disabilities and determining the effectiveness of a proposed intervention. So it’s an optimistic time. Many of the maladies that negatively affect educational progress may disappear as early diagnosis leads to an early successful intervention.

**Emotion and Attention**

Emotion and attention are our brain’s activation systems, in that our brain will...
only respond to emotionally arousing phenomena, and it must then frame and focus on the salient elements that led to the arousal (separating foreground from background). Emotion thus drives attention, and attention drives responsive decisions and behaviors. Most brain dysfunctions (from autism to schizophrenia) are emotional and attentional at some level, as is much classroom misbehavior. Our brain’s neuroplasticity is thus dependent on the activation of emotion and attention. Learning and memory exist for the long haul, but emotion and attention are about the here and now (and so are often called our working brain).

Emotion and attention issues are thus central to educational policy and practice, and teachers who don’t factor emotional triggers and attentional focus into their instruction might as well teach in an empty classroom. Unfortunately, the two systems are very difficult to study, and so although humans have always understood them functionally, scientists historically didn’t understand their complex underlying neurobiology and related maladies (such as autism and schizophrenia).

That is now changing. For example, the renowned neuroscientist, Antonio Damasio (2003) has recently written a very accessible description of his theory of emotion and its neurobiological base. Educators can expect that the centrality of these integrated systems and the problems the dysfunctions create will spark further research.

We’re not alone in our hope for an increased understanding. The success of marketers, politicians, TV programmers, and many others is also dependent on their ability to understand, bias, and regulate emotion and attention.

**Hemispheric Specialization**

The cerebrum at the top of our brain processes conscious thought and behavior. The sensory lobes at the back recognize and interpret current challenges, and the frontal lobes determine and execute an appropriate response. The role of the right and left hemispheres has been somewhat of an enigma.

Elkhonon Goldberg (2005) suggests that the major question a brain must ask whenever it confronts a challenge is ‘Have I confronted this problem before?’ He argues that in most people, the right hemisphere lobes process novel challenges and develop creative solutions, and the left hemisphere lobes process familiar challenges and execute established routines.

Childhood and adolescence are characterized by many novel challenges, and so the right hemisphere in young people is more robust. As we age, we develop an increasingly large repertoire of routines that we incorporate into the resolution of a wide variety of challenges. Although both hemispheres activate whenever we confront a challenge, the left hemisphere assumes a greater role and becomes more robust as we age. It takes a lot of energy to understand and respond to novel challenges, so we try to reduce emotional arousal and novelty in our lives, and tend to use responses we’ve already developed. We get set in our ways.

Schools are run by older people who *know the answers*, and the students are young people who want to *explore the challenges*. Schools thus often teach students the answers to questions they haven’t yet asked, that don’t engage them emotionally. Students obviously need to master basic skills and their cultural heritage, but the challenge for educators is to create the right
The mix of didactic instruction and creative student exploration – and to also reflect this mix in standards and assessment programs.

**The Arts and Humanities**

The arts and humanities effectively incorporate this curricular mix, in that they combine the best representations of our cultural history and the creative explorations of new cultural challenges. They should (but alas currently don’t) play a central role in the curriculum.

The arts and humanities have always played a key role in human life. The existence of ancient artifacts and legends attest to the seemingly innate human drive to add celebratory aesthetics to ordinary phenomena – to decorate clothing and utensils, to amplify ordinary events through extraordinary stories.

Scholars are trying to determine the biological genesis of this drive, and several intriguing proposals have emerged. Movement is a central human property, and it’s an essential ingredient of the arts and humanities. It isn’t enough for us to move, but we want to move with style and grace. For example, a child initially masters basic skateboard skills, but then focuses on the aesthetics of skateboarding. It’s the wheeled equivalent of the shift from walking to dancing. The marvelous thing is that such artistic expression interests those who do it, and those who merely observe others do it (perhaps reflecting the significance of mirror neurons).

Emotion and attention, the gateway to cognition, are also essential elements of the arts and humanities. Artistic arousal and focus help to maintain the vigor of our emotion/attention systems.

Further, the arts and humanities often play an important arousal/focusing role in society that’s analogous to the role that emotion/attention play in individuals. Picasso’s mural *Guernica* and Aristophanes’ drama *Lysistrata* are renowned examples of art forms that alerted and continue to alert society to the horrors of war.

The integrated nature of the arts and humanities may thus have emerged to stimulate various brain and motor systems to creatively and metaphorically solve imagined problems in non-threatening settings in ways that could later be incorporated into solutions related to real life challenges. At a very mundane level, the young skateboarder who artistically avoids danger will eventually drive in commuter traffic.

The recent disintegration of school arts and humanities programs is a biological tragedy that we will come to bitterly regret. Why is it so important that students know the sequence of letters that spell a word but not the sequence of tones that constitute a melody? Articulate speech and song are simply two forms of one language. Speech communicates information, and song communicates how we feel about the information. Information without feeling is robotic.

**Intelligence**

Towards the end of the 20th century, Howard Gardner (1983), Robert Sternberg (1985), and David Perkins (1995) proposed that intelligence isn’t a unitary global phenomenon (I.Q.), but rather that it exists within a set of distinct cognitive capabilities that may be differentially expressed in people. The idea of multiple intelligences resonated with educators, and the concept
has profoundly affected recent educational policy and practice.

Imaging technologies that were in their infancy when multiple intelligences theories appeared are now far more sophisticated, so it should come as no surprise that emerging new perspectives on intelligence are attracting popular and professional attention. Jeff Hawkins’ *On Intelligence* (2004) and Malcolm Gladwell’s *Blink* (2005) are recent examples of such widely read and discussed books.

It’s difficult to predict the next major breakthrough in our understanding of intelligence, but I suspect that it will incorporate variations in our ability to rapidly and effectively predict, recognize, and respond to environmental challenges, to communicate within a variety of venues, and to alter the environment through human/machine interactions. Whatever emerges will profoundly affect educational policy and practice.

**Consciousness**

Consciousness is the last major enigma in biology. It provides us with a unified sense of self, a subjective awareness of our existence and of the environment we inhabit. Consciousness had long been the purview of philosophers and theologians, who viewed it as a disembodied entity – mind, spirit, soul. Since neuroimaging technologies can observe conscious brain behavior, the neuroscience community is actively exploring the neurobiology of consciousness.

Conscious thought and behavior emerge out of unconscious emotional arousal, which alerts us to potential challenges and helps to activate innate automatic responses. If we have no innate response to a challenge, conscious feelings emerge, and these activate relevant brain systems that consciously (subjectively) and rationally (objectively) analyze the challenge and develop a solution.

Since school activities focus principally on conscious learning and behavior, the biology of consciousness will thus help to formulate credible 21st century educational theories. But since consciousness is also integral to religious belief and cultural behavior, its relationship to educational theory will certainly be controversial. Educational leaders will obviously have to understand consciousness in order to deal intelligently with the complex issues it will raise.

Since the grandmother of all Nobel Prizes will probably go to whoever works out the underlying neurobiology of consciousness, the world’s major neuroscience laboratories are working on the issue. Further, neuroscientists are writing excellent books on their discoveries that are accessible to educators (Sylwester, 2004).

If I were a young person looking for a challenging 21st century career, I couldn’t imagine anything more challenging than education. Contemplate the emerging issues discussed above, and the important roles they will play in transforming educational policy and practice – and by extension, the direction of our society. What a marvelous opportunity for bright young educators to be at the cutting edge of this emerging unprecedented cultural transformation!

**References**

Devlin, H. (August 12, 2006) “Protein block that makes the old less able to adapt to the new” The Times. www.timesonline.co.uk/article/0,,11069-2319339,00.html


Sylwester, R. (October, 2004 column) “Consciousness Research, Educational Practice” www.brainconnection.com


He can be reached at: Email: bobsyl@uoregon.edu Phone: 541-345-1452