The Brain: User-Friendly & a Fascinating Classroom Subject

Warren Marchioni

The brain, according to geneticist and Nobel laureate, James Watson, is "the greatest challenge in science today." Watson's co-discoverer of the structure of DNA, Francis Crick, recently has published a book on how the physical brain is wholly responsible for what previously had been known as mind and all the remarkable phenomena associated with it—consciousness, memory, personality. More knowledge of the brain and how it works has been gained in the past 25 years than in all the time of study before then. Over the years, the brain has been referred to as a machine, a switchboard, a pump, a file cabinet, and more recently, a computer (Restak 1984). Obviously, each generation has its favorite analogy, depending upon whatever is at the cutting edge of technology at the time. Many believe that the human brain may be the most complex substance in the universe. It contains more than 10 billion cells or neurons and some trillion synaptic interconnections. The number of different possible mental states of the human brain would therefore be raised to this power; that is, multiplied by itself 10 trillion times. This unimaginably large number is far greater than the total number of elementary particles (protons and electrons) in the universe (Sagan 1977).

Davis (1984) has criticized the choice of outer space as the last frontier of knowledge. He doesn't believe that the center of the atom or the bottom of the deepest oceanic abyss should be considered for that honor. He feels that the last frontier is within us—1400 grams of convoluted nerve tissue encased in our skull—the human brain.

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It is a complex subject, but some of the mysteries are unraveling and the findings are fascinating. It was for these reasons, and the promise of solving the problems of Alzheimer's disease, MS, Parkinson's disease, addiction, depression and others too many to mention, that former President

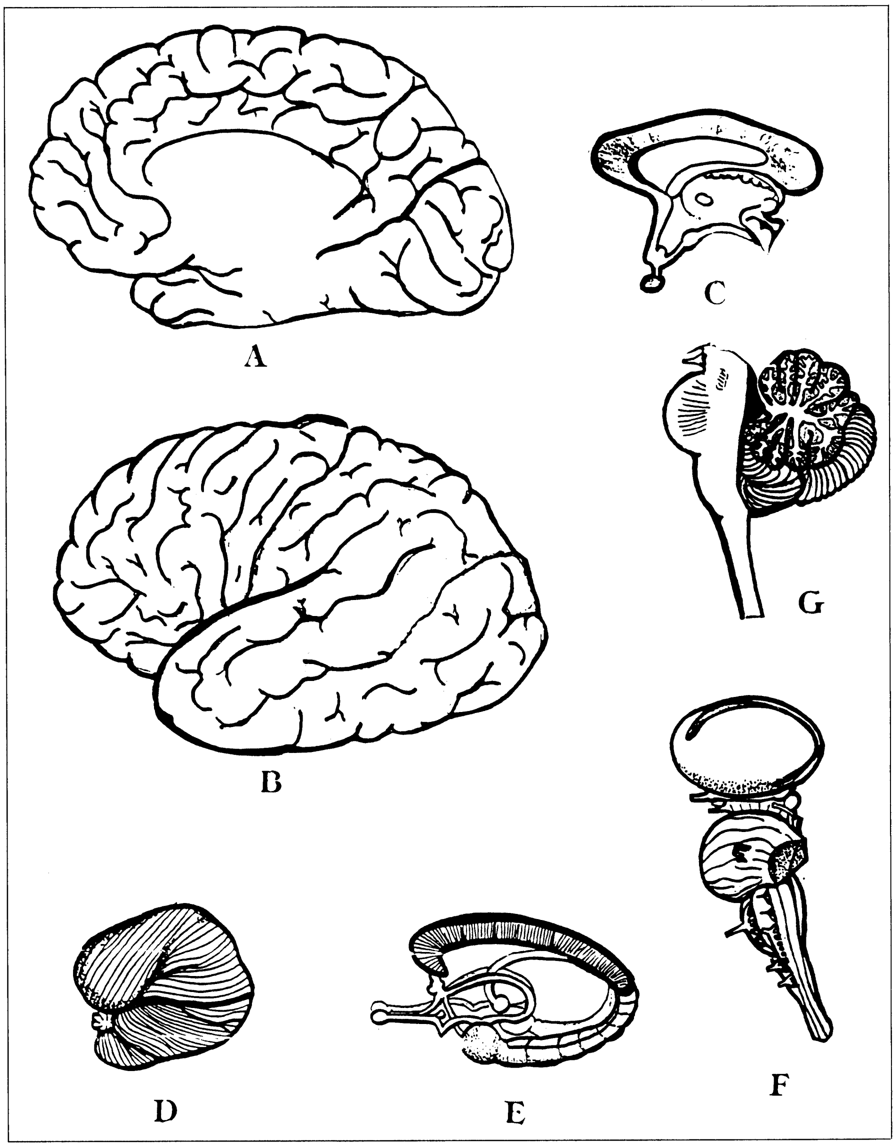

Figure 1. Template for construction of student 3-D model of the human brain.

George Bush formally proclaimed the Decade of the Brain, 1990–1999.

The scope, of course, of brain study for young biology students has to be limited by its complexity and the amount of time available in the current curriculum, but the section of the course dealing with it can be as lively as the daily headlines, where, more and more frequently results of current research can be found. The advancements in brain science seem to compete on a nearly equal basis with those resulting from studies of DNA and AIDS, the other two headline-grabbing areas of current biological science.

The size of the human brain shows intricate variation among individuals, largely, but not always, dependent upon body size. Women, for example, tend to have smaller brains than men, which is not surprising since women tend to have smaller bodies than men. The brain of an adult male is about three pounds (1.4 kg). By capacity, this brain would fill a space of 1400 cc or about the volume equal to three pints of milk.

Brain size in humans has turned out to be a poor indicator of intelligence, as one of the largest brains ever measured was that of a severely retarded individual, while several creative and productive individuals in history have had relatively small brains for their body size. As examples, the American poet, Walt Whitman, possessed a brain of only 1282 grams and the French author, Anatole France, had a productive, but unimposing brain of 1017 grams. Attempts have been made in the past to correlate intelligence with brain size, and brain size with race and ethnicity. The techniques employed and the results obtained were motivated and influenced by the prejudice of the times during which these researchers worked (Gould 1981).

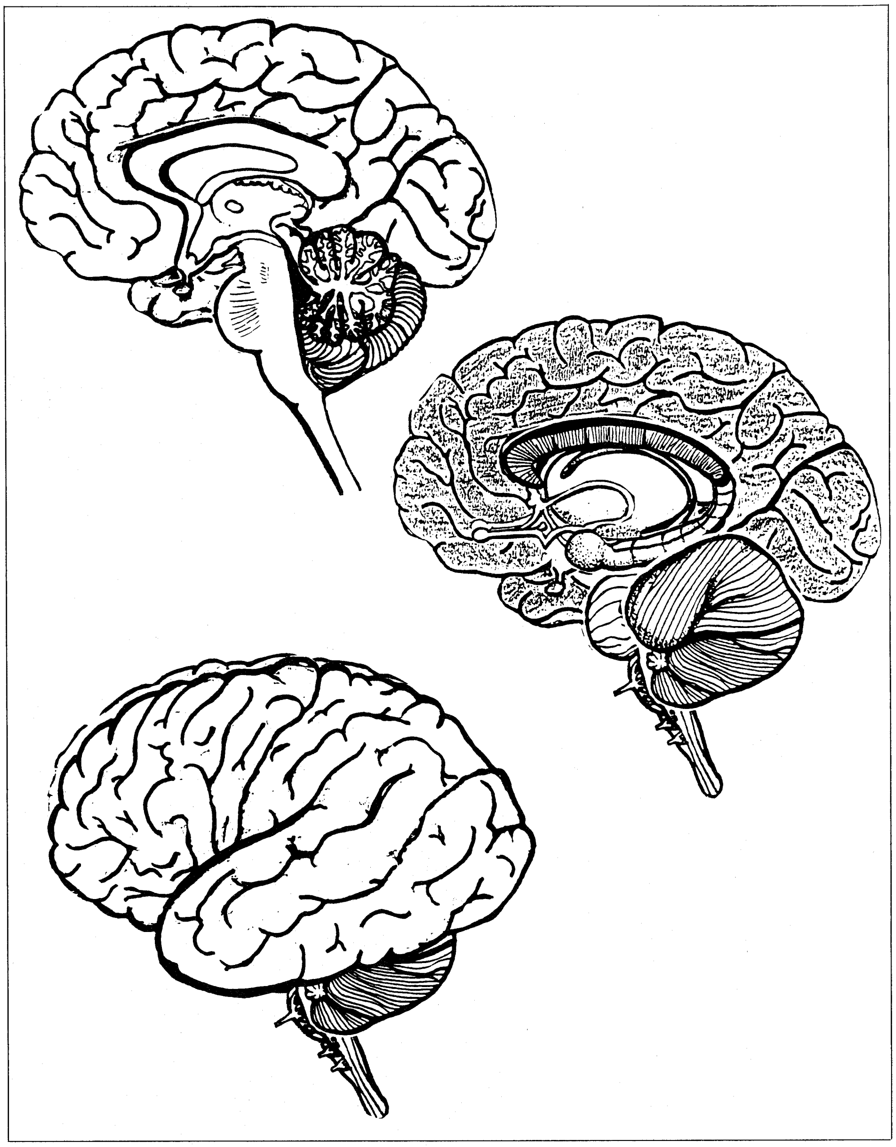

Figure 2. The brain model should be put together in the order shown here from top to bottom.

The human brain is an organ with many divisions, not all of them visible from the surface. For this reason, it is suggested that a better understanding by students of its anatomy will require them to construct a three-dimensional model. Figure 1 provides cut-out sections of a complete human brain. This template can be enlarged on a copying machine to approximate actual size. The template should be glued to thin cardboard and then cut carefully into the seven sections. The sections then can be layered into the correct positions according to Figure 2. Sections may be held together by a paper clip so that the model can be taken apart for study and review.

Based upon phylogenetic and embryological studies, the brain has been divided into three principal parts—forebrain, midbrain and hindbrain. The forebrain consists of the two prominent cerebral hemispheres (sections A and B) connected by the corpus collosum and deeper, not visible sections (C and F) that include the limbic system, basal ganglia, and diencephalon or "between brain." (The latter consists of the thalamus, hypothalamus, pituitary gland and pineal gland.) The small midbrain (a relay station for messages on their way to higher centers) occupies the uppermost part of the brain stem. The brain stem (pons and medulla oblongata) and the cerebellum make up the hindbrain (D and G).

For a more realistic view of the vertebrate brain, I discovered a reliable source of heads for brain dissections—the local poultry dealer. The only part of the fowl that generally is not marketable is the head, and sufficient numbers for your students are available usually just for the asking. The heads should be preserved until needed to prevent any possibility of salmonella infection when they are used. However, long periods of preservation, particularly in alcohol, tend to harden the skulls, making the dissections difficult. Otherwise, the porous bone of the avian skull slices away easily and the brain can be extracted in one piece with meninges

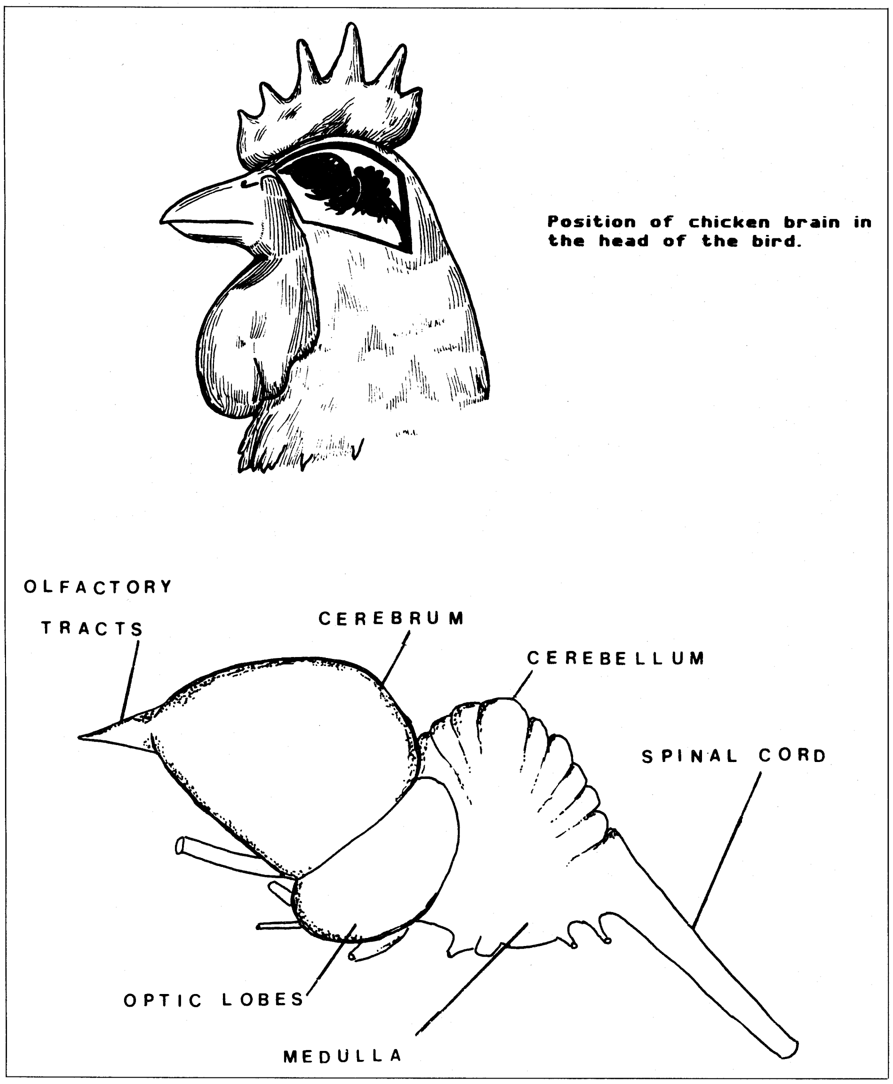

Figure 3. Position of brain in avian skull and a sketch of the major external parts of the chicken brain.

intact. Students, of course, should wear laboratory goggles and be instructed on the proper and safe methods of dissection. Figure 3 shows the position of the brain in the bird skull and the major components when removed.

As the brain is the most complex organ in the body, its development in the beginning of an individual starts early; for example, its rudiments can be seen in the embyro before the heart ever appears. One of the central problems in embryology is to understand how the billions of neurons can make the correct connections with each other. Cerebral neurons have many extensions, with a single nerve cell receiving as many as 100,000 different inputs (Wolpert 1991). From this intricate "wiring," programmed behavior is laid down in animals in fixed action patterns ranging from web building to navigation; the mental processes of consciousness, language and, perhaps, intelligence and creativity arise similarly in humans. Such possible correlations between human accomplishment and brain organization led to the request by scientists to examine Albert Einstein's brain after his death. Interestingly, the only unique feature that neuroanatomists could find was a greater than normal ratio of glial cells to neurons. Glial cells, which support and insulate the neurons, reproduce; neurons, with few exceptions, cannot.

The development of the central nervous system, which includes the brain and spinal cord, can be studied by using chick embryos. Sources of fertilized eggs can be found in most regions of the country or from biological supply companies. Incubation will be necessary only through the fourth day to demonstrate the marvel of vertebrate brain ontology. Eggs can be opened on a daily basis to demonstrate the progression from neural tube to head fold to the three-stage embryonic brain (proencephalon, mesencephalon, rhombencephalon) up to the final five-stage brain (telencephalon, diencephalon, mesencephalon, metencephalon, myelencephalon) (Figure 4).

Another approach to studying the brain in the classroom is to map a portion of the brain by testing the touch sense receptors of the skin. Human skin possesses several different sense receptors that can be differentiated from one another when a cross-section of skin is placed under the microscope. These different receptors respond to mechanical, chemical and thermal stimuli, allowing us to explore the characteristics of our environment.

Most of the activity in the cerebrum of the human brain is centered in a thin, convoluted surface layer only a few millimeters thick. Different regions of the cerebral cortex have different functions (Figure 5). For example, the somatosensory cortex straddles the foremost portion of the parietal lobe. Each point on this band of densely packed nerve cells represents sensory receptors from a different part of the body. Due to the crossing over of nerve tracts, the right half gets input from the left side of the body and vice versa. The specific amount of space in the brain designated to sensing each body part is proportional to the density of the sensory receptors in that area. As an example, the fewer the receptors in the upper arm, the smaller the upper arm sensory area is in the brain. Therefore, it is possible to map the entire body as it is "sensed," in this case through touch, by the cortex. Classically, this takes the form of a homunculus or "little man," which represents what a human would look like if built according to the sensitivity of body parts.

A device known as a sewing gauge, and calibrated both in the metric and English systems, is available from most sewing stores. This tool, with one fixed point and another one that slides along a calibrated scale, can be used to measure the distance between skin receptors. The class can be divided into teams consisting of an experimental subject (blindfolded) and an experimenter/recorder. Starting from the head and working down to the feet, each experimenter measures

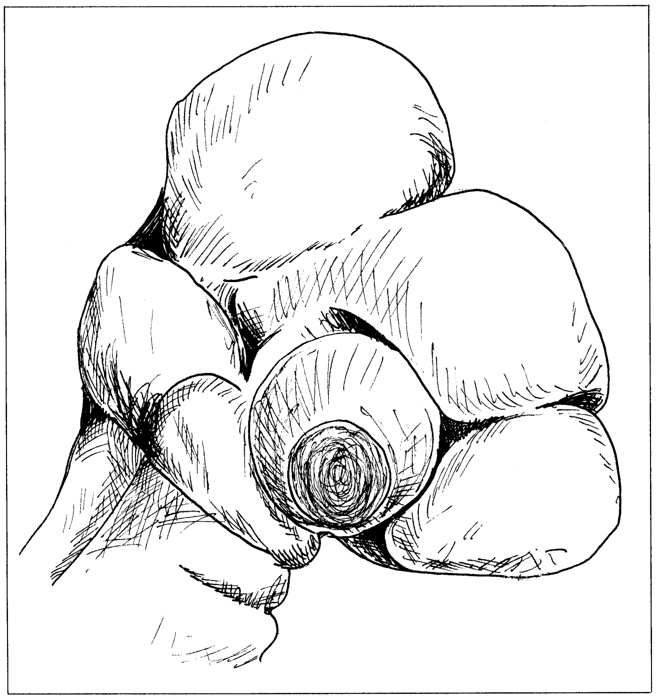

Figure 4. Four-day-old chick embryo showing the five embryonic sections of the chick brain.

the distance between touch receptor fields in specific parts of the right hand side of the body, using the following procedure:

1. Spread the points apart and press the points lightly on the skin of the subject. The subject should detect two points of contact before preceding.
2. Move the two pins closer together, 0.5 cm at a time, until the subject no longer is able to distinguish two separate points. Measure this distance in cm. At this time, both points are within the same receptive field on one sensory receptor, and so the two points cannot be identified separately.
3. Repeat this measurement twice in the same general area. Average these measurements and record the mean in the data table (Figure 6).
4. Students should measure as many parts of the body listed on the data table as possible.

The number recorded for each body part represents the distance between each sensory receptor field, therefore the distance measured is inversely proportional to the left cortical area dedicated to that body part. That is, the closer the receptor fields, the larger the area represented on the cortex. To calculate the inverse, divide each mean into the number 1. For example: If the distance equals 0.2 cm, 1/0.2 divides out to be 5.0. Calculate the inverses for each body part and record them on the data table.

Students can then draw a proportional picture of a homunculus on graph paper. If the inverse is 5.0, then the body part occupies five boxes on the graph paper, approximating the normal body shape. To enlarge the scale, just multiply all values by the enlarging factor. For example, to make the drawing three times larger, multiply the inverses by 3. A typical homunculus created in my classroom is shown in Figure 7. While homunculi will vary due to the creativity of students, their proportions remain remarkably similar.

The nerve impulse is, of course, a complex transmission involving the flow of ions across the neuronal membrane and the production of neurotransmitters that bridge the synaptic gaps between neurons. This involved physiological action can be made more vivid to students through a simple, but measurable, activity that involves the whole class.

This activity can be done in the classroom or outside in good weather. Students should stand in a circle with their hands joined, leaving one break in the circle. The student to the teacher's left should hold a bicycle horn in his/her right hand. The teacher should hold a stopwatch in his/her left hand behind his/her back.

Simultaneously, the teacher squeezes the hand of the person to his/her right and starts the stop watch. The student to the right then squeezes the hand of the person to his/her right, and so on around the circle until it reaches the last person, who immediately sounds the bicycle horn. The teacher stops the stopwatch the instant he or she hears the horn. Several practice runs should precede the actual experiment. By measuring the span between outstretched arms from tip of right hand to tip of left hand for several students in the class, an average distance the transmission traveled in one person can be determined. This length is multiplied times the number of people in the circle. By dividing by the time that elapsed, the speed of the transmission along large myelinated axons can be calculated. A comparison with laboratory data can be done by

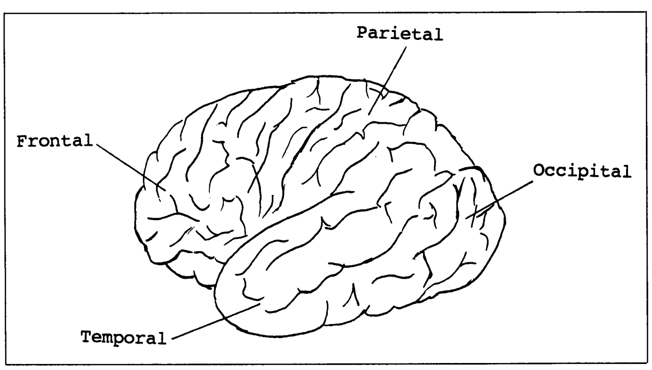

Figure 5. The human cerebral cortex with its four lobes: frontal, parietal, temporal and occipital.

Sensitivity Data Chart

Site	Distance in cm	Inverse Values
Scalp		
Forehead		
Cheek		
Lips		
Tongue		
Chin		
Nose		
Neck		
Upper Arm		
Lower Arm		
Palm		
Elbow		
Back of Hand		
Fingertips		
Chest		
Back		
Abdomen		
Thigh		
Kneecap		
Calf		
Heel		
Sole		
Toes		

Figure 6. Table for recording data from measuring skin sensory fields.

researching the literature on neurobiology. The differences can be discussed, bearing in mind the cerebral processes involved.

Through the activities described in this paper, students can learn about brain structure, development and function. They can also appreciate that this special organ of the body can be studied, directly and indirectly, by itself. For no other organ is this possible.

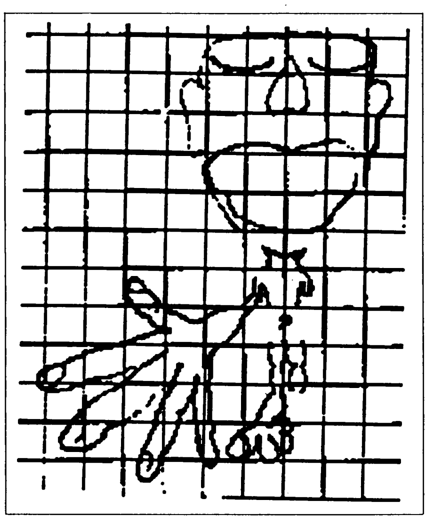

Figure 7. A typical sensory homunculus constructed by a student.

Acknowledgments

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Resources

Sewing gauge available from: Dritz Corporation, Spartanburg, SC.

BrainWork: The neuroscience newsletter is a very informative newsletter available free from the Eleanor Naylor Dana Institute, 1001 G Street, NW, Suite 1025, Washington, DC 20001.

Brain Facts is a primer on the brain and status of research in layman's language with illustrations. Available for $5 from the Society for Neuroscience, 11 Dupont Circle, NW, Suite 500, Washington, DC 20036.

The Brain, a highly acclaimed, eight-hour series on the brain, examining such topics as mental illness, stress, and the effect of drugs underlying sensation, perception, learning, emotions, and memory; and illustrating the brain's anatomy through state-of-the-art animated graphics. On ½" VHS videotape cassettes. From: The Annenburg/CPB Project, c/o Intellimation, P.O. Box 4069, Santa Barbara, CA 93140-4069.

Hologram of the skull/brain (3.4" × 3.4"). As you vary the viewing angle, the skull, with musculature, changes to reveal the brain and spinal cord. From: Arbor Scientific, P.O. Box 2750, Ann Arbor, MI 48106-2750. $15.