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IMPLICATIONS OF SELECTIVE BRAIN RESEARCH FOR THE PHILOSOPHY OF EDUCATION

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IMPLICATIONS OF SELECTED BRAIN RESEARCH

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Joyce McDonnold

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CHAPTER I

INTRODUCTION: THE PROBLEM AND ITS SETTING

Statement of Problem

This research proposes to review and study the contemporary theories of neuroscientists in the field of brain research to determine what implications there are for building a philosophy of education and for including the arts in education. The essential questions to be investigated are, first, are there theories from brain research that educators should be aware of in order to improve the educational process as well as brain development and functions; second, do any of these theories indicate that the arts should be a part of education; and third, what are the implications of these theories for building a philosophy of education.

Hypotheses

The first hypotheses is that the finding from the selected research on brain development and functions do relate to education.

The second hypotheses is that educators should be aware of these theories from the neuroscientific research.

The third hypotheses is that the neuroscientific research findings do indicate that the arts should be included in education.

The fourth hypotheses is that these theories need to be considered in developing a functional philosophy of education.

Limitation

Within the major scientific discipline of neurology there are sub-specialities that focus in on only one aspect of neurology such as neuroanatomy, neurobiology, neurophysiology and neurochemistry. There are other scientific disciplines that have researchers focusing on the neurological aspect within that field of study such as neuropsychology, neurosurgery, neuroembryology, neuro-opthamology, neurotology, neurohematology, neuropsychiatry and paleoneurology. There are many neuro-specialities and related fields of study. Some are formally organized and some are composed of people limiting their own research to the neurological aspects of their field of study.

This research will not attempt to review all the neurobrain development and the functions of learning. It will not review the chemical, psychopharmacology, nor nutritional aspects of neurology. For a more complete listing of the neurological sciences see the glossary. This research will review primarily the fields of neurology, neuroanatomy, neurobiology, neurophysiology and neuropsychology.

This research will be limited to the contemporary theories from the selected neuroscientific disciplines that concern brain development and functions that relate to learning. It will not attempt to develop a historical overview of the nuerosciences up to the present time. It will be limited further to report on only the aspects of the curriculum that relate to the role of the arts in the development-learning process.

This research will not attempt to study nor resolve the philosophical problem of mind versus body-brain.

This research will review only the research that has been published and is available through the University of Oklahoma Library.

The Research Methodology

According to Leedy, the method of research must be appropriate to the nature of the data. Historical data consists of written records and accounts of events and happenings in the past.[1] "Whatever its purpose, a report is invariably

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[1] Paul D. Leedy, Practical Research Planning and Design (New York: McMillian Publishing Company, 1974), p. 68

and necessarily historical. Insofar as it reports facts it gives an account of the past."[1] Recorded opinions belong to history because they belong to what has gone before. Even a description of the present, although recent, is still history, a description of the past, a backward glance.[2] "The historical method aims to assess the meaning and to read the message of the happenings in which men and events relate meaningfully to each other."[3] Within the framework of Leedy's and Barzun's criteria for the historical method of research this research study will use the historical method.

The Data and the Treatment of the Data

The Data

The data to be used for this research will be of both primary and secondary types. The nature and use of these two types of data follows.

The primary data. The published writings of neuroscientists will be considered primary data. It will consist of published reports, articles, papers, books and text of brain research and related neurological findings.

The secondary data. The data concerning brain function research that is published in summary form will be used

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[1]Jacques Barzun & Henry F. Graff, The Modern Researcher. rev. ed. (New York: Harcourt, Brace & World, Inc., 1970), p. 5

[2]Ibid. p. 6

[3]Leedy. op. cit. . p. 68

as secondary data.

Treatment of the Data

The selected data from selected neuroscientific fields concerning brain functions will be reviewed and analyzed for their distinctive findings that have implications for education.

Significance of the Study

Corroborating philosophical theories about education as the technology and scientific capabilities become available will provide the educator with a scientific base for choosing educational practices. Education can become a science, as well as an art, when educators become concerned and knowledgeable about the brain and begin collaborating with neuroscientists engaged in brain research. With corroboration, the philosophical theories and scientific findings become points for establishing educational policy and procedures.

Corroboration of the importance of the arts in education will give the educator a scientific, as well as, a philosophical reason for including arts in the curriculum. The educator needs a more scientific base for including the arts in the curriculum because many people consider the arts as play, frills, time waster and so forth, not understanding their value.

Corroborating philosophical theories about education with scientific theories about how the brain developes and functions in learning will add a new point of view in understanding the needs of the student, enabling educators to build a working philosophy of education to meet those needs.

CHAPTER II

REVIEW OF THE RELATED LITERATURE ON EDUCATIONAL THEORIES RELATED TO BRAIN RESEARCH

The first of four books to be reviewed is _The Brain Revolution_, by Marilyn Ferguson. She is a journalist and is actively involved in psychic research. She has written articles about creativity and learning theories which have been published in many national magazines. For the book, _The Brain Revolution_, Ms. Ferguson corresponded with and interviewed many of the country's leading brain researchers. She reviewed their literature and took part in many of their symposiums. She is one of the subjects in a continuing research project on alpha brainwaves and telepathic communications being conducted by one of the co-founders of the Bio-Feedback Society. Currently she is the editor of the Brain-Mind Bulletin.

Ms. Ferguson makes several direct, as well as many indirect, references to education in her summary of research related to the brain.

> The most astonishing reality of all appears to be the potential of the human brain. Science and the humanities

> have converged in the most unexpected way. In order to describe the wonders they have come upon, brain researchers have begun quoting Buddha and William Blake. And poets and mystics, long fearful of the dehumanizing aspects of science, now cite laboratory reports to verify what they had long held as intuitive knowledge. . . As Abraham Maslow observed, although our visionary artists and mystics may be correct in their insights they can never make the whole of mankind sure. "Science," he wrote, "is the only way we have of shoving truth down the reluctant throat".
>
> The findings of brain research and allied disciplines are revolutionizing scientific theory and society. They are setting off chain reactions in medicine, psychiatry, and education.[1]

Concerning this brain revolution, she quotes Sir John Eccles, the Austrailian neurophysiologist who won the Nobel prize in 1963. "There will be no end to this enterprise, at least for centuries."[2]

Commenting on the place of biofeedback in education Ferguson reports on several experiments and their outcome.

> At the Angie Nall School in Beaumont, Texas, a pilot alpha-training program was so successful that now all the children, most of whom are hyperkinetic, are receiving alpha training. The pilot training program reportedly helped some to sleep, had a calming effect, and seemed to benefit those with learning disabilities. . . [3]
>
> Children are notoriously better than adults at biofeedback. . . in the Menninger Foundation Biofeedback programs, children could rapidly learn to raise their hand temperature. . .
>
> At the Suggestology Institute in Sofia, Bulgaria, Georgi Lozanov. . . conducts classes in which difficult academic courses (such as foreign languages) are easily mastered in a state of yoga-like serenity and suggestion.[4]

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[1]Marilyn Ferguson, The Brain Revolution The Frontiers of Mind Research, (New York, N.Y.: Bantam Books, Inc., Taplinger ed. 1973, Bantam ed. 1975) p. xiii.

[2]Ibid. p. 3

[3]Ibid. p. 87

[4]Ibid. p. 104

Ferguson includes a chapter on creativity, entitled "The Anatomy of Creativity." The main theme of this chapter is that creativity is at the very core of our being. Creativity is responsible for our clothes, homes, transportation, commerce, all we have around us as well as language, music, art, dance and theater. "Suddenly creativity is the popular goal. Ironically, a quality dissonant with our conventional education process is greatly in demand in adults--and those who survive the system without losing their creative integrity are richly rewarded."[1]

In the chapter entitled "Five Senses. . . or Twenty?" as the name implies she discusses the research on our senses and sense perceptions. The conclusion is that we have more than five senses including some that are now considered mystical, dermo-optical, humor, eidetic imagery, sonar systems of the blind, timing mechanisms, kinesthetic imagery, synesthesia and other phenomena of perception.

> E. R. Jaensch of the University of Marburg, Germany, who devoted a lifetime to the study of visual phenomena, believed that eidetic imagery and synesthesia were natural human abilities educated out of most individuals. He and his associates found eidetic imagery in 80-90 percent of the children attending special German schools in which there was an emphasis on sensory activities.
>
> In Jaensch's view, the imagery was generally prevalent wherever there were no antagonistic processes in the environment. In other words, most human beings could preserve the phenomenon if they were not subject to a sterile, passive educational process. . . .
>
> Eidetic imagery and synesthesia are found more often in highly creative adults than in the average subject.

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[1] Ibid. p. 307

> Jaensch spoke of the shift from passive to active educational experience as an unshackling: "liberation, the awakening of higher activity."[1]

Eidetic imagery is the ability to see within the mind a clear representation in color and dimension of a person, place or thing. It may have been perceived in the past, sometimes even years earlier. The person, the eidetiker,[2] can hold the image and interact with it such as he might have done originally. He can often do the same thing with ideas or anticipation of future events. Charles Stromeyer of the Bell Thelphone Laboratories has studied numerous people and has helped to prove that eidetic imagery does exist. It is not just the product of a vivid childhood imagination. Artists and other creative individuals have usually retained this ability into adulthood.

Synesthesis is the ability to integrate the senses so that one not only creates mental images but puts color, sound and texture or tactile sensations with the image. Here again this phenomenon is most often seen in children, artists or altered states of consciousness.

The traditional "official" view of man was that he had five senses, they were obvious. Sometimes intuition was called the sixth sense but other phenomena, such as eidetic imagery, was considered fraud. However, John Pfeiffer pointed

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[1] Ibid. p. 247

[2] Eidetiker--a person with the ability to form eidetic images-a descriptor used by Ferguson.

out in The Human Brain that the body has many built-in sense organs working that are remote from observations but involve brain transactions which trigger sensations. Ferguson quotes him as saying "The number of senses is not known exactly. It is certainly more than five and probably somewhere around twenty."[1]

In Chapter 18, "Revolution in the Cradle," Ms. Ferguson comments that "Now the ancient nurture/nature, heredity/environment controversy may be in its death throes."[2] Both innate and experiential influence and potentials have been greatly underestimated. Talents and abilities are not singular but complexes of various innate potentials that are developed one way or another depending upon the training. Also some abilities, thought to be rare genetic traits can be acquired in the right environment, such as perfect pitch, which is common in Vietnamese people whose language is based on pitch to distinquish the meaning of many words that have the same sound.

It has been shown that experience changes the brain and this is a tremendously significant finding of recent research. "Early intervention offers the best hope for stimulating development in not only congenitally damaged children, but also those whose sterile environment contributes to poor brain development. . . ."[3] It has also been shown that there

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[1] Ibid. p. 258 (This reference is from John Pffeiffer The Human Brain.)

[2] Ibid. p. 262 [3] Ibid. p. 193

is a functional type of retardation that is evident in children reared in institutions. These changes can be both organic and functional in nature.

> Experience changes the brain. The implications of this discovery are as profound, as revolutionary as $E=mc^2$. Tradition has espoused a fatalistic, fixed-capacity view of the individual. If the brain can change, all the rules must be rewritten.[1]

Michele Malacarne, an Italian anatomist of the late eighteenth century, first reported research on the brains of animals in connection with learning. "Malacarne reported that postmortems showed more folds in the cerebellum of a trained animal than an untrained one."[2] It was almost a century later before anyone else became interested in the relationship of the brain to training. A French physician became interested in the relationship of training to brain size. His method was to measure the circumference of heads. As has been proven recently overall size is not an indicator of how well a brain functions and the French physician's investigations could not be verified by other researchers so they were dropped.

In the 1950's, at the University of California at Berkeley, a team of researchers, Mark Rosenweig, Edward Bennett, Marian Diamond and David Krech, began studying the brain. Through the technology and refined techniques available to them they

> . . . found indications that problem-solving experience had altered the level of a brain enzyme vital to trans-

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[1] Ibid. p. 262 [2] Ibid. p. 263

mission. To their surprise, they also found changes in the weight of the brain samples.

The Berkeley researchers first announced in 1964 the startling findings: Rats from the enriched environment had heavier, thicker, cortices and greater total activity of two important brain enzymes.

Later they also found that the stimulated rat's brains contained more glial cells.[1]

Walter Riege, also from Berkeley, found that even adult rats showed a weight increase from the enriched environment but it took a longer period of stimulation. There are many other reports accumulating every year to verify and extend the knowledge we have of how the brain responds to education. When W. Ragan Callaway published his monograph on the effects of early stimulation for reading, some of the world's leading scientists "expressed the fervent hope that educators would take notice."[2]

Until very recently, most colleges of education seem to have existed apart from scientific research, as if learning had little to do with the physical brain. . . Harvard's Jermore Bruner, a leading figure in early-learning research, criticized himself and his colleagues for "allowing an educational-psychology ghetto to grow up and then mocking it.[3]

Again, while discussing the early years of childhood, the child's experiences, or lack of same, Ferguson says

Too often formal education fails to challenge the young brain or thwarts its natural momentum with monotony and rigidity. John M. Branan of Valdosta State College in Georgia asked 150 students to write up in detail the most distressing experiences in their lives, confrontations that hindered their development. More than half reported conflicts with teachers. In another experiment, adults visiting at school open house were asked to record

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[1]Ibid. p. 263-264 [2]Ibid. p. 285

[3]Ibid. p. 279

spontaneously their most vivid memories of school. All of the reports were of unhappy experiences.

The attempts to retool American education involve two major changes.

1. Early education, to exploit the postulated critical periods of brain development.

2. A more individualized approach to learning, offering greater freedom, more self-direction, and environments designed to foster (or preserve) creativity.

"Our traditional education approach was founded on a colossal error," John Tunney told his fellow U. S. Senators. The vast majority of children under five, at the age when the greatest change in intelligence can be brought about most easily, were not in school and were not receiving good enough training at home.[1]

The next reference is a quote from an interview.

"We seek not wisdom but oracles," said Dwight Allen, dean of the school of education at the University of Massachusetts. "Thorndike, Hull, Dewey, Skinner, Bruner, Piaget--all have had the honor. At each swing we seem to assume that only one can have the right answer. . .[2]

Ferguson's last reference to education is the comment that "Education, now in the early throes of revolution, will change radically."[3] In discussing what tomorrow will bring into education as a result of all the new interest on how the brain functions, Ferguson says, "Education is at last coming into its own, both as folk art and fine art, a profoundly creative process dependent on both spontaneity and design."[4]

The second book to be reviewed is Human Intelligence by Jack Fincher who is a contributing editor of Human Behaviour. He was formerly news and science reporter for Life. Fincher acknowledges thanks to "over 200 scientists

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[1]Ibid. p. 285 [2]Ibid. p. 287

[3]Ibid. p. 369 [4]Ibid. p. 370

and academics in six countries" who, he says "either sent me their papers, answered my questions, or graciously granted me interviews-a phenomenal 95 percent of those I contacted."[1] Human Intelligence is a survey of the current research, experiments, and theories of human intelligence with special emphasis on the left and right cerebral hemisphere's capabilities. On the back cover, in a brief paragraph describing the book, it is stated

> Our society, especially in science and education is inherently prejudiced against intelligence of the right hemisphere. Nothing so amply demonstrated this than our preoccupation with intelligence (left hemisphere) testing and treatment of the gifted and mentally retarded, and the athlete and the artist, who fall victim to our peculiar myopia.[2]

Much of Fincher's book related to education and he has himself made that relationship more clear than most other people reviewing the brain research. He discusses language, learning, thinking, I.Q. testing, art, creativity, athletics and women. He reviews the literature on the questions of the human brain. Fincher thinks

> Our knowledge of those capacities and impulses is, to put it mildly, more than incomplete. It is tantamount to ignorance. Indeed, as astonishing new lines of scientific (and not so scientific) evidence suggests, our traditional concept of intelligence is at once static, lopsided and sterile. It has twisted our scale of values, warped our ways of education, and perverted our system of rewards until we stand on the brink of castastrophe. It pits the the old against the young, the black against the white, the haves against the have-nots, the "dull" against the

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[1]Jack Fincher, Human Intelligence, Capricorn Books, (New York, N.Y., G.P. Putnam's Soons 1976) p. 7

[2]Ibid. Back cover

"bright in a bitter social war none can possibly win, all may possibly lose.[1]

How researchers have become aware of the functions and capabilities of both hemispheres of the cortex, the limbic system, and the reticular activation system of the brain, as Fincher notes, was

> By painstakingly paying attention to what abilities were lost or impeded when either side of the cerebrum was damaged, researchers gradually pieced together, by clinical inference, a crude map of a brain hemisphereically divided in its labor. . . it could be shown that either hemisphere was vibrantly alive to the world of self and the world outside. Each was dominant in its own way but neither was dominant in all things. . . The name of the neural game, evidently was . . . specialization on the part of each.[2]

In relating this to education Fincher says "(A cloudy notion of dominance still persists in the canons of education today. It says that if language is fixed, and not the stakes in a floating neural crap game, we needn't worry about it.)"[3]

Roger Sperry, is the pioneer and a leading expert in right and left hemisphere functions. His original research team consisted of himself, his assistant Ronald Meyers, J. E. Bogen and Michael Gazzaniga, a graduate student. In discussing their work on the different functions of the two hemispheres of the brain, Fincher asks

> What difference does it make? . . .
> It matters and matters mightily, say the split-brain researchers, because the evidence indicates that each hemisphere not only cooperates with and compliments the other when the commissures are intact, it also responds

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[1]Ibid. p. 22 [2]Ibid. p. 53

[3]Ibid. p. 52

to reinforcement or the lack of it. . . Sperry and his growing army of disciples hand down a devastating indictment of civilized life today: Our society, they charge, especially in the fields of science and education, is inherently prejudiced against the intellect of the right, or nonlanguage, hemisphere. It is the linguistic, the abstract side of ourselves we test and educate and reward--and by such powerful social strategems catapult to an over-arching prominence in the human scheme of things.

"What it comes down to," declares Roger Sperry, "is that modern society discriminates against the right hemisphere. We are in short, neglecting fully half our thinking brain, not just quantitatively but qualitatively."[1]

The following quotes illustrate ideas Fincher gained from reviewing the research on the arts, creativity and the intelligence required for them. They certainly are not noncognitive in Fincher's view as many educators refer to them.

Foremost, creative people are highly esthetic, particularly in the ancient Greek sense of being alive to their perceptions. They thrive on the complex, the intricate, the asymmetrical, the complicated. This trait permeated the nature of creative mathematicians and scientists as well as artists, and is totally unrelated to IQ scores and academic skills. Apparently the creative have an uncommon capacity to integrate this wealth of chaotic sensory experiences into a higher order of mental syntheses. In plain words it makes them the kind of people who can turn junk into jewelry. . .

They tend too to notice what goes on around them more acutely, retain and retrieve sense impressions more readily, . . . are slow to label and screen out the irrelevant. They perceive life rather than judge it. . . a life that is open, flexible, spontaneous, stimulative, and receptive.[2]

. . . .

Creative people prove more intuitive, both about what is and what, . . . can be. . . they were far more willing to inject formless fantasies into their thinking than the noncreative, who are by comparison mentally rigid, self-limited and controlled.[3]

. . . .

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[1]Ibid. p. 73 [2]Ibid. p. 125

[3]Ibid. p. 126

> The secret of creativity, then, would appear to be in our ability to synchronize the complimentary functions of our cerebral hemispheres, to pool the experience and talents of each half in producing an integrated whole.[1]
>
> . . . .
>
> . . . it seems a shame that intelligence and art must both stand semantically exposed in half-brained endeavors . . . . . Intelligence could mean the full spectrum of mental modeling, both imagistic and symbolic, and art the fidelity of our expressions to these inner models of the outer world.[2]

Fincher is using art to mean "the art of music, literature, painting and sculpture, or the art of diplomacy, decision making, cooking and conversation."[3] He says. . . "The creative act, as we have seen demands the best energies of both hemispheres, especially the language arts with their requisite melding of symbols and imagery."[4]

Donald MacKinnon, a psychologist at the University of California; psychologist, Frank Barron, who wrote <u>Creative Power and Creative Process</u>; and Duke University's Michael Wallach; are a few of the people researching creativity, from which Mr. Fincher gleaned these ideas.

Education and society at large are both crippling our gifted and talented for fear of being called an elitest. Mr. Fincher personally visted a number of schools, both public and private, to see how they responded to the gifted and talented child. His comments on these schools were

> The paralyzing sameness of the traditional curriculum panders to the lowest common denominator. It turns the brightest kids off or into chronic losers. Although

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[1] Ibid. p. 131 [2] Ibid. p. 132

[3] Ibid. [4] Ibid. p. 138

> some non-verbal children when carefully tested have proven gifted, being nonverbal still too often means a one-way ticket to a trade school. Even when such children are detected, few schools know what to do with them or are equipped to do it if they did.[1]
>
> There is sadly ample evidence that many of our creative and intelligent best are being wasted, . . .[2]

In reviewing the work of John Calhound of National Institute of Mental Health, who built "Mouse Utopia" to study social habits, crowding and overpopulation and then related them to the human race, Fincher says,

> Calhound makes clear, if man is to be saved from himself it is men, manifestly, that must be swayed. The only indispensable single presence needed, he thinks, is that of the charismatic leader, especially in the arts who can "translate the new images into forms which can be appreciated intuitively without regard to their rationality or logic. But men, not man, must be willing to anticipate, to learn and relearn. . .[3]
>
> Elevating creativity, Calhound feels, would at once reduce mans aggression and promote a slowdown of population increase. . . Creativity thus becomes what the ethologist calls a releaser for militant enthusiasms, by defusing the threat. . . with the phenomenon of satisfactory discovery. The same. . . hold for what Eric Erickson calls. . . the sex urge, . . . an attempt at self-duplication.[4]

The last chapter entitled "Life with the Multimind" ends with this thought

> The mind is a multiplicity of parts whose various functions cannot always be seperated, but must never be confused if we are to understand the deepest nature of our intelligence. For our best hope for the future lies neither wholly in the left hemisphere-where we have in the main for so long been-nor wholly in the right. . . It lies--instinct, logic and insight all tell us--as those who work with clay know from the throwing lore of the potting wheel, in getting centered. . . .
>
> If we can do this, if we can keep our heads and put

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[1]Ibid. p. 278 [2]Ibid. p. 279

[3]Ibid. p. 374 [4]Ibid. p. 376 (My italics)

our minds to it, a new Renaissance may be coming.[1]

Mr. Fincher has extensive notes and bibliographies which are excellent. He had noted personal interviews, communications, unpublished papers lent to him by researchers and other illuminating information.

Nigel Calder's book, The Mind of Man is a summary of current research on the brain and human nature. He gathered his information by personally visiting the "laboratories of physiology and experimental psychology in eight countries during 1970."[2] He further supplemented the interviews and observations from learned papers.

Calder starts his review with the premature human infant and the new studies showing their brain-wave patterns. He goes on to discuss brain development, learning, attention, memory, left and right hemisphere functions, divergent thinking and creativity, language and the role of the frontal lobes of the brain. He discusses several philosophers, such as Rene Descartes, and several people who have influenced educational practices such as B. F. Skinner and Jean Piaget. While he does not have education indexed he does make several references to it.

The first reference is in relation to a discussion of research in sensory deprivation and curiosity, conducted by

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[1]Ibid. p. 437

[2]Nigel Calder, The Mind of Man (New York: Viking Press 1971) p. preface

students of Donald Hebb at McGill University (Woodburn Heron and others.) He says,

> The results. . . give clear evidence that the human brain depends, for its normal alertness, reliability and efficiency, on a continuous flow of information about the world. . . . The brain craves for information as the body craves for food, and other animals besides men will go to some pains to see new sights. . . .
>
> Hebb himself knew all about the human need for something interesting to do. He had once carried out, with confidence and complete success, a radical educational experiment. . . all of the 600 pupils in a school were punished by being sent out to play and were permitted to work as a reward for being good. Within a couple of days, teaching at that school was proceeding more efficiently and with better discipline than ever before, because the children preferred arithmetic to boredom.[1]

In discussing the organization of emotions within the brain structure Calder notes that while these conditions have not been fully traced it is evident that emotion can bias the perceptions of reality. ". . . Twenty years ago, Jerome Bruner found that poor children and well-off children did not see coins in the same way; the poor children judged the coins to be physically larger than they were."[2]

Recently it has been discovered the conscious mind has astonishing control over basic bodily functions previously referred to as the autonomic nervous system and thought not to be subject to direct conscious control by the individual. It operates independently of the will power. Usually it does, but it can be influenced and controlled as bio-feedback, meditation and other mind control experiments have revealed. Evidence that the mind did have more control than the scien-

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[1]Ibid. p. 91 [2]Ibid. p. 210

tists would give it credit for was there in everyday life for all to see: acting. Conscious control of feelings and the symptoms of feelings, anger, tears, fear, love, sadness, blushing and so forth, are the basic ingredient of good acting.

How has this attitude related to education? Calder notes

> After some exploratory experiments by Burrhus F. Skinner, it was quickly accepted that this operant conditioning or instrumental learning was ineffective in influencing the autonomic nervous system. Control pecking or running, yes; salvation or heart-rate, no. Thus did the psychologists carry over, into learning theory, the nineteenth century dichotomy of the neurologists.[1]

The next reference to education comes in a section on creativity. Concerning test of I.Q. and creativity, Calder writes

> the term "intelligence" is suppose to denote a general ingredient in human ability. The mass schooling. . . of our century have sustained a feudal urge to classify and grade everyone. Alfred Binet first devised intelligence testing for the French Ministry of Education, as a means of segregating the mentally deficient from normal classes; since then I.Q. tests have gained great importance in determining the education and careers of individuals.[2] . . .
> . . . .
> Such was the tyranny of the I.Q. test that, . . ., a child performing better at school than his I.Q. warranted was liable to be treated as a "pusher", disliked by his teacher and perhaps even sent to the school psychologist to find out what was wrong with him.[3]

Although Calder does not mention it the child doing better than his I.Q. indicated he could, was and still is quite often referred to as an overachiever.

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[1] Ibid. p. 91 [2] Ibid. p. 210

[3] Ibid. p. 211

Plasticity of the brain in childhood will allow the uninjured part to take over the lost abilities of the injured part. Language that is destroyed in early brain injuries can be relearned and the child can make excellent progress up to around age 10, after that it is much more difficult to re-acquire the lost language.

> Up to the same age, too, children can learn foreign languages in a non-academic way, . . . Wilder Penfield, . . . has for long urged educators to take account of the 'peculiar calendar' of the human mind and to insure that every child learns both English and French before the age of 10.[1]

On the effect of nurture, upbinging and the environment, David Krech suggest

> that for each species of animal there are specific experiences which are maximally efficient in developing the brain: he mocks the educators who would bombard the child from infancy on with every kind of stimulus change imaginable.[2]
>
> The performance of a young child at school is greatly influenced by what his teacher expects of him. We know that, from a . . . experiment done by Robert Rosenthal of Harvard University and Lenore Jacobsen, . . . a schoolteacher. . .
>
> The children. . . were given a fanciful "test of inflected acquisition" which was said to predict rapid development in some of the children. The teachers were later told, very casually, results of this "test". In fact, the names of some of the children had been simply picked at random. Yet the prediction that these children would be "spurters" turned out to be self-fulling prophecy. Among the youngest children, the average gains in I.Q. scores in the ensuing academic year were twice as great for the named children as for their classmates. The teacher's expectation was signalled to the children, perhaps unwittingly, and the children became more confident in their own ability.[3]

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[1]Ibid. p. 226 [2]Ibid. p. 234

[3]Ibid. p. 238

Donald Hebb offers an answer to the nature-nurture riddle as "100 percent nature and 100 percent nurture. . . . The genius of the genes and its evocation by the environment are both indispensable."[1]

In the section dealing with malnutrition and its effects upon the brain, Calder says, "we may see a tragic inconsistency in striving to end illiteracy in regions where malnutrition occurs, without also taking steps to defend the young brains for which the education is intended."[2]

Using the terms Lefty and Dexter for the left and right hands, Calder illustrates what each hemisphere of the brain can do through them.

> Perhaps Lefty's education has been grievously neglected. Here is fully half of the human cerebral cortex which is relegated to the status of a second-class citizen. He may represent a great waste of mental capacity, left poorly nurtured. As Sperry nowadays urges upon anyone willing to listen, the educational systems of many nations are immensely biased in their reliance on verbal inputs and outputs. We should be paying much more attention than we do to the cultivation of non-verbal skills at school.[3]
>
> The oversimplified views of the past have been a product of scientific specialization; with more pooling of knowledge, the richness and grandeur of the brain and its accomplishments have become plainer.[4]

Calder's review of the research into the mind of men is excellent and correlates well with other books on the same subject. Unfortunately, he did not document it with either notes or bibliography since he felt it "would not be appropriate in a book intended for the general reader."[5] He has,

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[1]Ibid. p. 238 [2]Ibid. p. 241

[3]Ibid. p. 251 [4]Ibid. p. 257

[5]Ibid. Acknowledgements

as he stated in the acknowledgements section, personally visited many laboratories and observed many experiments in progress. He also thanks "the large number of scientists who gave freely of their time and advice. . ."[1]

The fourth book to be reviewed is The Brain Book by Peter Russell, published in December, 1979. As with each of the other authors reviewed, his orientation is based on the area which is of most interest to him, learning. Mr. Russell is currently director of research for the Learning Methods Group in Great Britain. This group is now in the process of expanding into the United States. It is "set up to train people in the maximum conscious use of their inherent brain power."[2] He reviews much of the same research that other authors have, however, he devotes more space to educational aspects that educators should be aware of in his opinion. The book is divided into two parts with the first part devoted to the function and potential of the brain. He goes into the psychology, organization, the relationship of imagery and other aspects of learning and memory; then devotes a number of chapters to how to learn, to remember, how to study, read, take notes, how to develop mnemonics of your own, and the importance of mental set and beliefs.

Russell makes several references to a number of

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[1] Ibid. Acknowledgements

[2] Peter Russell, The Brain Book (Hawthorn Book, Inc., Pub. N.Y. - 1979), back inside flap of jacket cover.

philosphers and educators, such as Thomas Aquinas, Aristotle, Francis Bacon, Sir Francis Galton, William James, John Locke, and Maria Montessori. He also makes reference to a number of astists in various fields of artistic endeavor and to a number of scientists.

He devotes several pages to early educational programs, how they help set the mental development of children and their relationship to the environment. Russell gives the case histories of several child "geniuses" and the amount of early enriched training and adult-type treatment that they had. He says,

> A rich early environment can, though, be wasted if not properly followed through. Our present educational system is not well equipped to deal with prodigious rates mental development, and it is an unfortunate fact that the gifted child is sometimes held back by traditional ideas of what should be normal.[1]

He then relates a typical case of a child given an enriched early environment with the subsequent advance in learning and what happened when the child entered school. The child found it much easier to get along with the teachers if she was 'normal' and like all the other children. In defense of the teachers he does say that when prodigious children perform in this manner that they can hide their abilities so well that quite often teachers are completely deceived and really do not have any idea of the child's real capabilities. He then reviews a study by the Social Sciences Research Council in

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[1]Ibid. p. 13

England on gifted children. They found that the average gifted child was held back by the educational system by two and a half years. Educationally they were still ahead of their classmates but in terms of their own abilities, as measured by their I.Q. test, they were slow or backward students.

In the chapter on the two sides of the brain, their function, and dominant abilities, Russell, as the other writers here reviewed have, takes the position that the left hemisphere may not be naturally dominant but has been trained to be by our culture in the Western part of the world. We have emphasized linear thought processing, that is processing step-by-step or bit-by-bit, one after the other. The right brain takes several bits of information and processes them simultaneously by forming a syntheses of them. He says

> The emphasis of left-hemisphere processes goes back to early school days. When most of us went to school, education was still based largely around the three R's--reading, 'riting and 'rithmetic--all essentially left hemisphere function. Therewere, of course, art classes, music classes and the occasional dance or drama class, but in most cases these were seen as an extra. They were a special treat for Friday afternoons--providing, that is, you had got all your sums right and had corrected all your spelling mistakes.
>
> This type of education combined with society's emphasis on analytic rather than synthetic thinking, has led to the left-hemisphere's becoming dominant in usage. It also has had the unfortunate side effect that children who are better at using their right hemisphere may have been wrongly classes as subnormal or retarded.[1]

Russell discusses some schools that have increased

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[1]Ibid. p. 55

the amount of time spent on the arts, such as the Mead School in Connecticut, and the encouraging results of increased performance in all other subject areas. He says, "The extra time spend on developing the faculties of the right brain also helps those associated with the left brain. This is because the two do not work in insolation--each supports and compliments the activity of the other."[1] He then goes on to say

> A complete education should give equal emphasis to both verbal-analytic thinking and to aesthetic-synthetic thinking. If only the verbal-analytic side is being educated, the student is effectively being cut off from many ways in which he could directly experience the world around him. And without direct experience education can become dry, meaningless and boring. As one worker in this field put it, 'His brain is being systemically damaged. In many ways he is being de-educated.
>
> Yet tragically, whenever there is any cutback in the public funding of education, it is the arts program that is hit first. . . it is a grave loss to society.[2]

In support of his contention that a cutback in the funding of arts programs is a loss to society, Russell relates the story of Einstein and how he happened upon his theory of relativity. It came to him as a result of imagining himself traveling down a light beam. This was synthetic rather than analytic thinking, the result of creative thinking, intuitive insight that he later gave "a logical symbolic formulation" "using a a mathematical framework" in order to communicate it to others. The use of combining the left and right hemispheres special abilities is the common characteristic of the creative process in science and in art. Throughout history, the great minds

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[1] Ibid. p. 57

have had the ability to combine both types of thinking.

To make the most of your brain, you should use it and care for it. From the vast amount of research Russell has reviewed, he has come to the conclusion that "The adult brain, like the young child's, thrives on experience," and "we should make the fullest use of its innate potential and continue to grow in mental abilities throughout life."[1] We need to give our brains a rich, varied, stimulating environment to provide it with challenges and experiences. He defines education:

> Education. Coming from the Latin educare, means literally "to lead out", to bring out one's full potential. If the full potential has not been developed by the age of twenty--and it never has--then education should continue. There should be continued learning, continued mental challenges and continued mental exercise. . .

The ways to learn and to remember are rarely, if ever taught to students yet they are expected to remember a large amount of the information put before them by teachers. If they don't remember, they are labeled slow, retarded, or not very bright.

The second part of The Brain Book deals with various types of learning, memory and mnemonics. Of all our mental functions, memory is the one that is the most important in terms of our qualities that denote our being human. Without memory we could not learn from experience nor could we communicate with others, along with a myriad of other functions we call intellectual. It helps us to conduct our activities.

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[1] Ibid. p. 74

According to Russell, there are at least eight (8) different types of memories which he lists and discusses. They are: (1) episodic, memories of past events and episodes in life; (2) factual, which we learn through little episodes, but which tell of something apart that is or has happened such as historic dates, places or events; (3) semantic, memory for word meaning; (4) sensory, memory for sights, sounds, textures, smells; (5) skills, memory of how to do something; (6) instinctive, inherited and carried in the genes; (7) collective, archetypal symbols that are outside normal experience but are similar for large numbers of people such as appear mainly in dreams; and (8) past-life, memory of events that happened before birth, that are outside normal knowledge, but can be correlated with actual events in the lives of others. In order to study memory, learning and forgetting also has to be studied. Starting in 1879, Herman Ebbinghaus, in Germany, conducted the first experiments in memory and forgetting. Since then numerous other experiments have confirmed his general findings and the same general "forgetting curve." However, the more meaning, organization, interest and association there is in the material the less steep is the curve. Russell says "the general finding that the beginning and end of a learning session are remembered better occurs again and again in many different learning situations."[1] On page 86 and 88 he shows several memory-forgetting or recall curves.

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[1] Ibid. p. 86

The mind subjectively organizes material to be remembered in a variety of ways. Chunking is one way of organizing material. We can remember about seven chunks at a time, so to increase our memory we need to chunk the information into groups. As an example, the alphabet is usually chunked into segments of abcd efg hijk lmnop qrst u and v wxyz. Memories are also linked by associations and the more associations we can link to something to be remembered the better the ability to recall it, to retrieve it from our memory storage.

Organization is another very important aspect of memory. By organizing new material into chunks or groups and patterns, the easier it is for us to remember. The more consciously one is involved with anything the better the memory, so by consciously organizing, getting more involved with meaning and significance, processing in greater depth, the better the chances for remembering.

Imagery is also a powerful aid to memory. In discussing imagery, eidetic imagery especially, Russell thinks the reason it is found mostly in children is because it is "educated out" of them, a view which was first expressed by E. R. Jaensch in 1930. He believes everyone probably has the ability of eidetic imagery but that it has atrophied through lack of use. By developing the ability to image, and making greater use of it "everyone's memory can be improved."[1]

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[1] Ibid. p. 232

Mnemonies are any technique for increasing memory. They are not cheating and are "eminently sensible."[1] They were used extensively by the Greeks and Romans. Using rhythm, rhyme, patterns and pictures, they make fuller use of the imagery capacities of the right side of the brain. Russell stresses that "Memory is different from learning"[2] and that "Understanding is not necessarily remembering."[3]

On note taking as valuable aid to memory Russell says "The subject of note taking is, however, rarely studied, let alone taught. Thus, although much of a student's life is concerned with the taking of notes, he is seldom, if ever given much guidance on how best to do so."[4] He says,

> In addition to being a means of storing information, taking notes. . . performs the valuable functions of encoding the information; imposing organization upon the material, allowing associations, inferences and interpretations to be jotted down; bringing attention to what is important; and bringing attention to what is written.[5]

The memory process is thereby given tremendous help. One technique of note taking that Russell uses and strongly advocates is the making of mind maps. He ends each chapter with one that effectively summaries that chapter on one page.

Mind maps were developed by Tony Buzan as a more effective way to take notes. All the various factors that facilitate and enhance recall are used in making mind maps.

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[1] Ibid. p. 233 [2] Ibid.

[3] Ibid. p. 231 [4] Ibid. p. 174

[5] Ibid.

To make such a map, start in the center of the paper with the major idea and work outwards in all directions using lines, pictures, arrows, color, grouping to produce an organized structure that can continually grow. Try to be as creative as possible, think of original ways to note the information, for the greater the originality and creativity, the greater the interest, the more fun it is, the better the memory. Commenting on the uses of mind maps Russell give a personal illustration.

> This book, for example, was not written from beginning to end as a series of sentences, it was drawn as a set of seven major mind maps, springing from which came some 150 minor maps. All of the basic work was done in mind-map form. It was only when the book was finally being prepared for printing that it was transposed into a linear form.[1]

[1]Ibid. p. 185

CHAPTER III

INTRODUCTION: SELECT RESEARCH ON THE BRAIN: STRUCTURES, DEVELOPMENT, PLASTICITY

"To understand a bit of how the brain works is quite literally to gain insight into how man works,"[1] says Dr. Timothy J. Teyler, a neurobiologist. He has written "An Introduction to the Neurosciences" in The Human Brain.

The brain is a bilaterally symmetrical organ which weighs about three pounds in the adult. The outer layer is called the cortex. It has a highly convoluted (wrinkled) surface in order to have more surface area available in less space. The cortex is only a few millimeters thick. It is made up of billions of cells, called neurons, and their connecting processes, the axons, dendrites, and synapse. There are also neurotransmitter cells, called glial cells (glue

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[1]M. C. Wittorck, Jackson Beatty, Joseph E. Bogan, Michael S. Gazzaniga, Harry J. Jerison, Stephen D. Krashen, Robert D. Nebes and Timothy J. Teyler, The Human Brain, a Spectrum Book (Englewood Cliffs, N. Y.: Prentice-Hall, Inc., 1977), p. 5 (hereafter cited as Wittrock, et al., Human Brain).

like). The glial cells are even more numerous than the neuron cells. Within the cortex are areas devoted to specialized functions. The cortex is divided into two hemispheres, the right and left. Each hemisphere is then divided into four lobes, the frontal, at the front; the parietal, at the top back; the temporal, lower portion of the side center; and the occipital, at the lower back, below the parietal. Each lobe has different specialized functions and they are further divided into zones that are sensory-motor and associational.

The cortex has distinct layers that differ in structure one from the other. In some areas the functional differences of these zones are understood, such as the three visual zones, V1, V2 and V3. Each visual zone contains neurons that respond to a different simulus from the visual field, such as edges, angles, movement, light, color, shape, etc. The association zones are not sensory analyzers or motor programmers. They seem to be involved with the understanding and perception of more complex information. The amount of brain tissue devoted to the associational zones increases across species as the cognitive abilities increase.

Some of the specialized functions now known for each cortical lobe are as follows: (1) the <u>frontal lobe</u> is the motor area for all muscles, its neuronal axons connecting to other parts of the brain and spinal cord; (2) the <u>parietal lobe</u> contains the primary bodily sense awareness, receives, processes and passes on information from the sense receptors located throughout the body; (3) the temporal lobe contains the primary auditory senses, which receives and analyzes information from the cochlea area of the ear; (4) the occipital lobe contains the primary visual senses, which receives and analyzes information from the retina of the eye. The two hemispheres of the cortex are connected by a large bundle of nerve fibers called the corpus callosum that lies underneath the cortex but forward of the cerebellum. The corpus callosum relays information between the hemispheres and from other structures in the mid-brain and brainstem.

The cerebellum lies to the back, at the base, and just below the cortex. It, too, has a highly convoluted surface. Its primary function is fine coordination of muscle movement, tone and balance. It also plays a part in the cooperation and coordination of groups of muscles working together but very little is known at this time about how this is done. Both the cerebellum and the cortex can be seen from the outside of the brain.

The limbic system, located between the cortex and the mid-brain, is composed of a group of structures closely interconnected. Among these are the amygdala and hippocampus. While many of the functions of the limbic system are still unknown, it is known that in human beings damage to the hippocampus causes damage to the ability to retain information in the permanent memory.

The mid-brain, as the name implies, lies in the center, under the cortex. This area of the brain is composed of a number of structures, which includes the reticular formation and the hypothalamus. Some of the neurons that make up the reticular formation have incredibly long projections (axons and dendrites), with thousands of connections with many other areas of the brain. These cells receive the incoming touch sensory messages then activate other areas that need to process and react to the stimuli. It is often called the reticular activating system or RAS. The hypothalamus, located above the roof of the mouth, also has widespread connections with other areas. It is involved with both behaviors and processes such as eating, drinking, temperature regulation and with the regulation of glandular functions. Its main duty is to keep all internal conditions in balance (homeostasis). This regulation is accomplished by feedback information from various parts of the body.

The brain stem has changed the least across species. It contains the autonomic nervous system, which is a relatively involuntary system that controls the visceral organs, blood vessels and glands. There are two divisions to the autonomic system, one being the sympathetic, which has to do with stress and arousal, and the parasympathetic, which has to do with rest and relaxation.

At birth the human brain contains somewhere between 20 billion and 200 billion neurons. The neuron is the basic unit of the brain. Although we lose thousands of these cells daily, they are not replaced like in other structures of our bodies, yet they are so numerous we do not normally feel the loss even into very old age. There are a variety of kinds of neurons, differing in size, shape and number of processes extending from the cell body. Each of these neurons communicate with hundreds, up to a thousand, other neurons. Some neurons have so many processes extending outward they resemble a tree in winter and are called dendritic trees. The dendrites are short and branching and receive information from other neuronal processes. The long processes extending from the neuron cell body are called axons. Some neurons have only one or two axons while some have many of them. They are covered with a fatty tissue called the mylin sheath. Information from one cell to another is transmitted along the length of the axon, to another neuron or a muscle. The normal "direction" of operation is for information to be received by the dendrites, be processed and directed along the axon connecting to the cell that needs to receive the information. The synapse is the name of the axon terminal structure that actually sends the message across the synaptic gap from the neuron A to neuron B. The synaptic gap is about 1/50,000,000 of a meter across, so the synapses do not physically touch. The message from neuron A is relayed across the gap by a neurotransmitter which is a chemical substance that either arouses (excites) or depresses (inhibits) the receiveing neuron B. A neuron has hundreds or sometimes thousands of synapses, many of which are active simultaneously at any given time because any one individual synapse is not a secure communication channel. Synapses can be altered by their prior experience.

While neurochemistry is outside the scope of this paper, a very brief description of the chemical exchange of the neurotransmitter will be given for a background understanding of how messages are relayed between neurons. Within the synapses are packages of neurotransmitters that are released when the neuron is active. The neuron cell membrane acts as a pump, expelling positively charged sodium ions (NA+) and taking in positively charged potassium ions (K+). This pump membrane is also like a sieve that will let these very small molecules and ions flow through it but keeping out larger molecules and ions. Inside the cell are negatively charged protein molecules creating a negatively charged interior and a positively charged exterior. In order to create an action potential the membranes must open the minute gates of the sieve allowing NA+ ions to come inside and K+ ions to go out. This lowers the negative electrical potential of the cell from the resting level of -60 millivolts to about +10 or 20 millivolts. These electrical volts travel along the axon (up to 300 feet per second) to the axon terminals (synapses) which causes the synapse to release some of the packaged neurotransmitter, either excitatory or inhibitory, which crosses the synaptic gap to a receiving receptor site on the dendrite. It takes several synapses discharging excitory neurotransmitters to create an action potential (or spike on an EEG). An inhibitory neurotransmitter can counteract the excitory ones if it is strong enough.

Most of the current knowledge of brain processes concerns sensory and motor functions, with very little known about the "cognitive" processes. Dr. Teyler thinks that to understand the general principals of the sensory and motor processes may also provide understanding for the cognitive processes as well.

> The analysis of sensory events by the brain operates by a principle of feature extraction. As sensory information is relayed through the brain, neurons respond to particular aspects of the stimulus; some neurons code aspects of patterning, some code movement, and some code other aspects such as color or pitch. . . It is as if the sensory signal were being passed through an array of tuned filters, with each sensory event activating a different set of filters. . . .
> . . . feedback is an important aspect of brain functioning. Without feedback control, however, we would experience difficulty performing even the simplest act.[1]

When the system is confused by receiving conflicting information to the sensors, the brain makes adjustments. Dr. Teyler uses the "tilting room" in a fun house as an example. The visual information says the room is tilted, the brain integrates this information and signals the body to tilt to adjust to the visual signals.

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[1]The Yearbook Committee and Associated Contributors, _Education and the Brain_, _The Seventy-seventh Yearbook of the National Society for the Study of Education_, eds. Jeanne S. Chall and Allan F. Mirsky, Part II (Chicago: University of Chicago Press, 1978), pp. 22-23 (hereafter cited as NSSE, _Education and Brain_).

Dr. David Hubel describes the process as an input-to-output flow. Information comes into the sensor receptor cells which act upon it, passes it along to another set of cells, and so on until the end of the line and response is activated.

> In brief, there is an input: man's only way of knowing about the outside world. There is an output: man's only way of responding to the outside world and influencing it. And between input and output there is everything else, which must include perception, emotion, memory, thought and whatever else makes man human.[1]

At each stage the receptor cell has both excitatory and inhibitory impulses coverging on it, which it integrates before passing the information to the next receiving cell. The receptor cell usually responds best at the beginning and end of a stimulus. This is not just a one-to-one correspondence. The axon fibers that carry messages for the neurons branch off to supply a number of neurons, sometimes in other parts of the brain and central nervous system. On the ends of the axon branches are synapses, where the communication between neurons is made. A neuron may have many branches of axons with hundreds of synaptic connections or it may have only a few. "Each of these neurons communicates with as many as a thousand other neurons, making the total number of connections and the 'wiring diagram' very complex indeed."[2] "Many synapses

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[1] A scientific American Book, The Brain, the chapters ... originally appeared as articles in the September 1979 issue of Scientific American. (San Francisco: W. H. Freeman and Co., 1979), p. 8. (hereafter cited as Sci. Am., Brain).

[2] NSSE, Education and the Brain, p. 2

are altered by their prior 'experience' and are said to be 'plastic'-a characteristic presumably present in synapses that play a role in behavioral learning."[1] Also some synapses can both send and receive messages while others cannot. In speaking about the "wiring" of the neurons Hubel says "Memory and learning, for example, are surely cumulative processes involving change over a period of time, and very little is yet known about the mechanism that underlie them."[2]

Paul D. MacLean, M.D., Chief of the Laboratory of Brain Evolution and Behavior at the National Institute of Mental Health, also stresses the importance of experience at critical times for brain development. "There is now abundant anatomical and behavioral evidence that if neural circuits of the brain are not brought into play at critical times of development, they may never be capable of functioning."[3] He feels that "an interest in the brain requires no justification other than a curiosity to know why we are here, what we are doing here, and where we are going,"[4] and that is appropriate for education.

Dr. MacLean deals with the particular aspect of evolution involving where have we been. He describes the brain in evolutionary terms as a triune brain that has a mind of three minds. The oldest part is the reptilian, which is

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[1]Ibid. p. 8 [2]Sci. Am., Brain, p. 9

[3]NSSE, Education and the Brain, p. 308

[4]Ibid. pp. 309-310

called R-complex by MacLean. Next came the paleomammalian, usually called the limbic system, and then the neomammalian, usually called the cortex. The reptilian and paleomammalian formations lack the ability to verbally communicate, but they are intelligent and can communicate nonverbally.

> *Educationally, these are significant considerations* because it is usually assumed that we are dealing with a single intelligence. How much weight should we give to intelligence tests that largely ignore two of our ever-present personalities because they cannot read or write.[1]

In the ancient Greek system of teaching rhetoric they emphasized personal, emotional and intellectual appeal, which corresponds to the triune concept of primal, emotional and rational mind. The non-verbal communications of the first two minds are a very important part of our day-to-day activities. MacLean uses the word "prosemantic" to apply to any kind of non-verbal behavior--vocal, bodily, chemical. Prosemantic behavioral communications has meaning and orderly expression just as semantics and syntax do in verbal communications. Each become meaningful in terms of their components, contructs, and sequences of constructs (words, sentences, paragraphs). The prosemantic behavior of the primal mind involves self-preservation and preservation of the species. MacLean lists 24 of these primal patterns of behavior.[2] These include extablishment and protection of home and terri-

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[1]NSSE, Education and the Brain, p. 309-310 (my italics).

[2]Ibid. p. 325

tory; display of self as signaling used in defense, surrender, social hierarchy greeting and courtship; gathering of food; formation of social groups; grooming; mating and breeding. The basic communications of the reptilian brain are involved in the organized expressions of a ritualistic nature. These activities are coordinated by five behaviors; isopraxic, perseverative, reenactment, tropistic and deceptive. Isopraxic or imitative behavior involves interaction between two individuals of the same kind of activity and is basic for maintaining the species. The autistic child is an example of a human who has lost this behaviorial ability. Other human activities that illustrate these five behaviors, are: perservative, the slavish conformance to routine and old ways; reenactment, the personal and public rituals in day-to-day activities; tropistic, searching for precedent setting examples and; deceptive, in which we engage in all kinds of deceptions which were originally used in hunting and stalking game but today can be easily seen in the "games we play."

The mammalian brain is called the limbic system, and this is the seat of the emotional feeling mind. Two very important additions came with this evolutionary step. MacLean describes the first as "being a primal commandment stating: "Thou shalt not eat thy young or other flesh of thine own kind!"[1] The other was the sense of responsibility shown by progressive concern of care and attention that is paid to the

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[1] Ibid. p. 325

young. This concern is first shown to the young by the parent then extends to other members of the same group. The limbic brain's communication system operates through emotional feelings, including smell and taste that guides the required behavior for self-preservation and preservation of the species. We sometimes refer to this as a "gut feeling." It also has an important function in the recording of memory and to conviction in our beliefs and is involved in play behavior.

When the limbic system suffers a bioelectrical storm, common to epilepsy but which also can be caused by a number of conditions, the result is a temporary black-out of its other functions. The person can continue to carry on routine activities but have no memory of doing so after the attack subsides. Memory depends upon combining internal and external experience and limbic storms interfere with their recording. These storms can also affect the retrieval of memories.

The rational mind is the latest evolutionary development of the brain. It can make coldly reasoned decisions, and it contains the neuronal structures that enable us to produce symbolic language. "Mother of invention, and father of abstract thought, the new cortex promotes the preservation and procreation of ideas."[1] It receives its signals from the eyes, ears and body walls. These functions have a working relationship with both the R-complex and limbic systems. Though the neocortex is divided into two hemispheres, in the

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[1] Ibid. p. 332

normal individual they interact through horizontal connections to "speak as one mind."[1]

Where learning is concerned, the neocortex is of immense importance, but there is a significant "gut" component which is often overlooked. This fact should be of great importance to educators. A person responds with their viscera as well as with the rational neocortex. This accounts for stress that is associated with learning. In animal experiments involving conditioned responses, it has been found that associated visceral responses last for years after the conditioned response (muscle movement) has been eliminated. Delayed punishment also sets up the visceral reactions which can cause stress that affects behavior and learning. The interaction of these three parts of the brain is summed up by MacLean:

> The R-Complex represents a neural repository for programming behavior... for the reenactment of currently learned behaviors that have been emotionally conditioned through limbic functions or intellectually executed by the new mammalian brain.[2]

David Hubel and Torsten Wiesel, at the Harvard Medical School, found that a kitten's brain, at birth, possesses the elaborate system of detectors of lines and patterns, ready to work; but there are critical periods during development that deprivation of the proper stimuli will prevent that particular area of the brain from developing fully and will sometimes cause atrophy of the cells so that they will never

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[1]Ibid. p. 336 [2]Ibid. p. 339

develop. Kittens deprived of seeing certain lines of orientation lose the ability to use those lines. Also, if they are exposed beyond the normal environmental exposure to certain lines of orientation their brain cells are only sensitive to those lines. If the kittens are deprived of vision by the use of an eye shade or sewing an eye shut for as little as four days, during the fourth week after the kittens' birth, the system of detectors in the brain, corresponding to that eye, ceases to function and does not recover. The kittens then do not develop normal vision. "Plainly, there is a critical period when the visual system is maturing and use of the eye is essential if powers that already exist are to be reconfirmed."[1] These experiments along with others have provided evidence that while we do have genetic programs they must interact with the environment for full development. This idea can be observed in muscles of the body. If they are not used, they lose their innate abilities to function and will wither away.

The team of Rosinzweig, a psychologist, Bennett, a biochemist, Diamond, an anatomist and Krech, a psychologist, at the University of California in Berkeley, conducted experiments, using rats, on the upbringing of the young in relation to, and physical effect upon, the brain. Rats were divided

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[1]Nigel Calder, The Mind of Man, an investigation into current research on the brain and human nature, A Viking Compass Book (New York: The Viking Press, 1971, Compass ed. 1973) p. 220

into three groups. One group was left in the same type of cages and under the same conditions as was standard for the laboratory. These standard cages were small, barren, made of wire mesh and housed three animals. Another group was put into larger multilevel cages, nursery-schools, where there were many things to interest them, such as slides, trapezes, ladders, swings, cans, wheels, brushes and other toys. The third group went into individual cages where they lived alone. These cages had three solid walls, dim light and no noise. The rats had plenty of food and water, but nothing to do or any other rats with which to interact.

The experiment began when the rats were about twenty-five days old and lasted eighty days. At 105 days of age they were put to sleep, decapitated and their brains dissected, weighed and frozen.[1] Originally the experiment started out to determine chemical change in the brain due to mental activity which was suggested by Krech. The experiment had been in progress for a couple of years showing that indeed there was a chemical change of 2% more of the enzyme <u>acetylcholinesterase</u> in the schooled rats. But in reviewing the accumulating evidence, the researchers noticed that <u>the rats raised in the enriched environment</u>, where they had lots of opportunities for many experiences, <u>grew bigger brains</u>. This was a revolutionary discovery. <u>The cortex, the thinking part of the brain, was bigger in the schooled rats</u> than in the

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[1] Ibid. p. 231-236

control group by about a four to five percent difference in weight, and a 10 percent difference between them and the impoverished rats. There were other positive findings in the cortex. The rats with experimental opportunities had a visibly thicker cortex, cell bodies of individual neurons were 15 percent larger, and the number of glia or glue cells was greater and enzymes were more abundant. The whole quality of the cortex had changed. ". . . no one would dispute the effect of environment in exaggerating or moderating the effects of heredity."[1]

Maya Pines reports on some follow-up experiments by Krech. He next wanted to find out to what extent different environments could alter hereditary traits. He used rats that had been bred for generations to be "maze bright" or "maze dull". The brains of the two strains of rats had different amounts of enzymes and different ratios of cortex to sub-cortex.

Krech selected thirty genetically gifted maze-bright rats and put them in impoverished cages and thirty of the maze dull rats were put in enriched environments. This environmental treatment virtually wiped out any genetic difference in the two strains. Krech then experimented using the opposite conditions, gifted rats in enriched environments and the others in the impoverished cages. The difference between the two strains doubled,"all the advantages of inheriting a good brain can be lost if you don't have the right psychological

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[1] Ibid. p. 236

environment in which to develop it."[1]

As the team continued to study the effects of environment on the brains of rats, mice and gerbils they found that cortical changes are easier to produce than they had originally thought. Just two hours a day in an enriched environment will produce change and these changes are possible at any age. "The changes are not just an acceleration of normal maturation. In fact, one Berkeley investigator, Walter Riege, found that even fully mature rats respond to enrichment."[2] However, it does take longer to produce change in more mature animals. The intellectual changes will vary with the nature of the stimulus and the timing, but they are undeniably responses to experience. Experience does change the brain's development.

An Argentinian couple, Pedro and Vesna Ferchmin, in attempting to duplicate the Berkeley experiments actually devised a more supercharged environment that produced brain changes seven to eight times as fast. They moved their rats three times a day, first from the standard laboratory cage to a larger one much like the Berkeley nursery school, then to an oversize, five-foot-high cage. This cage not only had

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[1]Maya Pines, The Brain Changers, Scientist and the New Mind Control, a Signet Book (New York: Harcourt Brace Jovanovich, Inc., reprint: a Signet Book by the New American Library, Inc., 1975) p. 114

[2]Marilyn Ferguson, The Brain Revolution, The Frontiers of Mind Research, a Bantam Book (New York: Taplinger Publishing Co., Inc., 1973 Bantam, 1975) p. 264

an assortment of intricate and imaginative toys, but their placement sharply challenged the rats ingenuity for solving problems. For instance, the rats would have to figure out how to reach a top shelf on the side of the cage which had no direct access. In order to reach the top shelf they would have to figure out some roundabout way, across, through and over other objects such as rods, diagonal chains, nesting houses, boxes and other things. Also the problems changed every day so the rats had to problem solve rather than learn and memorize a route that they would then run by rote. The Ferchmins also introduced "masters" or teachers to serve as models. When four more mature rats with experience at problem solving were put in with the baby rats, it seemed to accelerate their learning.[1]

The reason animals, including people, "learn by doing" involves a process called feedback. The brain receives information about its efforts and the results of those efforts, then it makes necessary corrections. An animal cannot learn a new motor skill just by looking because this involves no feedback.

Another example of the part sensory input plays in determining the brain's developmental process was shown by Thomas A. Woolsey of Washington University School of Medicine. He was the first to recognize the importance of a group of distinctive cells called barrels in the sensory cortex of the

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[1] Pines, Brain Changers, pp. 115-117

mouse. The barrels are arranged in rows to correspond with the arrangement of the rows of whiskers on the mouse snout. Woolsey found that if a row of whiskers were removed shortly after birth, the corresponding row of barrels not only did not develop, but actually disappeared since each barrel receives its sensory input from a single whisker, and that barrel had no way to receive input. However, the barrels on either side developed larger than normal in order to fill the space of the missing barrels.

> These and many other observations make it clear that the developing brain is an extremely plastic structure. Although many regions may be 'hard-wired', others (such as the cerebral cortex) are open to a variety of influences, both intrinsic and environmental,"[1]

states W. Maxwell Cowan, a neurobiologist and colleague of Woolsey. Cowan goes on to say,

> The ability of the brain to reorganize itself in response to external influences or to localized injury is currently one of the most active areas in neurobiological research, not only because of its obvious relevance for such phenomena as learning and memory, and its bearing on the capacity of the brain to recover after injury, but also because of what it is likely to reveal about normal brain development.[2]

Of course, like any other biological structure there can be developmental errors of various regions and of varying magnitude. Cowan thinks that given the complexity of the mechanisms involved in brain development it is not surprising that there are sometimes developmental errors. "What is surprising is that they appear infrequently, and that they are

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[1]Sci. Am. Brain, p. 67 [2]Ibid.

often effectively eliminated."[1]

Much of our knowledge about the functions and plasticity of the brain has resulted from observing brain injured individuals. For instance, if a brain injury early in life destroys language that is already acquired, a child up to the age of about ten years can still make excellent progress because it is easier for other areas to take over for the injured one. Progress can still be made after the age of ten, really at any age, but it becomes much more difficult as a person becomes older.

> Up to the same age, too, children can learn foreign language in a non-academic way, ... But in the early teens, as the brain fully matures, it switches off its powers of spontaneous language acquistitions. Thereafter, language is no longer in the gift of nature but becomes a matter of toiling over textbooks. Wilder Penfield. . . has long urged educators to take account of the "peculiar calendar" of the human mind and to ensure that every child learns both English and French before the age of ten."[2]

The basic features of the organization of the brain functions are present at birth but they experience "tremendous growth in neural processes, synapse formation and myelin sheath formation"[3] up until the age of puberty. These basic processes can be profoundly affected by experiences with the environment; even to the extent of degeneration if the proper

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[1]Ibid. p. 67

[2]Calder, Mind of Man, p. 226

[3]Jeanne S. Chall and Allan F. Mirsky, editors Education and the Brain, The Twenty-Seventh Yearbook of the National Society for the Study of Education- 1978- University of Chicago Press, Chicago, Illinois, p. 24

environmental experiences that are necessary in order to activate them are missing or witheld. Genetics provides only a framework. Processes not used degenerate, but if given optimal experience are capable of further development. Even though the neurosciences are just beginning and there is still a tremendous amount unknown about the brain, one thing that is known is that the brain can be modified, for good or bad, by the environment.

In the early 1960's, Burton White and Richard Held studied babies and their environment in a hospital caring for unwanted children. "A startling, if not shocking, effect of a baby's environment on his development turned up."[1]

"For their first four months the babies lay in plain cribs-- 'a bland and uniform world,' was how White and Held described it."[2] They decided to enrich the environment visually for some of the babies. They used colored sheets in their cribs and hung brightly colored objects overhead. These babies "developed their ability to make purposeful reaching movements with their hands nearly seven weeks earlier than the children in standard cribs"[3] . . . The babies without this experience in seeing and reaching were delayed in their development.

Premature babies also exist for the first few weeks in a bland environment without the stimulation the full-term

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[1]Calder, p. 230 [2]Ibid.

[3]Ibid. pp. 230-231

baby usually receives. The premature baby is usually placed in a nursery in an incubator, surrounded by white, covered by a plastic dome that diffuses the light, hearing only the monotonous hum of the incubator motor, fed through tubes and rarely handled. Thus, the child is confined to a deprived environment during the first crucial weeks or months of its life although by current standards the nursery is a typical, good premature nursery. Premature babies also account for a higher ratio of school deficient, non-readers and retarded children than full-term babies notes Dr. Lewis Lipsitt.

> At Providence Lying-In Hospital, a colleague of Lipsitt's, E. R. Siqueland, separated the premature babies into two groups. Those in the control group received standard care and treatment. They were picked up only to be changed.
>
> Infants in the experimental group were rocked, sung to, patted and stroked, given all the stimulation and affection normal full-term babies would have received. When all the babies were later taught to illuminate a screen by sucking on a nipple, the stimulated infants were distinctly better learners.[1]

Ferguson reports on another experiment that corroborates the theory that experience through interaction and stimulation results in better learners with high I.Q.'s.

> . . . environmental influence are evident in the astounding results of a long-range program conducted by Rick Heber, a psychologist at the University of Wisconsin. A careful survey and testing of Milwaukee slum families indicated that grave functional retardation might be due to the retarded parents residing in the slum, rather than the slum itself.
>
> Heber and his associates located forty newborns whose mothers had an I.Q. of 70 or less. . . Half the children were given extensive stimulation over the next four years. From infancy they were picked up each morning by their

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[1]Ferguson, Brain Revolution, pp. 194-195

> teachers and transported to a center where they spent most of the day. . . .
>
> These children developed so phenomenally that even Heber was stunned. By age four these offspring of retarded mothers had a mean I.Q. of 130, ...
>
> Furthermore, the scores showed a steady advance, climbing from test period to test period. The control children at the same age scored in the 80's, . . .[1]

"Because of recently uncovered facts from the neurosciences, we can now suggest a new frame of reference for educational experiments,"[2] says Herman T. Epstein, Professor of Biology at Brandeis University. Dr. Epstein has found that the brain grows in spurts. Primarily in the age groups of three to ten months, two to four years, six to eight, ten to twelve or thirteen and fourteen to sixteen or seventeen years. He says these brain-growth stages are a scientific fact and not just a theory and mental growth stages correspond. To grow into, through, and into new stages, one from the other, requires changes and expansion in the structure containing the mind, the brain.

Brain growth has two components, first, an increase in weight corresponding with an increase in body weight and, second, spurts of five to ten percent in weight during the growth spurt periods with the latter two age periods slightly earlier in girls and slightly later in boys. Since cell replication in the brain ceases by about a year and half of age, increases in brain weight are due to changes within the cells.

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[1] Ibid. pp. 193-194

[2] NSSE, Education and the Brain, p. 343

The role of experience in shaping neural networks seems to be to select from the possible number of connections available. Intellectual experience is to select networks created by genetics during brain development. "If the complete spectrum of needed experience is not available to the organism, it loses forever the possibility of having those functions that are operated by the lost networks."[1] The consequences of either lack of experience or improper balances of experiences can be drastic.

Epstein reports on some work done by Patricia K. Arlin that gives evidence of another brain growth spurt between nineteen to twenty-one years of age. She calls this the <u>problem-finding</u> stage. Some of the other terms that Epstein thinks would be descriptive is creative thought, inductive reasoning or divergent thinking.

Several of the early education programs are reviewed by Epstein. Head Start concentrated on children in the four to six age groups, a period of minimal brain and mind growth. It was found to fall short of its goal for biological reasons. The Milwaukee Project by Rick Heber, took 25 black children before the age of six months and worked with them eight hours a day five days a week until they were four years old. The teachers were middle class black women. From the very beginning they exhibited an increase in I.Q. and they continued to make good gains up to about 30 points while the matched con-

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[1] Ibid. p. 354

trol group exhibited a deteriorating I.Q. and school failures. The Mother-Child-Home Program took two-year-olds. It interacted with the mother and child about one hour, one day a week. Even this smaller amount of time produced an I.Q. increase of about 17 percent over the control group. The Robinson's project in North Carolina also began with two-year-olds. They were in a day-care setting like the Milwaukee group and produced similar I.Q. gains.

The learning capacity and the difference in success or failure of intervention programs with disadvantaged children are tied directly to brain growth spurts. <u>The significance for education is that intensive intellectual input should correspond to the brain growth spurts</u>.

> This matching of inputs and receptor circuitry is probably related to the well-known pedagogical concept of readiness, which is parenthetically, an expression of the only accepted indication of the existence of stage-wise intellectual growth to have penetrated the school systems.[1]

But what should schools do during the plateau periods of brain growth? Here are a few of Epstein's suggestions. Expose children "to large amounts of information and to a wide variety of direct experiences with nature, science, people and work. . . enlarging his direct experience base."[2] Pressure for elaborate inferences should be avoided. This is a good time to work on memorization skills involved in the learning of poetry and facts such as in history, geography, health, science, legal affairs, citizenship and to increase

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[1]Ibid. p. 364 [2]Ibid.

skills already learned. Dr. Epstein feels experimentation should begin in the schools, and not in psychology laboratories, in order to determine a number of questions concerning learning and the relationship of brain growth spurts. In this way educators would be able to develop the curriculum to maximize the benefit to the child.

Steven Rose is an English neurobiologist. He helped establish the Brain Research Association while in London. Most of his research work concerns the biochemical basis of brain function, however, he has published a number of more general, interdisciplinary works, such as <u>The Conscious Brain</u>.

Rose describes the general development of the brain and central nervous system from conception to birth to adulthood. By the eighth pre-natal month most of the features of the convolutions on the surface of the brain are apparent though the frontal and temporal lobes are still small and the total surface area of the cortex is smaller than in the adult. The baby still has a long way to go in brain development when it is born. The newborn brain weighs about 350 grams, the adult's 1,300 to 1,500 grams. At six months of age the brain has grown to about 50 percent of the adult's weight. Growth then begins to slowdown. At one year it has grown to 60 percent of the adult weight; at two and one-half years, 75 percent; at six years, 90 percent; and at ten years, 95 percent of its total adult brain weight. The development of electrical patterns also begins before birth and reaches maturity between eleven and fourteen years of age. The most mature part of the cortex at birth is the primary motor area that controls the upper part of the body, turning the head, moving the arms, eye and other facial movements.

At birth, sensory input becomes very important. The baby is surrounded by new stimuli to every one of its senses and a vast amount of new information floods into the brain. The cortex begins to grow, neuronal connections increase, pathways are established, glial cells increase and the convolutions expand. As the months go by more bodily areas come under control in relation to the development of the primary motor and sensory areas of the cortex.

The baby also begins responding to the stimuli, to the world he is now in. He responds to sounds, faces, follows moving objects with his eyes, cries, laughs and makes other communication sounds. All of these sequences of motor and sensory developments compared to age have been well defined but there can be deviations in time and order of development without apparent later deficits. Between birth and adolescence there are a series of developmental stages of behavior that correspond to changes in the structure of the brain. The growth and development of the intellectual capacity also corresponds, but not in a one-to-one ratio.

Another emerging realization of brain growth and development concerns plasticity. Rose says "It is this plasticity of the brain which enables learning and memory to occur, and which impresses upon each individual a set of unique and characteristic behaviors, thoughts and emotions."[1] General growth and development that determines the species characteristics is termed specificity, and it makes us all alike as humans. Plasticity determines the distinguishing individual development in relation to the person's own experiences. This leads to numerous questions concerning experience, and the effects of environment upon brain structure and function.

Experiments on animals have shown that if they are malnourished or under-nourished during brain development the growth is impaired and the effects can remain for the entire life of the animal even though later he may be fed adequately. Malnutrition need not be a lack of food per se, but a lack of protein content in the food which is critical for adequate growth. This type of malnutrition is especially prevalent in the lower socio-economic classes.

Sensory malnutrition also effects the protein synthesis necessary for proper brain development as has been shown by Rose and other researchers. Rose relates the effects of visual stimuli on kittens reared in "defined visual environments" citing the work of Blakemore, Pettigrew, Hubel and Wiesel (reported elsewhere in this paper). The types of visual dectector cells found in the adult cats' brain relate

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[1] Steven Rose, The Conscious Brain, Updated Edition Vintage Books (New York: Random House, 1973, Vintage, 1976) p. 212

directly to its early environmental experience and the type of stimuli it was exposed to. Rose says "This is striking evidence of the plasticity during development of what had previously been believed to be a relatively 'hard-wired', genetically programmed analysis system." [1] Because of plasticity the individuals flexibility of mental processes can be enhanced, they are not just dependent on an inherited ability. "It is obvious there is a measure of genetic specification and a measure of environmental plasticity."[2]

The capacity of the brain to heal itself after damage is called neuroplasticity. This is the area of neurology that Rita G. Rudel, Ph.D. of Columbia-Presbyterian Medical Center in New York City has been concerned with for over twenty years.[3] She is concerned with the neuroplasticity of the brain and its implications for both development and education. The extent, location, state of brain development and age of occurrence are determining factors for recovery and in children these are complicated by not always knowing exactly when the damage occurred. The presents of damage can be inferred by both behavioral and neurological signs. Along with damage there is also difference in organizational structure, dysfunction, deprivation and poor early training to be considered. The problem is complex and raises many as yet unanswered questions for both neurology and education.

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[1] Ibid. p. 218 [2] Ibid. p. 220

[3] NSSE, Education and the Brain, p. 269

Just as animal studies have shown that early deprivation of sensory experience or rearing in isolation will cause developmental changes from the norm, children reared in isolation and in institutions do not develop normally even though no definite lesions have been located as a result of this early deprivation, implicit in the results is altered synaptic arrangements and connections. But the immature brain is capable of a considerable amount of recovery under proper conditions. The earlier the damage the less disruption of functions, but on the other hand some problems do not appear until later in life. There is also some evidence that an uninjured portion of the brain can sometime "take over" for the injured portion.

There are some general effects of damage at any age such as slow reaction time, slowness on tests involving language, visual information recall, ability to make repetition movements and in psychophysical judgments such as determine the midpoint of a line. This loss of efficiency may be due to the "take over" function being less direct and precise than the damaged original area.

When damage occurs to a portion of the brain before it is functionally mature enough for utilization, it often is not apparent until time for the normal development. This delayed damage effect can be observed in some educational difficulties, the damage having occurred years earlier. The diagnosis of brain damage is usually based on impaired motor function. The exact relationship of motor difficulties to cognitive-perceptual difficulties is still unclear but it may be due to impairments and the corresponding educational difficulty. She cites a number of studies done on both people and animals of all ages on which these problems are based.

> *There is no question that early experience is crucial in determining development*, from the simple observation that a child never spoken to can learn no language. . . *Early stimulation has been shown to be vital to emotional responsiveness and there are undoubtedly critical periods for stimulation after which certain functions no longer develop normally.*[1]

Rudel summarizes work by both Kagan and Goldman that help substantiate her statements. Kagan worked with socially and physically deprived Guatemalan children and found that their intellectual abilities survived up to two years, but it depended upon remedial help following this time period. Goldman's work was done with monkeys. She operated on them in the orbital prefrontal cortex to affect delayed response performance. If these animals that are operated on early in life are given extensive test experience between the ages of one and one-and-a-half years, they are able to do the delayed response task by the time they are two or three, although at the beginning they could not perform the task. Control monkeys, without testing experience, never developed or regained the ability to do the task. These studies clearly show that experience enhances recovery of function even if it does not appear to be doing so at the time. What seems to be unsucessful training

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[1] Ibid. p. 289 (my italic)

at one stage of development may be of decisive benefit at a later stage. Rudel syas "At the very least, training or test experience may help the child develop compensatory processes or alternative strategies."[1] And again she says "*early experience with the task is crucial for the establishment of structure-function relationship*."[2]

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[1] Ibid. p. 290 (my italic)   [2] Ibid.

CHAPTER IV

SELECTED RESEARCH ON LATERALIZATION AND SPECIALIZATION: LEFT AND RIGHT HEMISPHERES, INTEGRATING FUNCTIONS

That the brain has specialized regions for various abilities has long been suggested and was finally demostrated by Paul Broca in 1861. He discovered that a lesion in the back third of the interior frontal gyrus on the left side resulted in the person being without the ability to speak or to form motor images of words. This disability is called "aphasia." Lesions in the corresponding area on the right side did not damage or destroy the ability to speak. Carl Wernicke, in 1873, discovered that a lesion in another part of the brain, the back portion of the superior temporal gyrus on the left side produced a condition where the person could not understand speech but he was still capable of speech himself. (See Plate I.) Other specialized areas were soon discovered. Music, mathematical computation, writing, spatial orientation and artistic abilities appear to depend on specialized areas that form a functional system. "In some cases the functional specialization of a neural system seems to be quite narrowly defined: hence one area on both sides of the human cerebral cortex is concerned primarily with the recognition of faces," says Norman Geschwind of Harvard.[1] (See Plate V.) The primary motor area of the cortex is in a strip of brain tissue that runs from ear to ear across the top of the cortex. Running parallel and in the back of this strip is one called the primary sensory area. (See Plate I.) The various areas of the body are represented across these two strips. (See Plate IV.) They work in conjunction with the secondary and associated areas for motor movements and sense perceptions.

How fine the functional distinction can be between "two networks of neurons" in highly specialized areas is illustrated by Geschwind by a series of experiments dealing with learning in monkeys.

> A monkey can be taught to choose consistently one object or pattern from a pair. The task is made somewhat more difficult if the objects are presented and then withdrawn and the monkey is allowed to indicate its choice only after a delay during which the objects are hidden behind a screen. It has been found that performance on this test is impaired markedly if a small region of the frontal lobes is destroyed on both sides of the brain. Difficulty can also be introduced into the experiment by making the pattern complex but allowing a choice to be made while the patterns are still in sight. Damage to a quite different area of the cortex reduces ability to carry out this task, but it has no effect on the delay test.[2]

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[1] Sci. Am., Brain, p. 108 [2] ibid.

How close but distinct the functions can be in the brain is brought out by the results of damage to Broca's area which is adjacent to the motor cortex area that controls the face, tongue, throat and jaw. There is almost always damage to this area when Broca's area is destroyed. It would seem speech damage might be due to a weakness or partial paralysis of the muscles required to produce speech. Two other observations explain why the muscle weakness alone is not the reason for the inability to speak. First when the damage is in the corresponding right side, with the same muscles affected, no aphasia appears. Second, while the person with aphasia cannot speak, or can speak only with difficulty, they can sing with ease. There are also speech components present in aphasia such as faulty grammar and using phonetically incorrect letters. The same kinds of speech errors are also made in handwriting.

Wernicke's area, also concerned with speech, is connected to Broca's area by a bundle of nerve fibers but damage to it causes a different problem. These patients choose inappropriate words, inject nonsensical words or syllables, and take an extremely roundabout way to express their thoughts. There are other problems that occur depending on the exact location of the lesion in Wernicke's area. If the connecting nerve bundle is damaged the person can speak fluently but cannot understand the meaning of what they are saying since information cannot pass through from Wernicke's area; however they can still understand spoken and written words. Due to the plasticity of the brain, sometimes some of these functions can be regained to some extent if the region destroyed is not too large. (See Plate VI.)

Another disorder that illustrates how highly specialized some brain areas can be is the condition known as prosopagnosia which is the inability to recognize faces. The area for face recognition is located on the underside of the occipital lobe and extends to the inner side of the temporal lobe, on both sides of the brain. (See Plate V.) It is quite a large area for so limited a task. Damage to this area usually is confined to visual recognition of faces but not to reading or naming seen objects. The person can usually name the other person as soon as he hears him speak, can describe facial features of a particular person and even match front and side view photographs of people, but he cannot recognize and identify that person on sight alone, even when they are immediate family members.

Dr. Geschwind points out that the seemingly bilateral symmetry of the brain is only illusory since many of the more specialized functions are distributed asymmetrically. (See Plates V and VI.) Language is primarily located in the left hemisphere while music, the perception of melodies and the ability to sing is located in the right hemisphere; as is the perception and analysis of nonverbal visual patterns, such as perspective drawings, although the left side does make a contribution to the function as a whole process. A lesion or lobectomy of the left temporal region can damage the ability to remember verbal material but does not disrupt the ability to remember faces, melodies, spatial locations or visual patterns.

"One of the most surprising recent findings," says Dr. Geschwind, "is that different emotional reactions follow damage to the right and left sides of the brain."[1] Lesions on the left side causes feelings of loss and depression due to physical disabilities. Lesions on the right side causes the patient to be unconcerned with his condition, to give inappropriate emotional responses and to be unable to recognize emotion in others, emotional tone of voice or actions such as anger or humor. "Guido Gainotti of the Catholic University of Rome has made a detailed compilation of these differences in emotional response."[2]

> The "laughter site" in the brain was discovered accidentally by a distinguished German surgeon, Richard Hassler, during an operation in 1955, and confirmed on subsequent occasions.
>
> It is a region of the thalamus, deep inside the brain, where stimulation can make the most gravely ill or anxious patient smile or laugh out loud. Many signalling systems of brain and body coverge at the thalamus, so there is plenty of scope for a pooling of influences so far untraced, to turn a tickle, a surprise or a witticism into a tightening of the diaphragm or an outright laugh.[3]

Nigel Calder says of his investigation into research

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[1]Ibid. p. 115 [2]Ibid.

[3]Calder, Mind of Man, p. 216

on the mind

> Of all the remarkable experiments and discoveries we encountered in our world-wide search for new knowledge about the mind of man, the human split brain remains the most haunting. The demonstration that zones of perception, decision-making and consciousness have been divided by the surgeon provides the most forcible evidence of the unity of brain and mind that medical science is ever likely to give to the doubting onlooker.[1]

The research into the effects of split brain surgery began in the early sixties (1960s). In the nineteen fifties (1950s) Dr. Joseph Bogen concluded that by cutting the corpus callosum, interhemispheric epilepsy could be controlled. The corpus collosum is the cerebral commissure that interconnects the left and right hemispheres and is the largest of the nerve tracts in the brain. At that time, very little was known of the corpus callosum's function and it was generally believed cutting it would not produce any significant neurological or psychological effects. The surgery did help the severe epileptics, but it was soon discovered that there were side effects. Dr. Roger Sperry and Dr. Michael Gazzaniga devised a number of tests which they gave to Dr. Bogan's split-brain patients.

The first finding of major importance was that the hemispheres exchanged information from the senses through the commisure. The commissurotomy, as the operation was formally called, totally disrupted this information exchange process.

> The effect was such that visual, tactual, proprioceptive, auditory, and olfactory information presented

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[1] Ibid. p. 244

> to one hemisphere could be processed and dealt with in that half-brain, but each of these activities went on outside the realm of awareness of the other half-cerebrum.[1]

All the information going into the left hemisphere could be processed and described verbally by the patients but they could not verbally describe information that went into the right hemisphere.

Gazzaniga and Sperry devised special testing techniques of a non-verbal nature to study the right hemisphere. They discovered it had a rich mental life of its own, it had some language, could initiate its own response, had emotion, and could learn and remember. It could do all these things without the left brain knowing anything about it. For example:

> A word could be flashed in the left visual field which, in man, is exclusively projected to the right hemisphere-the word spoon in this instance- and the subject would say, "I did not see anything." Subsequently with the left hand, he would be able to retrieve an object from a series of objects placed out of view. . . . The left hemisphere did not see the picture. . . nor did it have access to the . . . touch information from the left hand. . . yet clearly the right hemisphere recognized the word spoon because it reacted appropriately. . ."[2]

They proved, through these tests, that the left hemisphere excelled in verbal processing of information of all kinds and the right hemisphere excelled in managing visual spatial tasks.

Gazzaniga includes a brief section on the educational

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[1] Whittrock, et al., Human Brain, p. 91

[2] Ibid. p. 92

significance and another one on the philosophical implications of education in his chapter on the "Review of the Split Brain" in The Human Brain. He says, one of the intriguing possibilities resulting from the split-brain research is that man can be specialized in a variety of aspects of mental life, he can be superior in either the left brain verbal areas or the right brain visual-spatial area. A particular child might be able to solve a problem verbally while another child would have to solve the same problem using visual-spatial relations.

> The motivational aspect of this observation, of course, cannot be overemphasized. When a child's talents lie in visual-spatial relations and he or she is being forced into a curriculum that emphasizes the verbal articulatory modes of solving a conceptual problem, this child will encounter enormous frustration and difficulty which may well result in hostility toward the teacher and, worse, toward the learning process itself. If the teacher were to be made aware that the child is specialized in visual-spatial skills and the same conceptual problem is introduced, both the discouragement and the subsequent hostility might be avoided if the child is allowed to use his special talents. Conversely, the child with high verbal skills may quite frequently be unable to visualize the spatial aspect of an assigned task; in this case also, far better results could be obtained if he is not forced into academic areas for which he is not naturally equipped.[1]

Other brain processes that Gazzaniga and his colleagues are investigating are long- and short-term memory systems, rate of processing of information, and how much can be kept in mind in a given space of time. He hopes to develop tests that will help diagnose the individual for

> once these specific capacities have been identified, they will obviously be of great benefit to education. A

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[1]Ibid. pp. 94-95

> teacher thus informed will be enormously aided in knowing how best to present materials to his or her class and obtain speedy comprehension and proficient use of these materials.[1]

On philosophy, Gazzaniga says that the findings from the split-brain research now allows us to think in terms of modes of consciousness but the split brain "experiences a real decoupling."[2] This is what writers, poets and scientists have been telling us for centuries and now we can assume it is true.

These and other recent research findings have changed the conceptions of the right hemisphere and its function. Dr. Robert D. Nebes, Ph.D., Duke University Medical Center Department of Psychiatry contributes a chapter on the right hemisphere in The Human Brain. It has been known for almost a century that the left hemisphere had a unique cognitive function, language. This was discovered by carefully noting loss of function due to left side brain injury. Scientists term the left hemisphere "dominant" or "major." Little attention had been paid to right non-dominant or minor hemisphere, but over the years there had been an increasing number of reports of specific cognitive defects resulting from right hemisphere injury. It became clear that each side was dominant for only certain functions and the concept of dominance was replaced by specialization. Research is now concerned with how different mental processes are distributed between the two hemisperes and how they interact and integrate.

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[1] Ibid. p. 95 [2] Ibid. p. 96

Three major approaches have been used in order to study the hemispheres. One, studying groups of patients with brain damage; two, studying the patients with surgically severed hemispheres; and three, normal people, comparing their ability to process stimuli coming into the right or left side.

Studies on unilateral brain damage showed that right hemispheric injury produced two types of cognitive defects. One defect was difficulty in perceiving, manipulating and remembering spatial relationships. A second defect was that the person had difficulty remembering visual, tactile and auditory stimuli that were fragmentary, complex or difficult to label and describe verbally. The spatial disorientation was a very dramatic symptom because the patient would become lost very easily even when familiar with the surroundings. They could not make or use maps or describe previously wellknown routes. They were baffled by simple mazes and they misjudged size, distance and directions of objects. They could not match or copy correctly the slant of a line or the position of a dot on a piece of paper, they could not copy simple shapes, or arrange blocks and sticks to make a required pattern. Nor could they mentally rotate shapes to determine likenesses or spatial position compared to themselves. These disabilities were not confined to the visual alone, but included the spatial aspects of all stimuli. That these spatial relationships are lateralized or specialized in the right hemisphere has been confirmed by experiments on normal people. The normal person is faster and more accurate in response to such stimuli when it is presented to the right hemisphere first.

These patients with right hemispheric damage also have difficulty perceiving and remembering faces, inverted numbers, unfamiliar or complex shapes, drawing the missing part on the contour of an object, melodies and chords of music, and other nonverbal sounds. The results achieved in these circumstances are in striking contrast to results with verbal material.

Studies of the drawings of patients with right hemisphere damage was one of the first indicators that the two hemispheres process information differently.

> Drawings made by patients with right hemispheric damage (and having an intact left hemisphere) tended to be full or details but dis-articulated, with no coherent organization, while those made by patients with left-hemispheric damage (and an intact right hemisphere) had the correct overall configuration, but were greatly oversimplified, with few details.[1]

Nebes says it is evident from all the findings that the right hemisphere makes important contributions to human performance and that its functions are complimentary to the left hemisphere's functions. Creativity, imagination, id, ESP, are some factors currently being assigned to the right side. The right side has given the mystical and humanistic aspects of culture while the left has given the scientific and technological aspects according to many researchers. Nebes says,

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[1] Ibid. p. 102

> If there is any truth in the assertion that our culture stresses left-hemispheric skills, this is especially true of the school system. Selection for higher education is based predominantly on the ability to comprehend and manipulate language-a fact which might help explain why it took so long for science to come to grips with right-hemisphere abilities. If the right hemisphere does indeed process data in a manner different from the left, we may be shortchanging ourselves when we educate only left-sided talents in basic schooling. . . . Many problems can be solved either by analysis or synthesis; but if people are taught to habitually examine only one approach, their ability to choose the most effective and efficient answer is diminished.[1]

Dr. Stephen D. Krashen, a professor of linguistics at the University of Southern California, describes left hemisphere functions in The Human Brain. The left hemisphere contains the majority of the functions that make up verbal speech and language processing in most all right-handed and many left-handed people. This is amply demonstrated by patients with brain damage to the left side of the brain, and by people who have had the left side temporarily anesthetized. But not all aspects of language are contained in the left side and the left side does more than just control language functions. The left hemisphere is specialized for particular aspects of speech perception such as the restructuring needed to decode the acoustical sounds, the linear succession of discreet speech sounds, analyzing the grammatical structure of sentences and linguistic tones; it also has the advantage for naming and codifying information. However, recognition of intonation does not seem to be affected in left hemisphere

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[1] Ibid. p. 105

damaged patients since they can often tell the difference between questions, commands or declarative sentences. Whereas right hemisphere damaged patients often cannot make this distinction.

Some of the non-verbal language processing that takes place in the left hemisphere appears to be time related. These include temporal-order judgements, such as the following. Which of two stimuli comes first, called simultaneity judgement. The stimuli seemed to be simultaneous when the left-side stimulus preceded the right-side stimulus by about three milliseconds. The temporal resolution, which is the ability to perceive clicks as separate entities, requires a longer time interval between the clicks for left-side damaged patients. The ability to make rapid motor sequences required for speech also seems to be a time related, left hemisphere function.

Kashen states that the findings of specialization of non-linguistic functions in the left hemisphere along with the linguistic leads to the question of the relationship of language and non-linguistic functions.

> Language production and perception are of course heavily dependent on the temporal capacities of the brain . . . what is essentially involved in language production is the programming of an idea, . . . into a sequence of linguistic units, . . .[1]

Krashen cites some controversial studies on the development of dominance. Early studies indicated that the infants brain was not firmly specialized and that the adult

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[1]Ibid. p. 118

level of lateralization and specialization was not established until around puberty. Krashen presented evidence in 1973 that indicated lateralization was accomplished by about five years of age. He cites a number of studies from 1972 through 1976 that have shown clear signs of hemispheric symmetry in newborns and very young children and he points out that Kinsbourne has argued that language is lateralized to the left side from the beginning.

> The "age five" position is consistent with the hypothesis that the process of first-language acquisition and the development of cerebral dominance are related, as the fundamental parts of first-language acquisition are also complete around five.
> . . . .
> . . .Children over five who exhibit deficits in linguistic development (dyslexis, or poor readers) do not show the adult level of cerebral dominance when tested by dichotic listening. . . children who suffer from retarded language show deficits in temporal processing. . .[1]

These studies have supported Krashen and Harshman's 1972 suggestion that language development may not only involve but depend on cerebral lateralization of certain functions, especially the time related abilities.

Charles Furst noted that

> ". . . Most children who are rendered aphasic recover fully, especially if they are young enough at the time of the injury and if the right hemisphere is spared. The lateralization of language functions to the left hemisphere is probably not complete until after age 12 or so."[2]

After the age of 12, the majority of people with nor-

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[1]Ibid. p. 119

[2]Charles Furst, Origins of Mind, Mind-Brain Connections, A Spectrum Book (Englewood Cliffs, N.Y., Prentice-Hall, Inc. 1979) p. 136

mal brains find it more difficult to learn a new language and they usually speak with a foreign accent.

Jack Fincher says the "evidence continued to mount that the right hemisphere was far from asleep." It is now scientifically accepted that the right hemisphere is better than the left at recognition tasks such as faces, objects or pictures and at perceiving and understanding spatial relationship. Musical ability is located in the right hemisphere, including style, rhythm, melody and memory of tunes. The right side is better at constructional task that involve arranging and building things. "On top of everything else the maligned right hemisphere retained at least a passive comprehension of language, if not the means to use it actively in formulating abstract ideas, . . .[1]

Research by Robert Orienstein and others into eye movement in response to questions or tasks has shown that people look in different directions depending on the type of question asked. When a person was asked a verbal-analytical question such as definitions, they would tend to look to the right, indicating mental processing in the left hemisphere. A spatial question caused the person to look to the left, indicating right hemisphere processing.

Furst says ". . . people may differ in the degree to which they rely on right-or left-hemisphere thinking. . . .

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[1]Jack Fincher, Human Ingelligence, Capricorn Books (New York: G. P. Putnam's Sons, 1976) p. 53

some people may tend to approach problems using the verbal, analytic machinery of the left hemisphere, while others may rely more on holistic, right-hemisphere visual thinking."[1]

The following chart illustrates some of the abilities now generally believed by the neuroscientists to be lateralized to the left and right hemispheres.

Left	Right
Rational	Intuitive
Logical	Relational
Mathematical	Spontaneous
Verbal	Non Verbal
Analytical	Holistic
Sequential	Integrative
Linear	Simultaneous
Precise	Diffuse
Mediate	Immediate
Time Dependent	Time-Independent
	Spatial Organization
	Artistic-Pictorial
	Esthetic
	Imaginative
	Musical

The frontal lobes of the brain are less understood than the other parts, but a few conclusions have been reached by working with patients with damage to that area. Aleksandr Luria, working with the Soviet war-wounded, found that fewer than one-tenth of those with damage in the frontal lobes could master a task in occupational therapy, compared with four-tenths of those with damage in other areas of the brain. Their characteristic problem was in being unable to work through a number of actions systematically toward a goal.

The late Hans-Lukas Teuber, of M.I.T., said that the

[1] Furst, Origin of Mind, p. 151

powers of voluntary control are impaired when the front of the brain is damaged or out of action. The person may be able to foresee a course of action, but he is not able to picture himself in relation to that course of action.

M. I. Livanov of the Institute of Higher Nervous Activity in Moscow, in the mid-1960s, using electrodes to pick up the electrical currents of the brain discovered synchronous electric activity in the frontal lobes during a directed mental process. When the person was sitting quietly there was no pattern of electrical activity, just a jumble of disconnected waves from different areas of the brain. But when the person was given a mental task such as multiplying two two-figure numbers (38 x 92), the electrical activity became synchronous in some areas of the brain and especially across the frontal lobes. It seems the frontal lobes are very much involved in the problem solving process. Livanor expanded his research to include the abnormal person or circumstances. He found that a tranquillised person showed the common rhythms in the frontal lobes reduced markedly. A patient with a delirious form of schizophrenia had feverish synochronous activity. When the person had damage to the frontal lobes, he showed no such patterns, not even during a mental task.

"A language lump in the human brain was found in 1968, by Norman Geschwind and Walter Levitsky at Boston University"[1]

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[1]Calder, Mind of Man, p. 194

In right-handed people and nearly half the left-handed people this language lump is located on the left side of the brain. The language powers are almost entirely contained in the left side of the brain and in nine out of ten brains examined by Geschwind and Levitsky, the left side was conspicuously larger. This lump is in the same area indentified by Wernicke as involving the higher analysis of speech sounds.

The frontal lobes, which generally are associated with programming and planning, also contain some language abilities. A person with damage in this area will often, meaninglessly, repeat letters or words when he is trying to write. Handwriting tests can help in locating the existing damage and its extent. Damage to the left temporal area often results in letter confusion, "b" for "p" or "t" for "d", and these patients often cannot write because they cannot remember the letters of words. The acoustical area for recognition of sounds is also in this area and in writing people often rely on saying the words to themselves. This was shown in an experiment conducted in a Russian school. The children were told to keep their mouths wide open during spelling tests. They made six times as many mistakes as they would have normally, with their mouths closed. Chinese children do not respond this way because their words are pictorial.

Dr. Aleksandr Luria, a Russian neuro-psychologist, has been one of the leaders in investigating the functions of a given area of the brain by refining clinical observation techniques and devising tests to illustrate the unique problem of damage or malfunction of an area. His book _The Working Brain_ summarizes his efforts and achievements. Luria came to believe it was not "our fundamental task" to localize processes, but to "_ascertain . . . which groups of concertedly working zones of the brain are responsible for the performance of complex mental activity_.[1]

> For instance, a local focus in the parieto-occipital . . . region of the left hemisphere, disturbing the spatial organization of perception and movement, invariably gives rise to other symptoms also; these patients as a rule cannot interpret the position of the hands of a clock or find their bearings on a map; they cannot find their bearings on a way around the ward where they are staying: they cannot solve even relatively simple arithmetical problems and they are confused when faced with the problem of subtracting from a number of two digits requiring carry over from the tens column: . . . Finally they begin to have great difficulty in understanding grammatical structures incorporating logical relationships, such as "the father's brother" . . . "spring after summer," whereas the understanding of simpler grammatical structures remains unimpaired.[2]

Spacial orientation, mathematical calculations and complex logical grammatical relationships all have common links in the mental processes needed to assure their functioning properly. This is true with a great many processes, but the reverse of this is also true at times. For example

> To the unprejudiced observer, _musical hearing_ and _speech hearing_ may appear to be two versions of the same psychological process. However, observations on patients with local brain lesions show that destruction of certain

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[1]Alexandr Luria, _The Working Brain, An Introduction to Neuropsychology_, trans. Basis Haig (New York: Basic Books, Inc., Pub. 1973) p. 34

[2]Ibid. p. 40

> parts of the left temporal region leads to a marked disturbance of speech hearing (discrimination between similar sounds of speech is completely impossible), while leaving musical hearing unimpaired. . . . This means that such apparently similar mental processes as musical hearing and speech hearing not only incorporate different factors, but also depend on the working of quite different areas of the brain.[1]

Luria distinguishes <u>three principal functional units of the brain</u>. All three units must be working for any mental activity to take place. Briefly he describes them as: one, the unit for <u>regulating tone or waking</u>; two, the unit for <u>obtaining, processing and storing information</u> that comes in from the world outside; and three, the unit for <u>programming</u>, <u>regulating</u> and <u>verifying mental activity</u>.[1]

Within each of these three zones there are at least three more zones that work together in a hierarchical nature, the <u>primary</u> or projection area which both receives and sends messages, the secondary or projection-association area where the information received is processed and the <u>tertiary</u> or <u>zones of overlapping</u> areas which is where the most complex forms of mental processes takes place. Problems anywhere along the line lead to some type of problem with the mental processes. Luria says the tertiary zones are specifically human structures. They contain the cortical ends of various analyzers working together. Luria says the work of this zone is essential. It plays an important role in the converting of concrete perceptions into abstract thinking. Thinking

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[1] Ibid. p. 43

always proceeds from the concrete into the abstract via internal schemes and then into storage or memory.

In his research into specific functions lost or altered by lesions in various places, Dr. Luria has made extensive use of tests that use writing and drawing abilities as well as language-reading abilities, spatial orientation and memory processes.

In the laboratories at Bispebjerg Hospital in Copenhagen and at the University of Lund in Sweden, Dr. Niels A. Lassen, Dr. David H. Ingvar and Dr. Erik Skinhøj are charting cerebral blood flow to directly observe the localization of cerebral functions. Their method is to inject a radioactive-isotope into one of the main arteries of the brain, place an array of detectors on the brain surface and use a digital computer to display information from the detectors in color graphic form on a television monitor. By this method they can determine which area of the brain is activated. They assign a different color to each of twenty blood flow levels above and below the mean blood flow rate. About 500 people have had their brains studied by this method. Of the 500, about 80 had normal brains.

The resting pattern in the normal brain is highly characteristic and is reproducible. It served as the departure point for measurement and interpretation of the functional activity patterns of different types of activities which included purely mental activities as well as sensory and motor activities. Even when the person was at rest the flow rate in the front cortex was always substantially higher by about 50 percent than in the central and rear parts. "The hyperfrontal resting flow pattern therefore suggests that in the conscious waking state the brain is busy planning and selecting different behavioral patterns."[1] In the broad sense, the function of the prefrontal areas is responsibility for planning behavior.

The body was also in a resting position, lying comfortably in a silent lab with eyes closed. When the person opened his eyes to look at an object, the blood flow pattern changed dramatically. The visual association cortex flow increased by about 20 percent and the frontal eye field located in the premotor cortex became active. The primary auditory cortex and the auditory association cortex became active when a loud, meaningless noise was introduced. These areas became even more active when simple words such as bang, zoom, or crack were spoken. These regions include Wernicke's area which is involved in understanding spoken language. In tests of tactile perception, the primary sensory cortex and the adjacent association area for receiving that particular sensory information was activated. "These areas were the only ones that were consistently activated by sensory input, suggesting

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[1] Niels A. Lassen, David H. Ingvar and Erik Skinhøj, "Brain Function and Blood Flow," Scientific American Vol. 239 No. 4 (October, 1978). p. 66 (hereafter cited as Scientific American October 1978)

that modality-specific forms of memory are localized in the association cortex specific for that modality."[1]

Rhythmically clenching the fist increased blood flow in the hand area of the primary motor cortex and also in the primary somatosensory cortex that monitors signals from the skin, tendons and muscles. This increased blood flow rate pattern could only be seen in the hemisphere opposite the hand being clinched, in the hemisphere on the same side there was no increase in the blood flow pattern. The prefrontal motor cortex can be activated by the contractions of voluntary muscles. This type of activation seems to always involve both hemispheres and is located in the same area regardless of what part of the body is moved. Near the midline of the prefrontal motor cortex is an area called the supplementary motor area. It is involved in complex motor tasks of all kinds. It shows the highest level of activation during voluntary muscle contractions. "We found that activation of the supplementary motor areas was more marked during dynamic muscle movements, such as operating a typewriter, than it was during steady muscular contractions."[2] From this, Lassen, Ingvar and Skinhøj "have concluded that the upper premotor cortex, including the supplementary motor area, is involved in the planning of sequential tasks."[3] One of the experiments involved only thinking about a sequence of finger movements, but not actually

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[1]Ibid. p. 67 [2]Ibid. pp. 68-69

[3]Ibid.

moving the fingers. The supplementary motor area was activated by just imagining the fingers to be moving. When actual movement was added then the primary motor cortex and the somatosensory cortex also became activated. "These findings suggest the supplementary motor area is a programmer of dynamic movement, whereas the primary sensory cortex is the controller and the primary motor cortex is the executor."[1]

The speech processes have been investigated in detail by this team. They were impressed to find both hemispheres taking an active part and in much the same areas and with much the same intensity. Listening to spoken words activates the auditory area on both sides. Speaking the words aloud activates three additional areas: one, the face, tongue and mouth area of the motor cortex and the somatosensory cortex; two, the upper premotor cortex in both hemispheres; and three, Broca's area on the left side and the corresponding area on the right side. Reading aloud adds three more areas: one, the visual association cortex; two, the frontal eye fields; and three, the primary visual cortex. The seven seperate areas activated by reading aloud form a Z-like figure in both hemispheres. It was surprising to find as much activation of the right hemisphere in the area corresponding to Broca's area on the left side since lesions in that area have no discernible effect on speech; suggesting that "it makes some contribution (albeit a nonessential one) to the final synthesis and mobil-

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[1] Ibid. pp. 68-69

ization of speech."[1] Further studies by Larsen and Lassen on slight differences in blood flow rates to the two hemispheres during speech indicate that in the left side there is an increase in the mouth area and auditory cortex as seperate areas but on the right side they form one confluent area. Also, the supplementary motor area is usually more active on the left side during speech. These results confirm the conclusion reached by A. R. Luria that complex behavioral processes are distributed throughout the brain and each cortical area that is activated makes a specific contribution.

Risberg and Ingvar found an overall increase of about 10 percent in the blood flow rate in addition to the local activation during psychological testing. The greater the mental effort with a more difficult problem the greater the increase of blood flow. Very simple tasks did not cause an increase.

> Hence it appears that for the brain to "understand" the surrounding world, to perceive its meaning and to take action in difficult tasks the cerebral cortex must be activated not only locally but also totally.
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> These observations support the hypothesis that the general activation of the brain is accompanied not only by an arousal of electroencephalographic activity but also by an increase in cerebral blood flow and oxygen uptake, and that this reaction is related to an increaseed level of awareness.[2]

Stress is the form of various types of problem solving activates the brain pathways and increases one's awareness of the environment, the self and the interaction of the two.

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[1] Ibid. p. 70 [2] Ibid. p. 71

CHAPTER V

SELECTED RESEARCH ON FUNCTIONS OF THE BRAIN IN LEARNING: M.B.D., MEMORY, ATTENTION, PROBLEM SOLVING, AND IMAGERY

"Caution: brain factors at work here,"[1] is the way Martha Denckla, M.D., neurologist at Harvard Medical School, defines the term "minimal brain dysfunction" or MBD. MBD is synonymous with learning disabilities. She reviews the controversy over the term and some of the suggested replacements such as "minimal cerebral dysfunction" which is used by the British and the other "neurologically-based learning disabilities syndrome" suggested by some neurologists. The term MBD is more of a resting place during the diagnostic procedures needed to make a more specific diagnosis. The term "brain" allows inclusion of functional variation as disease or damage. "Brain," she feels is really the best part of the term because

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[1] NSSE, Education and the Brain, p. 231

"it reminds us not only that the brain is the organ of the mind but also that variations in the organization of brains underlie temperaments, cognitive styles, talents and habits."[1] The brain is designed to both assimilate and be modified by experience. Any dysfunction is an imbalance that is not compensated for. If there is any persistent maladjustments in assimilation and modification of experience it becomes a dysfunction and since the brain is the organ of the mind, the dysfunction rapidly becomes an emotional block or psychological as well as organic.

Dr. Dencla says, "The concept of different types of brains, of biological variation model rather than a disease model, opens an exciting era for MBD."[2] The D she sees as including difference, dysfunction and developmental lag as well as damage. As Director of the Learning Disabilities Clinic of Children's Hospital Medical Center in Boston, she works with children with many problems that have great implication for education and she feels there should be greater collaboration between education and medicine. Who is referred to the Clinic is partly a social-cultural interpretation of learning disabled, for instance tone-deaf or the unathletic are rarely seen.

Longitudinal studies of children with three or more left side motor system impairments, indicating right hemi-

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[1] NSSE, Education and the Brain, p. 231

[2] Ibid. p. 253

sphere brain dysfunction, do have some imbalance in verbal functions, indicating a right hemisphere contribution to the verbal process. These children are often delayed in learning speech and in reading; in verbal reasoning, inferential meanings found in puns, humor, metaphor; and the sociolinquistics of what to say, when, in what context and to whom. Other problems are mathematics disability, geographical disorientations, especially in real life, facial and vocal expression meaning processing disability, and poor socio-emotional control. As more becomes known about the functions of each hemisphere of the brain it is becoming more clear that they interact and contribute something to the processes of the other hemisphere. Denckla details a number of neurological dysfunctions and their correlations with learning disabilities.[1]

"The implications of each of the MBD syndromes for education are philosophically enormous," says Dr. Denckla. "The teacher must become a clinician. . ."[2] The clinician-teacher needs to be explicitly aware of each child's case rather than just knowing typical age developmental patterns or just a certain body of subject matter. Emphasis in teaching should be upon "finding and bringing out what is good about the child. . . promote and support the child's motivation and effort. . . willingness to change course of approach as the child grows and changes."[3] The problems of teaching

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[1]Ibid. pp. 232-253 [2]Ibid. p. 258

[3]Ibid. pp. 258-259

dyslexic children goes beyond books and <u>if mainstreaming is to be effective the regular classroom teacher must be aware of both the problems and solutions</u>. Many of these children process incoming verbal language slowly and too much language given too fast will cause them to "blow a fuse" just as an electrical circuit does that has too many appliances plugged into it. This condition can lead to a total lack of understanding of anything that has been said. Instructions and questions must be given more slowly and in shorter chunks. Another characteristic of many dyslexic children is that they are verbal. They must verbally, talking out loud, wander through mental associations looking for the cues for the exact words to express their thoughts. If impatiently pushed or ridiculed in some manner, they may begin to stutter, withdraw into silence or habitually say "I don't know." The good thinker but poor memorizer is another type of problem often seen as stupid or lazy and not trying. This person is both a slow learner and smart, once again illustrating the lack of unity in intelligence.

Verbal deficiencies can also create peer group problems not directly related to book-learning. Physical aggression, disruption of games, retreat and withdrawal are direct social consequences. The teacher needs to be aware of these problems so they can become a "sort of social-emotional therapist for the child"[1] by helping him with his language problems.

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[1] Ibid. p. 261

The brighter than average child who is seriously delayed in reading needs to be with a similar peer group, in a small class. The teaching needs to be done through experiential, hands-on type of learning, outside of books. They need experience in the so-called non-academic skills "such as woodworking, nature, camping, sculpture, music and so forth. Without these total milieu components no amount of tutoring in reading can be expected to be successful."[1]

MBD of the right hemisphere shows up in skills involving spaces, faces, mazes and mapping. These cognitive-perceptual-spatial problems become social-emotional problems for some children. Academically these problems show up as mathematic disabilities in spatial concept and place value of material on the page; in geography there are problems with reading and making maps. Socially and emotionally these problems show up as clinging to the parent or teacher, refusing to participate in games, being terrified of school and other places because of fear of getting lost.

Another problem that becomes social-emotional is the ability to perceive subtle changes in facial expressions and vocal intonation patterns. The socializing feedback necessary for interaction with others is lost in these children. They fail to notice irritating or disapproving looks, boredom and impatience in others. They may touch or hug the other children too much, chatter on and on, not notice irritation in the

[1]Ibid. p. 261

voice of others, and, therefore, both peer relations as well as response to adults can be erroneous, causing problems. The child needs explicit training in the facial and vocal patterns of emotion. The teacher needs to point out facial features and vocal patterns that indicate emotions, such as sad, mad, glad, with explicit verbal labeling and explicit verbal rehearsal of social situations. Teachers have a very important role in helping these children learn social skills.

The hyperactive child may or may not have academic learning disabilities, but he does have social learning problems, is impulsive and has a short attention span. These kinds of learning disabilities are with him twenty-four hours of the day and home and school must work together. These children must have supervision and support because their most basic characteristic is not being overly restless but that they cannot organize their activities without help. If someone will be the monitor and attention focuser for them, they are capable of a good many things. Learning the "do's and don't's" of life is very difficult for them. They respond to what attracts them and is of interest rather than to social regulation. They are inconsistent because one day they can do something and the next day they can't. They lack the self control to remain at a task if it is not catching their attention. These problems are neurologically based. A large part of the nervous system is devoted to the processes of control, selective inhibition, selective attention and organization of responses.

These children need "people power." A warm supportive, "cheerleader" kind of supervision"[1] according to Dr. Denckla. It takes time, effort, a firm and positive attitude on the part of parents and teachers who must be the supervisor, organizer, monitor and the attention focuser. "The issues here are those of learning how to live in a society with other people."[2]

> I would argue that the whole concept of mainstreaming is meaningless if we continue to insist that poorly organized children go in and out of resource rooms that, when compared to an old-fashioned self-contained classroom, are almost like Grand Central Station. We are demanding navigational and organizational skills from the very children who lack such skills.[3]

Even mild deviations in the central nervous system can cause problems. These problems often show up as difficulty with handwriting and most always as difficulty working under the pressure of time. This type of child cannot be fast, neat and accurate all at the same time. The simple common sense solution, and one often overlooked by teachers, is to give either less work or more time.

> MBD is a collection of hints, clues, hypotheses and circumstantial evidence which point, "This way to the brain." In truth, what we have to offer education is the outstretched hand. . . in the spirit of "let us try this out together."[4]

Dr. Richard A. Gardner, M.D., a practicing child psychiatrist wrote <u>MBD, The Family Book About Minimal Brain Dysfunction</u>. The first part is for parents and the second part

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[1]Ibid. p. 264 [2]Ibid. p. 265

[3]Ibid. p. 226 [4]Ibid. p. 253

for boys and girls to read or have read to them. Dr. Gardner feels that the MBD child needs to know what is wrong with him and to know that he can be helped; that his defects are in certain areas but that he can improve. Being truthful with the child can alleviate much fear, distrust and many emotional problems that these children face from being different. Discussions between parents and child, parent-child-teacher, and parent-child-doctor helps to reduce additional psychological problems that add to the child's physical problems.

Following is a list of some of the signs and symptoms of organic impairments. No one child will have all of these problems, but the ones present will depend on which areas of the brain has been affected. It takes a cluster of these signs to diagnose MBD.

Neurological Signs and Symptoms of M.B.D.

Developmental Lag-
late in sitting, standing, walking, talking, etc., muscle coordination slow to develop

Difficulty in communications-
using "up" for "down", etc., counting, naming colors, reading problems

Marked and continuous hyperactivity-
restless, did not cuddle, colic, hypertalkative, repetitive actions, practically continuous fidgeting, can't sit still, hyper-reflexes

Distractability or poor attention span-
hard to distinguish between important vs. unimportant stimuli, noise interrupting and disrupting instructions, inner thoughts dominate, often called day dreamers, visual confusion when looking at a page of words, needs short sessions of concentrated learning

Coordination problems-
poor handwriting, throwing a ball, riding a bicycle, running, poor copying of geometric figures

Perceptual problems-
these interfere with learning but usually are not due to

poor visual sight per se but due to fine visual discrimination problems, figures are rotated, fragmented, angular, etc., reversals and mirror images persist longer than normal, trouble with depth perception, spatial relationships, distinguishing the foreground from the background, can't find the hidden object in a picture or word-within-a-word

Auditory perceptual problems-
again this is fine discrimination-such as between cook and crook, putting sounds together to form words or taking them apart, remembering what he has heard, lag in repeating series of numbers, problems with rhythmic patterns

Tactile perceptual problems-
discriminating between larger, smaller, smooth, rough, felt shape of letters with eyes closed

Erratic retention of what is learned-
may not learn from his errors, repeating mistakes

Concepts and abstractions are problems-
does not respond to humor appropriate for his age, mathematical problems, hard for him to understand rules of games

Impulsivity, tantrums, frustration, helplessness, bed-wetting, repetitive speech habits

Right or left handedness and footedness not strongly established

> Everything possible must be done to enhance your child's learning because many of his psychological problems are significantly related to his learning disability. In educating such children the exact nature and extent of the neurological impairment, especially in perceptual areas, must be determined. Attempts should be made to educate him primarily through his intact or better functioning sensory systems.[1]

Dr. Gardner discusses some parental reactions and then some adoptive reactions of the child. In the section on "Reactions To The Learning Impairment," he cautions again to tell the child that only a small part of his brain is not functioning properly but the rest of him is fine. It may take him a little longer and he may have to work a little harder

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[1]Richard Gardner, MBD, The Family Book About Minimal Brain Dysfunction (New York: Jason Aronson, Inc.), 1973. p. 30

to learn but he is not worthless and can improve. Dr. Gardner thinks these children should be in classes with children with similar problems. Mainstreaming the child, taking him out of the regular class for special instruction in certain academic areas can "mortify" such a child. "With it they not only must face the painful comparison with normal peers throughout most of the day; but in addition, when they are singled out to leave the room for special instruction they suffer further humiliation."[1]

The second part of Dr. Gardner's book is written for the child to read. It concerns the nature of brain dysfunction and how the child can help himself. The language is on an elementary level. He has used many pictures to effectively illustrate the text.

Contrasting retarded with MBD, Dr. Gardner emphasizes that retarded children learn <u>most</u> things more slowly while MBD children learn <u>some</u> things more slowly, some things at an average rate and some things faster than other children. The dysfunction is usually only in one or two areas and actually the MBD child is sometimes extremely intelligent and leads the class academically.

In her chapter on "Hurt Brains: Who is Normal," Marilyn Ferguson says "It is a hard blow to one's self-image to realize how fragile is our claim to normalcy."[2] It is estimated that one-fourth of the population is predisposed

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[1] Ibid. p. 53 [2] Ferguson, p. 171

to schizophrenia; one-fourth is prone to flicker fits, as many as one-half can be driven to seizures under certain circunstances. There are probably a million people who are undiagnosed temporal-lobe epileptics; millions of alcoholics and people who are hyperkinetic, or who are senile. As many as one-tenth of the population have dysrhythmic EEGs.

These problems are due to a number of factors: genetic predisposition, birth trauma, meningitis, high fevers in childhood, head injuries, hormone imbalance, unconsciousness, lack of oxygen supply to the brain, focal epilepsies and disease as well as purely psychological causes. Focal epilepsies are the most common kind, more common than either grand mal or petit mal according to a Boston team of neurologist and psychiatrists studying abnormal behavior in relation to brain dysfunction. Dr. Frank Ervin heads this team. The other members are neurologists from Boston General Hospital and Massachusetts General Hospital.

Hyperkinesis affects millions of children, including all ability levels. It seriously impairs their learning abilities because of their inability to concentrate, their uncontrolled activity and their low tolerance for frustration. Calming techniques such as meditation and brainwave or biofeedback training have been found to help many of these hyperkinetic people.

Memory is divided into two spheres, long-term and short-term. Raw information coming into the brain through the senses must be evaluated and analyzed. Much incoming information is dismissed immediately but some is kept in short-term memory. Another selection process is made and what is kept is put into long-term memory. When we concentrate on remembering something we are really trying to keep the information in short-term memory long enough for it to make the transition or implantation to long-term memory.

Storage for long-term memory is widely distributed throughout the brain but its implanting mechanism is located in the hippocampus. Karl Lashley spent his career trying to locate a special region for memory, but what he really discovered is that memory does not have a specific region. He ablated brains of living animals, removing progressively larger sections, but as long as they lived and had even a small portion left (for example the visual cortex) they could still remember how to carry out tasks they had previously learned.

That stores for memory are widely diffused throughout the brain was discovered by Lashley, but there is one specialized area that contains the necessary neural implanting processes. This area is the hippocampus, located under the temporal lobe, inside the temple area of the head in both hemispheres. Again this was discovered through brain diseased or damaged patients. For a brief time in the early 1950s, neurosurgeons removed parts or all of the mid-brain structure called the hippocampus to control severe epilepsy. The operation was soon stopped because of the tragic and unexpected results. H. M. an American, who had the operation in 1953 at the age of 27 is the most famous case. His case has been followed closely. He lost the ability to store information in long-term memory. His personality was not changed and he can remember his life up until the operation, but since then he has lived on an hour-to-hour basis. He is unable to recognize people he meets or to recall having met them before. He cannot remember a new home address which the family moved to after the operation, even after he had lived there a number of years, he would read the same magazine over and over without remembering he had already read it, or would work the same puzzle over and over with no improvement or memory of having worked it before. Yet, H. M. still could do well on short-term memory tests and his I.Q. score actually went up about 15 points, probably because of the decreased severity and frequency of epileptic seizures.

Through long term study of H. M. another surprising development was that he could learn and remember mirror drawing and other non-verbal motor skills. So the hippocampus did not play as decisive a part in the acquisition and long-term memory of motor skills. It was also found through these and other studies on similar patients that music could be remembered, even simple lyrics. Tactile information and visual configuration are two more areas that do not seem to require an intact, well-functioning hippocampus for long term memory.

That memory has a time related component has been determined from people who experience retrograde amnesia from getting hit on the head and losing consciousness. They cannot remember what happened to them for a few minutes to a few hours before the trauma. Donald Hebb advanced the theory of a consolidation period during which time the events or information input must remain essentially undisturbed if it is to be stored permanently. This theory has been supported by results of psychiatric patients being given electroconvulsive shock treatments which causes a similar type of retrograde amnesia. The older memories begin returning first followed by more recent ones. But there is a short period of time just preceding the shock, that the patient never remembers.

The time element of memory can also be observed in memory retrievals or remembering. We cannot always immediately remember what we are attempting to remember, or put another way, we cannot always retrieve a particular item of information on a moments notice. It usually takes a few minutes and sometimes a few hours, days or weeks. Associations help lessen the time required to retrieve a memory. When the inability to retrieve a memory is associated with a personal problem it is usually called a repressed memory or a memory dissociation. Furst says,

> Above all else, cases of memory dissociation point to the fact that what we regard as our enduring, personal conscious idenity, or self, is strongly tied to a body of

> past memories. Memory binds one's past to one's present and so gives us a sense of idenity. Memory links waking consciousness in the morning to the consciousness which was extinguished the night before. The etymology of the word "mind" embellishes the point. In Middle English, "mynd" meant something like "remembering."
>
> Just as through memory, your present is linked with your past, so through planning, your present is linked to your future.[1]

According to Rose, memories are the records of our experiences and without them, if they are lost, a person is not himself. It is the memory of experiences which distinguished one person from another. Certain types of amnesia cause the person to lose all his conscious recollection or memory and that person is no longer the same as he was before amnesia.

The stage between input of experiences and storage into memory banks is called learning and it is a process. When the memory is called upon to compare new input of experience with a stored memory of experience, the process is known as recall or remembering. In order to move from input of experiential sensation to memory to recall implies that something physically happens in the brain. It has been called memory trace, engram or mnemon, all referring to a thing, as opposed to a process such as learning or recall. A third process is called forgetting when a memory cannot be recalled. Another factor in memory is the modification by subsequent experience. Insight is the term used "where a response is the result of the understanding of new relationships."[2]

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[1] Furst, Origins of Mind, p. 180

[2] Rose, Conscious Brain, p. 234

There are special cells in special parts of the brain that store particular memories. ". . . essentially, . . . learning represents the opening of new functional pathways within the brain."[1] Learning, the process of storing memories, "can be detected neurophysiologically, biochemically and anatomically."[2] It takes time to learn anything, usually several trials before the new pathway is established, the exception being the "burnt-child-dreads-the-fire principle."[3]

Short-term memory is the name used to describe things we remember for only a few minutes or hours before we forget them. One aspect of short-term memory which neurophysiologists are currently directing their research is the relation of the electrical processes and habituation. Habituation is explained by the example of a person putting on clothing, being aware of how it feels for a short time then not feeling it. The sensations of fabric against the skin gradually disappear, they fail to generate a response. This is both behavorial and psysiological phenomenon.

Anatomically, short-term memory seems to be located at a different site in the brain than long-term memory. Patients with damage to the hippocampus have trouble memorizing tasks and some cannot remember anything from the time of the damage to the present. However, they still remember things processed and stored before the damage. E. N. Sokolov and

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[1] Ibid. p. 235 [2] Ibid. p. 238

[3] Ibid.

Olga Vinogradova, neurophysiologists in Moscow, have recorded the behavior of individual cells in the hippocampus. Some fire in response to a new stimulus only, others can count and some can remember. Rose says, "Clearly cells with such properties. . . could have an information-processing and short-term storage role."[1]

Both neurophysiological and neuroanatomical studies have shown changes in the synapse structure, both electrical and in size after learning experiences. Brian Cragg, doing electron micrograph studies, has shown change in both size and number of synapse structures.[2] Rose found changes in the protein synthesis. Bennet and Rosengwieg found evidence of synaptic thickening (reported elsewhere in this paper).

We learn only because heredity has provided us with programs in our brains that enable us to do so. We even learn how to learn, but the power to learn varies between individuals. At all times the child is acting out its own life in the immediate present-not preparing for some undiscernable future. . . . meeting his own emotional and physical needs may be at all stages actually a requirement of maturation.[3]

> To a biologist. . . The memory of a person or animal is something that is constructed and grows, the result of a unique series of experiences and actions from conception

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[1]Ibid. p. 243 [2]Ibid. p. 247

[3]J. Z. Young, Programs of the Brain, Based on the Gifford Lectures, 1975-77 (Oxford, Eng., Oxford Univ. Press, (1978) p. 76

> onwards. It can be added to but never wholly remade."[1]
> . . . .
> An animal or man will only learn if he tries to do things. . . . whatever the memory is, it is certainly a part of an action system.[2]

Anne Triesman of Oxford University feels that the rate information is processed and registered in our minds is not always the same. The processes or strategies that the brain uses to select what it will attend to, and what it plans to do about it, are varied. Triesman points out two kinds of situations. One is where we are trying to focus attention on one thing and exclude the distractions. The other is where we are dividing our attention, or trying to, between two or more things. Dividing attention is possible only if there is time to switch attention back and forth, for apparently we can think clearly about only one set of information in a given instant. Broadbent feels man can normally make the switch only about once a second.

> Attention is the bit of machinery which decides from moment-to-moment what it is we're going to notice and therefore what we shall do. . . None of us can take in at the same time everything that is striking our eyes and ears. There seems to be a kind of filter inside the head which protects the central systems against being overloaded [3]

comments Donald Broadbent of the British government's Applied Psychology Research Unit at Cambridge.

Dr. Jackson Beatty of the U.C.L.A. Department of Psychology and Brain Research Institution wrote the Chapter on

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[1]Ibid. p. 79 [2]Ibid. p. 81

[3]Calder, Mind of Man, p. 28

"Activation and Attention" in <u>The Human Brain</u>.[1] In his introduction to the Chapter he says, "By understanding something about the physical basis of attention, the educator may be able to adapt instructional procedures to minimize attentional problems in education."[2]

The term activation refers to brain mechanisms that control the arousal of behavior and it is a physiological concept. The functions of information processing by the higher cortical areas depend upon the activating and integrating functions of the brainstem core. The brainstem activating system is often referred to as the reticular activating system or the R-complex system. Advances made in the fields of neurophysiology, neuroanatomy, neuropsychology and physiological psychology began to reveal the brain systems that mediate behavior. That the reticular system serves to help regulate brain activation was first discovered by Morizze and Magoun in 1949.

Beatty uses two experimental approaches that are concerned with the relation of attention and brain activation. One approach investigates the peripheral signs in activation that occur during cognitive processing. The changes that occur in the nervous system appear in the peripheral portions, especially in the autonomic portions of the nervous system. One of the best indicators of activation of the autonomic system, in the peripheral system, is the movement of the

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[1]Whittrock, et at., The Human Brain, p. 63 [2]Ibid.

pupils of the eye. Since the early 1920s it has been recognized that the pupil of the eye widens during information processing. This widening of the pupil, called dilation, can be observed under conditions of ordinary constant light. In the last few years these processes and their relationships have been studied in more detail.

> The <u>activation theory of intensive attention proposes</u> that cognitive processes require specificable amounts of intensive attention or "mental effort" for their execution and that the momentary level of effort involved is reflected in momentary increases in brain activation, which may be measured by appropriate physiological techniques (Kahneman, 1973). . . . The idea is that cognitive functions can be characterized by their information processing load. . . and that this processing load can be measured by the momentary level of task-induced activation (Kahneman and Beatty, 1966).[1]

According to Beatty this hypothesis is supported by a variety of lines of experimental evidence, his own as well as others. He says that "These dilations occur with great reliability, indicating that the activation changes that they reflect are a constant accompaniment of perceptual processing."[2] Even in experiments with music, the listener's judgement of what he heard could be predicted from 66 to 92 percent of the time by his pupillary dilation alone. Larger dilations occur for problem solving involving processing more difficult material and for the storage of such material in the memory. Similar activation patterns occur when a person tries to retrieve material from his memory and organize it for an immediate serial report.

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[1] Ibid. p. 68 [2] Ibid. p. 70

Sustained attention is another of the areas of present research. Sustained attention is required for prolonged tasks, especially monotonous ones. The research tasks involved in these experiments have been termed "vigilance" task because the assumption is that performance becomes limited due to a decline in nervous system "vigilance" or activation. There is a reasonable amount of evidence to support this theory, much of it accumulated in experiments in which a person performs such tasks for prolonged periods of time. To Beatty ". . . it is clear that brain activation mechanisms and behavioral attention processes are intimately related. The task is to explore more deeply and to clarify more exactly the nature of these relationships."[1]

It is known that the brainstem net is actively involved in the process of attention but not how decisions of attention are made. This is one of the most important aspects of mental functions that remain to be explained and one that is extremely important to educators.

The brain stem, reticular formation is the anatomical name, is the stalk-like mass of cells running from the top of the spine into the middle of the brain, the core of which contains a fine net of inter-connected cells. It monitors all the nerves connecting body and brain. The reticular formation sends out impulses which stimulate or inhibit nerve action through the entire body, including the brain

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[1] Ibid. p. 82

itself. It provides the selecting mechanism of attention by regulating signals from all the sense organs.

In 1949, Giuseppe Moruzzi and Horace Magoun at Northwestern University in Illinois, showed that brain stem signals were necessary to keep the top of the brain active and awake. Donald Hebb at Montreal in 1949-1950 suggested, and was proven correct, that insufficient information coming into the brain from the senses could produce emotional disturbances. Hebb moved to McGill University as Chancellor and there some of his students began investigating the effects of sensory deprivation. These and subsequent experiments clearly show that the brain must have continuous sensory input to remain alert and healthy. <u>The brain must have information just as the body must have food</u>. Man is not the only animal to seek out new sights and information, labeled curiosity.

Hebb suggests that the brain must have mild excitement to operate its most efficient, but that when too much excitement produces intense emotion, the person can no longer cope with it and efficiency falls off. "Blind with rage" and "rigid with fear" are not just fanciful expressions, they indicate too much excitement, so parts of the brain "shut down", become less efficient.[1]

Timothy J. Teyler, both M.D. and Ph.D. is an Associate Professor of Neurobiology in the College of Medicine at Northwestern Ohio University. Dr. Teyler says, "Learning

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[1] Calder, Mind of Man, p. 34

implies a relatively permanent alteration of behavior as a result of experience."[1] The brain has special areas for learning special or certain types of things and disruption or lesions in these areas result in learning difficulties while other areas of the brain do not seem to be involved in the learning process. He says, "Many areas of the brain do show neural changes associated with behavioral learning."[2]

> For some brain researchers, the acquisition of special influences of one neuron on another across a synapse, presumably by chemical change, is the whole secret of the brain's ability to learn by experience. . . cells that have cooperated frequently in the past are likely to go on doing so.[3]
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> Donald Hebb. . . stated the idea. . . as a "neurophysiological potulate" as follows. When cell A repeatedly or persistently takes part in firing cell B, "some growth process or metabolic change takes place in one or both cells that A's efficiency, as one of the cells firing B, is increased."[4]

Any particular experience stimulates many sensory nerves and the brain immediately starts making comparisons from the incoming sensory signals. Inferences and deductions of what is happening and decisions as to what action to take then are made by the brain. The more experiences a person has, the more comparisons he can make, which will influence the number of alternatives he has for making decisions. The more often a person has the same experience, the more "automatic" the decisions become.

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[1]NSSE, Education and the Brain, p. 24

[2]Ibid. p. 25

[3]Calder, Mind of Man, p. 142 [4]Ibid. p. 131

The way Young describes the brain operations in problem solving is essentially the scientific method. In thinking about problems the routines involve "first identifying a goal or end and then choosing a method"[1] for attaining it. Next we explore a number of possibilities, testing to see which will advance us nearer our goal, or aim, or end. We continually check back for references. This is a special operation and many parts of the brain may be used, some in "parallel". Brain injury in various parts of the brain interrupts this process of problem solving and interrupts it at different points depending upon where the injury is located. The first stage of solving a problem is recognition of the problem and motivation to try to solve it. Lesions deep in the brain or in the frontal lobes distrubs this goal-seeking capacity. People with such lesions, given a written problem, will simply restate the problem not recognizing it as a problem nor realizing they have made a mistake.

The second stage of solving a problem is to identify its components and conditions, using restraint while waiting for them all to be realized. People with frontal lobe lesions impulsively give fragmentary answers because they do not have this capacity for restraint and waiting.

The third stage is to select the best strategy from a number of possibilities for solving the problem. We try to identify the problem with some other similar or familiar

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[1] Young, Programs of Brain, p. 199

situation. This selection process is impaired in people with left parieto-occipital lesions. The problem is recognized and the person is motivated to solve it, but he cannot put the parts together correctly to achieve a solution. These people are often unable to recognize when the problem or task is complete and will continue helplessly and without a plan.

The final stage of problem solving involves choosing an answer, checking and comparing it with the existing conditions then deciding if it is correct. People with either too little motivation or inability to identify correct solutions usually fail to take the necessary steps. Since many areas of the brain are interacting throughout the entire problem solving task the sequence is not quite so simple. The act of thinking is a serial activity. It is the fitting of pieces, things, together to form a pattern and reconciling it with the model we already have in the brain.

> Every act of perception is an act of thinking. . . . So we can at least begin to describe how the brain operates in thinking. The process involves the motivation for search and exploration, including functions of the frontal lobes, the perceptions of the sensory cortex, the study of relations by the association cortex, and the satisfactions of achievement, that are linked ultimately with those live promoting activities of the hypothalamous and reticular system that are at the center of all consciousness.[1]

Programs or innate mechanisms in the brain "have to be set in operation through action and experience in using them."[2] Evidence also points to the conception that "learning

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[1] Ibid. p. 204 [2] Calder, Mind of Man, p. 220

consists largely of selection among the many possible pathways in the brain."[1] We learn by choosing between or interacting with a number of possibilities. Young says,

> Our traditional methods of education seem to depend so much on instruction that many people find it hard to understand how selection could have produced all the wonders of living form. . . . the acquisition of the wonderful powers of our brains, such as language, depend upon selection of certain pathways at critical times and the loss of others.[2]

Calder puts it this way,

> . . . the development of a particular mental faculty often depends upon a coincidence. The brain must be ripe and the appropriate event must occur in the environment. . . . definite events become due at particular periods when our brains are ripe for certain crucial kinds of interaction with the environment, and particular stages in our development are reached.[3]

Young says,

> As more is learned of these processes of selection of pathways at critical or sensitive periods this point of view should help to resolve many old problems of nature and nurture. Even more important--it should provide a factual basis for deciding when, how and what to teach to children.[4]
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> . . . .
>
> Until recently it was not understood that organisms contain standards and that their actions are adjusted until each standard is met. In this sense the ends or aims are indeed the "causes" of living actions.[5]
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> . . . .
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> Life depends upon choice among various possibilities. All living things must choose. Human beings have a greater number of possibilities of action than any other creature and therefore the widest burden or privilege of choice.[6]
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> . . . .

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[1] Young, Programs of the Brain, p. 26   [2] Ibid.

[3] Calder, Mind of Man, p. 220-221

[4] Young, Programs of the Brain, p. 264

[5] Ibid. p. 16   [6] Ibid. p. 20

The basic system of connections laid down before birth by heredity determine what may be called pre-programs. Some of these provide for immediate needs such as for breathing and sucking. But a great number of other systems of connection are pre-programmed for social life.[1]

. . . .

The human way of life is essentially social. To get the things needed to keep alive we cooperate with other people. This requires special programs of the brain and the whole pattern of human lives is organized around social activities. The sequence of human development, early helplessness, long childhood, late adolescense and long adult life, is designed to allow the brain to develop and to acquire and use a set of programs for the skills of a social life.[2]

For each of our senses there is an area of the brain that receives the initial information. These areas are laid out like maps in a "topographically precise way on the surface of the brain. They encode the incoming messages, each set or channel of cells responding to a particular item, then combining and recombining, making selections and sending their information on to other areas for more processing.

In reviewing the development and maturational stages of children, Young says, "It is worthwhile to examine the changes that take place, and for educational theory it is fundamental. . . . evidently the use to which the brain is put fundamentally influences its later development.[4]

In his chapter "The Generative Processes of Memory" in the book The Human Brain, Dr. M. C. Wittrock begins with a historical overview of methods for learning and memory

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[1]Ibid. p. 264 [2]Ibid. p. 25

[3]Ibid. p. 52 [4]Ibid. p. 74 (my italic)

advocated by leading philosophers, educators and orators beginning with the ancient Greeks. The vast majority of these systems for learning and remembering consisted of using imagery. After the Renaissance, however, the use of imagery declined. There has been a renewal of interest in imagery due to findings from recent research on the brain and how it learns. Wittrock, who is a professor of educational psychology in the Graduate School of Education at the University of California in Los Angeles, says that in America from 1900 to about 1950 the "behavorists directed research away from cognitive processes, such as thinking, attention, memory and imagery."[1] The emphasis was on verbal and motor behavior, as instruments to learning and memory, through practice for the hope of reward and reinforcement. This was known formally as S-R or stimulus-response method. But recently there has been a shift to research on attention, motivation and imagery as components of learning and how it is retained and retrieved. The findings of the researchers studying lateralization of the brain have also contributed to this renewed interest in learning, "Their findings. . . have fundamental significance for understanding human learning and memory."[2]

Wittrock summarizes work done by Allan Paivio in 1971 in describing the results of studies on imagery. There are three techniques in imagery that help facilitate recall or

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[1]Wittrock, et al., Human Brain, p. 169

[2]Ibid. p. 170

memory. One way is to instruct the learner to "image" the information and to form image interactions involving two or more of the words or ideas to be remembered. Another, the use of high-image or concrete words produces a sizable gain in recall and third, the use of pictures. Wittrock paraphrases Paivio as writing "imagery is the single most important variable determing free recall."[1]

Several experiments involving the use of imagery with school-children have been conducted at UCLA. One such study was conducted to learn if kinetic mulecular theory could be taught to kindergarterners and primary children by using pictures and concrete examples with simple verbal explanations. These studies were done by Keislar and McNeil in 1962 and Wittrock in 1963. Colored drawings done by artists were used to explain molecules in motion, matter and the status of matter. The children were given from two to four weeks of instructions. The verbal descriptions were taught using imagery that was both concrete and familiar to the child. A year later two-thirds of the children remembered the concepts taught. A number of other studies have confirmed these findings.

Bull and Wittrock did a study on word definition with elementary school-children using three different procedures. The first procedure was to read and write the material (verbal).

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[1]Ibid. p. 170 (taken from Allan Paivio, Imagery and Verbal Processes, New York: Holt, Rinehart and Winston, 1971)

The second was to read and trace a given picture (verbal and image), and the third procedure consisted of reading and then to draw their own pictorial representation (verbal and self-generated image). They found the best recall in the reverse order. Generating one's own image produced the best results following by tracing the given image. Least effective was to read and write only.

Using creative writing, that is generating one's own story from a list of words, was also very effective. Two groups were given list of words to be remembered; the control group remembered 14 percent whereas the group that wrote their own story using the words recalled 93 percent. Other studies have confirmed these results. These studies show that the kind of informational processing is important. Self-generative processing increases retention greatly, usually doubling it, even when no logical order or grouping patterns were discovered.

Wittrock has developed what he calls the generative hypothesis which "interprets learning primarily as the construction of concrete, specific verbal and imaginal associations, using one's prior experience as part of the context for the construction."[1] He thinks that school learning should be reconceived on this basis, that teaching "is the process of organizing and relating new information to the learners previous experience,"[2] that it is more than stimulus-response, reinforcement reward.

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[1] Ibid. p. 173 [2] Ibid. p. 177

CHAPTER VI

SELECTED RESEARCH FROM THE

NEUROSCIENCES ON THE ARTS AND

OTHER EDUCATIONAL IMPLICATIONS

Young devotes Chapter 20 in Programs of the Brain to the arts. He entitles it "Enjoying, playing and creating." "Art and religion are surely among the most truly characteristic human activity."[1]. . . belief and creative art are essential and universal features of all human life. They are not mere peripheral luxury activities.

Our reward system is continuously searching for satisfaction and pleasure. We often hardly notice the routine of our daily lives but let something unusual or interesting happen and we are quickly on the alert. This occurs because our reticular activating system keeps the sensory system alert. "Many of our actions . . . involve continual search by the eyes, ears, nose and brain for items of interest or satisfaction." We try to fit these items into our expectations

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[1]Young, Programs of the Brain, p. 231

that we have developed through personal experience. Works of art signify that this process is functioning properly, by confirming our expectations, such as naturalistic art and well-known music; and providing new stimuli to arouse new interest and perceptions, such as cubist art, or emotions and thought raised by good poetry or novels.

> "This is why I say that for human societies the creative aesthetic activities are among the most important things we do . . . <u>The creation and satisfaction of art</u> include and symbolize both our individual acts of perception and the expression to others of what we perceive. <u>These are the very brain actions that give us the powers of communication by which we obtain all the rest</u>, food, shelter, sex and social life."[1]

Design, symmetry, balance, symbolism enter into the production and choice of almost everything around us and everybody has some feelings for these aspects of objects, though they may not realize it. Young contends that works of art epitomize and bring forth the basic features of our life programs and leads us into new features that had gone unrecognized. He says one ambition of those who think about life is "to learn how to combine exact thinking with the symbolism that satisfies emotion,"[2] and he believes "study of the brain can help us to find an answer that will satisfy both the philosopher and the artist."[3] To be able to combine logic with metaphor and to understand the relationship of these two kinds of truth. Art helps us do that, which is one of its values.

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[1]Ibid. p. 233 (my italic) [2]Ibid.

[3]Ibid. p. 235

Reading, pictures, music, can help us understand the relationship of exact description and symbolic representation. In looking at a picture, or hearing music, we often ask ourselves what is it saying to me, do I like the feelings it evokes, do I understand what the work of art is about and if not, why not? If we think about such questions we can learn what is involved in communication, coding, perceiving, abstracting. We examine the nature of reality, which comes to us entirely by coded signals which are then interpreted by our emotions. In the most general sense the artist helps us with our perceptions which we are always creating. The artist extends our way of seeing, hearing, thinking. We live in two realities, outside in space and inside within us and art brings them together, it lies at the heart of our being, through art man's inner reality becomes inscribed in outer reality. The artist brings the mystery of the two to our attention.

> Once we realize that the brain itself works all the time with arbitrary symbols we begin to understand how all works of art can be understood. They are symbols, in spoken words, or on canvas, or in musical sound that somehow correspond to the code of the symbolism of the brain. That code is partly innate, but also largely learned.[1]

Man makes and uses symbols all the time. These take the form of words, numbers or objects. Whatever he makes reflects the needs and thoughts within. Paleolithic man drew animals for much of his thinking went into hunting game which met his bodily needs of food, clothing and sometimes shelter as

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[1]Ibid. p. 238

well as ornaments for his body. In order to hunt, he had to think and speak of game so it was natural that he would "write" draw aspects of the hunt. When a person's brain is full of thoughts of sex and violence, that is what he puts in his works of art. "Representation, like thought is a substitute for reality. . . . after all the meaning of 'imagination' is the making of an image."[1]

People who live in rich urban communities show a preference for more complex art forms whereas people from rural or small communities usually prefer simpler art forms. That this would be so is rather obvious when one considers the information intake and the degree of arousal. In the cities our senses are bombarded with information so it takes more, or a higher level of stimuli for arousal whereas with rural people who lead a simpler life high stimulation is too much. It just does not take as strong a stimuli for the "simple life" person. The most common preference of people in general is for moderate complexity as opposed to the very simple or very elaborate. "They like variety, but also regularity, symmetry and continuity of line."[2] But much of the appeal of any work of art depends upon its symbolic evocations of emotions towards some person, place, thing or activity. Some symbolic preferences have universal and timeless appeal such as the golden mean, a ration of 1:2; angles represent activity while flowing curves represent tranquility; sorrow, joy and

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[1]Ibid. p. 239 [2]Ibid. p. 242

marching have distinct patterns in music; in color red is hot and slow while blue is cold and fast. "By playing upon these and many other responses artists have stimulated and assisted mankind in many ways over the centuries."[1]

The human brain program is especially attracted and sensitive to the human image. A relatively large portion of the underside of the cortex on both sides is devoted to human form perception. This is why an immense number of people worship or give respect to visual images such as the Virgin Mary, the Crucification or idols in some non-Christian societies.

There are areas in the brain that are especially concerned with music. They lie around those in the temporal lobe that are responsible for hearing. They are mainly on the right side whereas those concerned with speech are on the left. Music, the most abstract of all the arts, exists only to be enjoyed and almost all people, normal people, that is, respond to it; it suggests and portrays, it is sensuous rather than factual, it produces a symbolic emotional response. All art forms try to introduce us to new ways of perceiving and feeling, to new levels of understanding.

Playing is also an art form. It has some common features with the other art forms. Both are self-rewarding but can also be enjoyed by others at the same time, they both express the need for surprise and for change. They are both

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[1] Ibid. p. 243

pleasant which relates them to one of the fundamental aims of life and they are symbolic of life, they are important components of the homostatic system. Play introduces us to social life and allows us to experiment in socialization. It is not only pleasant, but also interesting, creative and helps our learning processes. One of its special features is that it is not restricted to childhood.

Young feels "we are surely lucky to have brain system, that urge us on to continue to look and listen, to play, to experiment, to inquire, to imagine and construct and to find satisfaction in what we have made or discovered."[1] Colors, planes, textures and forms both naturalistic and abstract, fit with our visual systems just as music fits with our auditory system. These systems can be developed to become more aware and more discriminating in their choices as we learn the new codes and extend our concepts. In the early 1900s Einstein extended our concept of space just as Braque and Picasso extended our concept of vision, to see things from several directions at a time, to go beyond what the camera sees. Our brain programs already do this for us all the time. The eye needs to see only a fragment or a few lines of many objects to recognize them. We can recognize a familiar person by a number of fragmentary clues such as the back of their head, the sound of their voice, then we can reconstruct an image of the entire face and body in our brain. Humans

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[1]Ibid. p. 246

need to have objects, including buildings, around them that suit their brain programs. In turn their brain programs are influenced by what they see. Visual design is extremely important for they are significant symbols for everybody. Architects often teach us to enjoy new sights and symbols by breaking old conventions. But, Young thinks, there are some architects who ignore the importance of visual design and symbolism. They say they are only concerned with the functional aspects "not understanding that <u>the most important function activities of the human brain are symbolic</u>."[1] Because we are compelled to view buildings around us, the architect has a special responsibility. Young closes the chapter on the arts by stating,

> . . . A proper understanding of the brain shows <u>the cultivation of the arts is of profound practical and emotional importance</u>. The artist arouses needs and satisfies them. His work is not an impractical luxury, but is closer than that of any other labourer to meeting the continuing long-term needs of man. <u>We are all symbol-creating creatures by the very working of our brains.</u> Art assures us that our activities are proceeding satisfactorily, it <u>symbolizes the central fact that life is worth living</u>.[2]

Young discusses the place of value judgements in our hereditary "programs." He feels that they relate closely to the pleasure centers of the brain and have "fundamental consequences for philosophy and pratical affairs."[3] The pleasure centers influence our ideas, aims and actions.

We know now that they are basically regulated by the

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[1]Ibid. p. 250 [2]Ibid. p. 250 (my italic)

[3]Ibid. p. 140

organization and activities of certain parts of the brain, . . . decisions about values spring from the efforts to meet needs. Value judgements are statements about what is good and what people ought to do. . . . Value statements are practical, while purely factual statements are theoretical. . . the origins of human beliefs just as the origins of our desires and fears . . . are all the products of our human nature.

Jack Fincher puts athletics and art together in chapter five of his book Human Intelligence. Both activities are usually considered "non-intellectual" as if the brain had no control over them. Both art and athletics are predominantly contolled by the non-verbal parts of our brain, the right hemisphere, the limbic and reticular activating systems with the exception of creative writing which attempts to balance the symbols of words and imagery. "The more creative the writing, the more right-hemisphere the mental investment,"[2] says Fincher. But even in the most abstract right-hemisphere produced works of art or athletic ability, there is a left-hemisphere component of sequencing and analyzation at some stage. Both hemispheres make a contribution, although one may contribute more than the other at any given point in time, and they must work together. Fincher says,

> . . . "It isn't enough to recognize talent when it surfaces. For the good of society and the self we have to go out and find it, or at least create optimum conditions for it to emerge." . . .[3]

Nigel Calder sums up from his research

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[1]Ibid. p. 140

[2]Fincher, Human Ingelligence, p. 138

[3]Ibid. p. 123

> The I.Q. is primarily a measure of "convergent thinking," roughly the ability to learn or deduce correct answers to questions in contrast with "divergent thinking," the ability to discover and invent. These different abilities may be found to a marked degree in the same talented individual, but not necessarily so; many people with high I.Q.'s have scarcely a spark of originality in them.[1]
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> . . . .
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> The artist uses his brain to modify reality with an imaginative vision. We say. . . that the simplest processes of visual perception involve the formation of abstract "models" in our minds, that the same machinery is used by the "mind's eye", and that the raw material of the models can be reprocessed to produce completely new ideas. . .[2]
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> Knowledge about the brain is growing and inevitably this brings changes in the way we speak about ourselves.[3]

Dr. Joseph E. Bogan, M.D., is a neurosurgeon at the Ross-Loos Medical Group in Los Angeles and associate clinical professor of neuro-surgery at The University of Southern California School of Medicine. He discusses the educational implications from recent brain research, how it can help improve education. He suggests that education should stimulate development of brain processes. He says that <u>what we know now about the brain</u> "<u>bears directly upon everyday pedagogical practice</u>."[4] We now know that each cerebral hemisphere is capable of functioning independent and in a different manner from the other. Each side has functions that are specialized in it but at the same time interacts somewhat with functions from the other side. In this sense the brain is double, we do two

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[1] Calder, Mind of Man, p. 210

[2] Ibid. pp. 212-213

[3] Young, <u>Programs of the Brain</u>, p. 267

[4] Wittrock, et at., <u>Human Brain</u>, p. 135 (my italic)

types of thinking and information processing. This is new information to apply to an ancient problem--the dichotomous nature of knowing. Bogan lists in a table a number (about 50) of students of the mind who have come to the same conclusion "that we commonly employ two different _kinds of intelligence or modes of knowing or_. . . _sets of information-processing rules_."[1] These people have labeled these two processes in different terms but what is important is not the different terms but the fact that so many discovered two types of thought.

Bogan quotes Sri Aurobindo, a yogic philosopher of India writing in 1910, discussing education and the two types of thinking. Aurobindo says both are essential to the completeness of human reason, they are important functions that must be raised to their highest level of power if the education of the child is to be complete and not one-sided and imperfect. It is now quite clear each hemisphere has its own special type of information processing and which hemisphere is dominant is dependent upon the nature of the task.

> Since education is effective only insofar as it affects the working of the brain, we can see that an elementary school program narrowly restricted to reading, writing and arithmetic will educate mainly one hemisphere, leaving half of an individual's high-level potential unschooled.

Bogan illustrates the point by referring to the popular term _culturally disadvantaged_, which refers to people whose left

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[1] Ibid. p. 134 [2] Ibid. pp. 141-143

hemisphere powers have not been adequately developed from lack of relevant exposure. He says people who have not had the right hemisphers powers developed are in a similar position. He says it is clear that "the extent to which capacities are developed is dependent upon environmental exposure."[1] Many cultures remain nonliterate, not using the full left hemisphere capabilities. Our own society seems to be right-hemisphere illiterate. Bogan caracterizes it as "<u>a scholastized, post-Gutenberg-industralized, computer-happy exaggeration of the Graeco-Roman penchant for propositionizing</u>."[2] On the use of I.Q. tests, much of this testing is biased toward abilities more useful in the classroom than real life, even though the usual justification is that by predicting scholastic achievement we can predict life success. Bogan asks what is meant by "success", how is it measured, and by whose standards and where is the concern for the quality of human existence? He quotes Stanley (1971) who did a review of the Scholastic Aptitude Tests and its prediction of success. Stanley says of 1000 eight-year-old boys with an I.Q. of 90 there will be not one Ph.D. level mathematician or Shakespearian scholar. "Why not a sculptor, singer, painter, poet or politician?"[3] asks Bogan. He says many are concerned with sensitivity as well as rationality, with making a life as well as living, and "It is time we learn to live within nature as bilaterally

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[1]Ibid. p. 145 [2]Ibid. p. 145 (my italic)

[3]Ibid. p. 146

educated, whole persons."[1] As an example of this new aesthetic thinking the <u>Journal of the American Medical Association</u> uses pictures and paintings on its cover and the <u>Journal of Neurosurgery</u> has been using arty covers since 1970, as opposed to title only or the table of contents on the cover.

Giving equal time to each hemisphere is "saving from neglect a cognitive potential as important for high-level problem solving as language skills."[2] It is not just enrichment as is often termed. "On the one hand, our belief that hemispheric specialization tends to be process-specific rather than material-specific suggests that subject matter may be less important than its method of presentation."[3] More laboratory and field-experience are needed for right hemisphere developement. Where subject matter does make a difference is in the increased effectiveness of left-hemisphere functions through increased right hemisphere development because of the interaction between the two. Some activities are typically bihemispheric such as symphonic orchestration.

> It may be a principle virtue of these more recent findings about the brain not only to serve as scientific support for a more diversified curriculum, and not only to provide some direction for this diversification, but also to stimulate a new set of questions for those who will pilot the future of education. We have a few new landmarks; hopefully they will help us to steer a better course.[4]

In the last part of <u>Education and the Brain</u>, Jeanne

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[1]Ibid. p. 146 [2]Ibid. p. 148

[3]Ibid. [4]Ibid. p. 149

Chall and Allan Mirsky combine their effors to identify and comment upon the more forceful themes form the neuroscientist writing the previous chapters. The neuroscientist point out to educators that _education is central for maximum brain development_. _Environment and experience are central for the growth and development of the brain and this is the main area education needs to be concerned with_. Educators also need to be aware of the physical aspects of what we call the psychological process in learning: attention, cognition, motivation, language and behavior.

Through education, many people with neurological dysfunctions and deficiencies can be helped provided they are given proper stimulation and practice. Proper stimulation and practice also helps the neurologically healthy to realize greater potentials. "Because of this strong relationship between the brain and the stimulation it is given, many of the authors state directly that collaboration of educators and brain scientists in research and practice is essential."[1]

From the literature on lateralization there emerges at least two areas with implications for education. First, students with weak left-hemisphere processing (academic skills) need to have these areas strengthened through utilization of right-hemisphere processing. Second, right brained children who are weak in academic skills need more right brained activities such as music, art (especially constructions), dance

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[1] NSSE, _Education and Brain_, p. 372

and drama in which they can excell and find a sense of self-worth. The usual remedial work is still left-brained and only leads to more frustration and failure. These suggestions merit serious study and controlled experimental tryouts.

The brain is a constantly growing, changing plastic organ that requires knowledge, vigilance and care from the teachers, but it also opens the door for much greater opportunities in teaching-learning. The teacher, above all, needs to know about these changes and the various approaches to learning. Collaboration between neuroscientists and teachers is a must. Neurological theories need to be tested in the classroom and problems from the classroom need to be related back to the neuroscientists. Chall and Mirsky say "Conceivably, a new specialty of educational neuroscientist, or educational neuropsychology could emerge and would combine both kinds of expertise."[1] The educational neuroscientist would be called upon to accurately assess the child's developmental stage, strengths and weakness, talents, strongest mode of processing information, and any neurological problems. The teacher, equipped with this information could then plan the teaching program best suited for optimal educational efficiency-rather than set an arbitrary class average, teach to that level, and hope the child "gets it." " . . . it should help in the development of a pedagogical effort and program designed on the basis of how <u>each</u> child is growing and

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[1]Ibid. p. 377

maturing, on each child's talents and weaknesses, and not on the basis of an average, normative set of values that fits any single pupil in only a loose way."[1]

On the implications for teaching from the recent research on the brain, Dr. M. C. Wittrock emphasizes three. First, that educators need to understand the multiple processing systems of the brain and devise methods to facilitate their use and interaction. Second, that this research gives us a better understanding of a wide range of reading/learning problems and should help in the development of new diagnostic test. Third, this research suggests we need new concepts about subject matter and the methods of presentation. For example, pictures can be used both imaginal and verbal-semantic by having the learner verbally describe the picture. "The important point," Wittrock says, "is that the treatment must be understood in terms of the types of processing of information it stimulates."[2]

In the summary of his chapter, Wittrock says that teaching methods "should be designed to stimulate students actively to construct meaning from their experience rather than stimulating them to reproduce the knowledge of others without relating that knowledge to their own experience."[3]

Kenneth M. Heilman, a professor of neurology, says

I believe an understanding of the neuro-psychological

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[1]Ibid. p. 378

[2]Wittrock, et al., <u>Human Brain</u>, p. 180 [3]Ibid.

> processes underlying behavior is essential for teachers. Learning disorders are common problems, and understanding how the brain works has helped investigators develop theories and investigate paradigms that will uncover the pathophysiology of these problems. . . . an understanding of the brain mechanisms underlying language may also enable educators to develop educational methods that best use the innate capabilities of language-processing systems of both normal and abnormal children and adults.[1]

Commenting on the use of knowledge of their own self's physiological status Barbara B. Brown, a pioneer of bio-feedback, says

> One of the most constructive future use of bio-feedback may be in education. . . . They might, for example, learn the physiologic patterns accompanying concentration, thereby setting the groundwork to learn to concentrate all the more effectively.
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> A simple but very meaningful use of a bio-feedback technique could be in conjunction with teaching machines. It is well known that the attention span of children is short. An accurate indicator of the length of each span of attention would be useful in maximizing the use of the teaching machine. The display screen of the teaching machine might, for example, be capable of changing color: greenish for periods when the child's attention level is high-a go-ahead signal; and reddish for periods when attention begins to wander-a stop signal. The color of the screen would be controlled by two basic brain wave patterns, the "alert" EEG associated with high attention levels, and the "nonalert" EEG pattern associated with non-attention. Similarly, physical and mental attitudes more suitable for learning could be learned more readily as well as improvement of their attention span by their own violition.[1]

Dr. A. R. Luria says,

> . . . It is the work of the brain as an apparatus organizing human mental activity which is of the greatest interest, and which must be of the most immediate concern

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[1] NSSE, Education and Brain, p. 143

[2] Barbara B. Brown, New Mind, New Body, Bio-Feedback: New Directions for the Mind. Bantam Books (New York: Harper & Row, Pub., Inc., 1974, Bantam ed. 1975 2nd printing)

to the philosopher and psychologist, the teacher and physician.[1]

[1] Luria, Working Brain, p. 342 (my italic)

CHAPTER VII

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The recent advances in neuro-scientific research have revealed new knowledge about the brain's structure, how it grows and how it functions. It has also revealed many new areas for further research, raised many new questions and begun to answer old philosophical questions. The brain is beginning to study and know itself.

The basic structure of the brain is determined by genetics, but what happens to its development is determined by the environment in which it lives. Environmental influences actually begin before birth, during the development of the fetus and continues until death. Nutrition and drugs are two powerful pre-natal influences that neuroscientists now know will profoundly affect the developing brain and nervous system. The general health and mental attituded of the mother are also known to be factors influencing the developing fetus.

When birth takes place, the environment which the individual is in becomes the primary influencing factor to further development since all the neural cells are already present.

Experience, which cannot be separated from the environment, has been shown to be so vitally important that certain brain cells will not develop if there is a lack of the proper kinds of experiences that they need for development. Conversely, with enriched experiences the brain cells seem to develop even beyond the average expectations. This has been determined by the neuroscientist working with both animals and people. It has been shown with rats and cats that sensor cells not only fail to develop but actually disintegrate and disappear if they do not receive the necessary stimulation. Newborn babies that received extra sensory stimulation learn tasks faster than the controls. Babies and toddlers, whose parents have below normal intelligence and would therefore have a greater genetic tendency toward low intelligence, prove to develop normal and above normal intelligence when they are put in a special nursery school designed to give them extra stimulation through experience that they would not receive at home.

The brain does not grow at a constant rate. It has growth spurts at which time enrichment experiences seem to have greater effect. During the growth spurts the brain enlarges and gains weight due to changes made within the cells.

New connections between neuronal cells and synapse formations are made more rapidly, making experiences more meaningful. The growth spurts are from three to ten months, two to four years of age, six to eight years of age, ten to twelve years of age, fourteen to sixteen years of age and possibly in the early twenties. Certain abilities and thinking processes develop during particular growth spurts. The time between the spurts seems to be a period in which consolidation and refinement of the newly learned abilities takes place. This knowledge raises many questions concerning the most appropriate time for introducing new concepts to students and when it is best to work on more routine memory tasks.

A person needs a large base of experiences in order that many neural network connections can be formed. The lack of experience or the improper balance of experiences can have a drastic effect, on the developing brain's intellectual capacity.

The brain is capable of healing itself to some extent after damage. Several determining factors include the state of brain development, size and location of damage and the age of the person at the time of damage. Children usually heal faster and better than an adult with corresponding damage, although it is not always as easy to tell exactly when the damage occurred in a child. Damage, along with dysfunction and difference or organization, can be determined by both neurological and behavioral signs and symptoms. The younger the person is when damage occurs usually means less disruption of functions but may cause functional disruptions later in life. Some educational difficulties are due to earlier brain damage. Early detection and proper intervention are extremely important to insure maximum recovery of functions by undamaged portions of the brain.

There are specialized regions in the brain for various functions and abilities. Secondary and tertiary areas add special features to the primary areas. These areas operate together to form a functional network. Damage anywhere in the network will cause some kind of problem even it the primary ability is spared.

The brain appears to be bilaterally symmetrical but functions are not distributed alike in both hemispheres. Language is primarily localized in the left hemisphere. Musical abilities are primarily localized in the right hemisphere. Damage to certain areas of the right side can leave the person without tone or rhythm to their voice. Although damage to the left side may leave a person unable to speak, the person usually can still sing and can oftentimes communicate by song if he is taught to put his information with a familiar tune.

The right hemisphere is the primary location for visual-spatial relationships which also are factors in the reading and mathematical abilities of the left hemisphere. Artistic abilities are also right hemisphere functions even though they may be executed through the left side's writing-drawing abilities. The two hemispheres exchange information, each adding its own particular specialized contribution to a given ability.

That the two hemispheres do indeed work together is shown in patients that have had commissurotomies; the separating of the two hemispheres of the cortex by surgically severing the corpus callosum which relays messages between them. These people become two minds in one body, many times one mind not knowing what the other one is doing or thinking. The side of the brain with the primary specialized area for the task at hand takes over and, although there are missing aspects, a casual observer might not at first recognize that there is a problem. The left side is mostly verbal and the right side mostly non-verbal but each side has a rich mental life of its own as well as complimenting the other sides functions.

Each half of the brain also has its own way of processing information. The left side uses the sequential, linear, analytical, logical, rational approach. The right side uses the holistic, intuitive, spontaneous, integrational and relational approach. The right side responds to the immediate, the left can mediate a response. The left is time dependent, the right time independent.

People with frontal lobe damage have a difficult time, if not impossible, trying to plan, and then to work through a number of actions systematically toward a goal. It is difficult for them to master an occupational therapy task which may be due to the localization of secondary motor control in the frontal lobes. Voluntary control is also impaired. During mental task electrical activity becomes synchronous across the frontal lobes. All of these observations and tests have led to the belief by neuroscientists that the frontal lobes are involved with problem-solving programming and planning of activities. This is an indicaiton of how various areas of the brain, working together, contribute to the whole of our abilities. Newly devised techniques of measuring blood flow during mental functioning, projecting the result via computer on a screen, now enables us to actually "see" different brain areas functioning simultaneously during a given task.

Neurologists are beginning to take note of developmental lag, difference in organization and dysfunction as well as disease and damage. When any one of these problems exist, even to a minimum degree, it causes the person to have problems in relating to his environment. Many educational problems that are now considered behavioral only are actually neurologically based, but they project themselves as behavior problems. Dyslexia and other learning disabilities have a neurological cause and teachers must take these into consideration if the student is going to progress. Children are now labeled MBD for minimum brain damage and are sometimes put into special classes or schools. However, there are many children in regular classrooms that have MBD syndromes, especially if the "d" is expanded to include the other categories of dysfunction, developmental lag and difference of organization. These children usually have normal intelligence and many are actually above average in some academic areas. They do need more training on the social-emotional consequences of their actions because they fail to perceive emotions in others, especially subtle emotions. They need hands-on, experiential type of learning activities.

Developmental lag, to the neurologist means slow to develop. Although the regular phases of development are gone through and fully achieved it is at a much slower pace. These children sit, walk, talk and develop other muscle controls at a later age than the average child. When these children start school they learn slower but what they learn is retained as well and sometimes better than their faster, "smarter", peers. They are not less capable if given the proper amount of time they need to master a skill; but in today's school they tend to get left behind then left out, therefore never having the opportunity to develop their potential abilities.

Memories are our personal records of our experiences which makes each person unique. It is not known at this time exactly where in the brain memories are stored, they seem to be widely diffused, but a few of the processes necessary for storage are known. The primary area for implanting memories is located in the hippocampus. Both long and short term memories seem to go through this area. An event must be held in the hippocampus for a short time, hence the name short term memory. The time held varies from a few minutes to a few days. Then it is transferred to long term memory if it is to be kept. People with damage to the hippocampus have difficulty storing information in their long term memory banks although they have no trouble remembering what was stored before the damage occurred. The amount of difficulty is related to the extent the hippocampus was damaged.

Remembering, or retrieval of a memory, is another area of memory the neurologists are investigating. A person is not always able to retrieve the memory he is searching for, especially at a moment's notice or if he is under tension or stress. This means there is a time element related to memory retrieval as well as memory implantation. Associations have been found to help reduce the time required to retrieve a memory. Pictorial associations, especially self-generated ones have long been used to help improve memory, which indicate they help in the implanting process also.

Information processing, storage and retrieval by the higher cortical areas all depend upon activating the brainstem core, known as the reticular activating system or R-complex. Attention is the term usually used to indicate mental activation. There are other peripheral signs that appear, especially in the autonomic nervous system. Eyes dilate or widen, heart rate increases, sensory systems become alert which are all controlled by the autonomic nervous system. The degree of activation of the R-complex is determined by the attention to the task at hand. Prolonged tasks require sustained attention. Signals from the R-complex are necessary in order to keep the cortex awake and active. The brain must have continuous sensory input to remain alert. It operates its most efficiently during mild excitement. Too much excitement can produce intense emotional reactions in the R-complex system so that the brain can not operate as efficiently. It will tend to "shut down" its operation and the person becomes nervous, rigid with fear, blind with rage or blacks out. The reticular activating system, the R-complex, keeps the sensory system alert. Sensory information is "food" for the brain.

Art, in all of its forms, feeds sensory information into our reticular activating system, alerting and focusing our attention, signifying that our mental processes are functioning, providing new stimuli to arouse new perceptions and interest. Art is symbolic, a creation of the brain as a means of communication and reward. Art is based upon perceiving, abstracting, coding and communicating, which is what our brain is designed to do. Art blends the inside world of our mind in our brain and the outside world in which we live.

Special areas of the brain are devoted to various art forms such as music, human form perception, spatial relationships. There are cells especially designed for color, shape and line. That this is true has been determined by working with brain damaged patients. That creativity is predominantly a right hemisphere function was discovered by close observation and testing of people with right side damage. Most of our methods of communication have a right-side component which, if damaged, can affect their effectiveness and efficiency.

The right-hemisphere's functions and contributions are so important that many neuroscientists are calling for educators to become aware of the workings of the brain. They say education has only been developing left hemisphere functions. Also, educators are unaware of many neurological signs and symptoms that affect learning. Only by becoming knowledgeable about the neurological aspects of learning can educators give the person the kinds of experiences, proper stimulation and practice that will enable their brain to develop fully. Many of the neuroscientists are stating directly that collaboration between the brain scientist and the educators is essential. What they have discovered and are discovering has enormous implications for educational philosophy and practice. Much of the future research needs to be done in the classroom based upon actual educational procedures rather than in laboratories. Philosophies and practices need to be based upon these findings. Only then can education be said to develop the whole child. Neuroscientists are pointing out to educators that education is central for maximum brain development.

Conclusions

The first hypothesis was that the findings from the selected research on brain development and functions do relate to education. The conclusion is that some of these research findings do in fact relate to education. It has been found by neuro-research that the brain must have experiences in order to grow and develop. The more experiences that a person has leads to the development of more synaptic connections between the neural cells, therefore creating a greater capacity for intelligence. If a person is deprived of sensory experience it affects his mental functioning.

It has been found that the left and right hemispheres of the brain process information in different modes. The left hemisphere processes information in a linear, logical, sequential, analytical, rational manner. The right hemisphere processes information in a holistic, pictoral, intuitive, spontaneous and relational manner. Each hemisphere makes a contribution to the functions of the other hemisphere. People process incoming information primarily in either left or right hemispheres before sending the information to the other one and getting its contribution to the process. How information is processed in relation to mode of processing required has a determining factor on how much is understood or retained. Ideally, information should be presented so both hemispheres can make their maximum contribution; especially when the person predominantly processes all information via the right hemisphere. More synaptic connections are formed in areas that receive exercise through experiences.

The question then becomes one of what or which environment will foster the greatest development. How do we nurture the infant, the child, the young adult, so that he will reach his native potential? How do we determine what is the limit of an individual's native potential? These and other similar questions have begun to be answered by the neuroscientist.

Since the brain is the organ of the body which contains the mind and since education is for the purpose of imparting information to the mind, any research that sheds light upon the brain and its functions should be of vital interest to education.

The second hypothesis was that educators should be aware of those findings from the neuroscientific research. The conclusion to the second hypothesis is that educators should be aware of the findings from the neuroscientific research.

Educators should be aware of the stages of brain development for certain functions so that the necessary subject matter for the full development of that function be introduced at the proper time. As well as normal brain development, the educator needs to determine both developmental lag and acceleration. Both lag and acceleration can be only in certain subject areas or it can be global. These determinations are vital to the student. Curriculum needs to be introduced at a slower or faster pace than average. Experiential needs of the students may be different depending on development. Subject matter and the way it is presented should be determined by both the developmental level and the developmental speed at which learning takes place.

Knowing that the right hemisphere's functions make a contribution to the left hemisphere's functions, predominantly language and mathematics, allows for the designing of the presentation of subject matter to take advantage of and enhance both hemisphere's contributions. Concrete words are easier to remember because a picture can be associated with them.

Because the brain is plastic, especially in the very young, when damage, disease or dysfunction develop the educator can plan for alternate methods of teaching. Personally, for the educators, knowing it will take longer than usual to teach certain skills due to damage, disease or dysfunction will help them remain confident and not so easily discouraged.

The fact that experience changes the brain, makes it grow additional neuronal connections should be the core of all curriculum development and methods of teaching. The educator must know that he is quite often the cause of a person's failure with a subject as well as his success. Experiences are the building blocks of an intelligent mind. Worthwhile educational experiences are the educator's responsibility.

The third hypothesis was that the neuroscientific research findings do indicate that the arts should be included in education.

Reading, writing and arithmetic are considered the basics in education. Yet each of these functions has an arts related component. Design, spacing and spatial relationships are "basic" components of all three. Letters and numbers are first designed in a certain way and that design must be maintained within the structure of creative change for the letter or number to retain its meaning. A person must learn the basic configuration and be able to recognize it in its many divergent forms even when the form is only fragmentary, in order to "know" what a letter, a number or group of them mean. Drawing pictures are clues to the person's ability to form shapes and lines in his mind and then transpose these to mental functions. It is one of the earliest signs of readiness to read. The child needs experiences in drawing to help him get ready to read. The visual spacial brain cells have been shown to respond to stimuli of the proper configurations or to disintegrate from lack of stimuli. Teaching line, space and geometric form as a stimulant to cell development can be accomplished through the visual arts.

The spatial functions which are predominantly a right hemisphere function are vital in our daily lives. If we cannot picture in our minds the space we move through we get lost and cannot go from point A to point B and back again.

The neuroscientist usually call this ability mapping. Some animals map by smell or sound but humans map by visual sight and internal pictures. The ability to notice detail and especially subtle detail is necessary in order to map ones environment. We must be able to judge color, size, shape, texture, distance, position, direction of objects, match or copy lines, shapes, textures and spaces in order to mentally form the required patterns that have certain meanings. The necessary sensory information comes in by way of both vision and touch. They are the nonverbal coding and decoding components of these functions. The arts are an excellent means of teaching these abilities since the same components are present.

We have brain cells adapted to processing information about color and stimulation of those cells results in increased learning capacities. The research with newborn babies showing increased intellectual abilities following color stimulation indicates that color is important in our mental development. Colorblind people have had damage to the cells that recognize color and they must learn other alternate methods of discrimination to compensate for their loss. Color discrimination is one of our means of survival.

The right hemisphere contributes rhythm and emotional tone in speech. It also contributes the ability to recognize emotional tone in the speech of others. Words, their order and literal meaning comes from the left hemisphere, but the nonverbal aspects of meaning such as tone of voice, facial expression and other body signs come from the right side.

Body image, awareness and orientation in space are mainly right hemisphere functions. Right hemisphere lesions that damage these functions cause problems with self orientation in space and time, perception of space, personality changes and the ability to recognize that there is a problem. The importance of the nonverbal aspects of communication can be developed and enhanced through the arts, especially dance, drama and visual arts.

What the neuroscientific research has shown is that each half of the brain makes important contributions to the functions of the other half, yet education dwells on only a few functions of the left half, mostly ignoring the functions of the right half. The arts are the creation and the mode of thought of the right hemisphere. So it is through the arts that the right hemisphere must be taught. In the process of developing the right side functions we will enhance the left side functions. Only then will educators be teaching the "whole child."

The third hypothesis seems to be true. The findings from the neuroscientific research do indicate that the arts should be included in the educational process.

The fourth hypothesis was that these findings need to be considered in developing a functional philosophy of education.

The brain-mind has begun to develop tools and methods that enable it to understand itself. This has fundamental implications for education. The method and material of education has been determined by beliefs about the mind vs body; the child and his needs for both physical and mental development; what subjects are the most important, when should they be taught and by what method. Now the neuroscientists are beginning to answer some of these fundamental questions. Now educators can base more of their philosophy of education on scientific findings.

One of the major findings is that experience makes the brain develop more fully, increasing the intellectual potential. The brain must have experiences, they are the "food" necessary for development. A sound philosophy of education should include many and varied personal experiences. Nature, the intellect the child is born with, is not enough, it also takes nurture for a person to develop his native capacities.

Another major finding of the neuroscientist is that the right hemisphere has a life of its own. It has a different mode of processing information. It also contributes some functions to the left hemisphere's abilities, just as the left side makes some contributions to the right. This means that for a fully developed mind both hemispheres need to be developed. A sound philosophy of education needs to include subject matter that will help develop the full potential of both hemispheres of the brain. Both left and right modes of processing information need to be considered and methods developed to present subject matter so that it can be processed by both sides.

It has been found by the neuroscientific research that there are optimal times for the development of certain functions. This developmental timing needs to be considered in a philosophy of education.

In the western world formal education has been concerned with a narrowly prescribed set of left hemisphere functions, namely linear, sequential reading, writing, arithmetic, with little attention if any given to other functions of either the left or right. The creative aspects of these left hemisphere functions have been mostly ignored. A philosophy of education should include the creative aspects of all functions of both the left and right hemispheres. Old philosophies of education will need to be re-examined in light of this new knowledge.

The fourth hypothesis is true. The findings from the neuroscientific research do need to be considered in developing a functional philosophy of education.

Recommendations

The recommendations from this research are of two types; first, awareness; second, additional research.

Every educator should be aware of the research by the neuroscientist that relates to education. The findings should be compared with the current philosophies that guide educational practices and procedures. All philosophies of education need to be reviewed in light of these new findings, keeping what has been confirmed, discarding what has been found to not be true and asking questions about what has been neither confirmed nor denied.

A cooperative effort on research of the brain that relates to learning needs to be developed between educators and neuroscientists. There seems to be enough new knowledge in this area for a person to become an educational neurologist. In a few places, usually universities, educators and neurologists are already working together. It is a small beginning that should have tremendous influence upon the future of education.

The brain has already begun to understand what it needs for survival, development and repair. The brain is what education tries to develop. Educators must become aware of all aspects of the brain in order to help people develop a better quality of mental life.

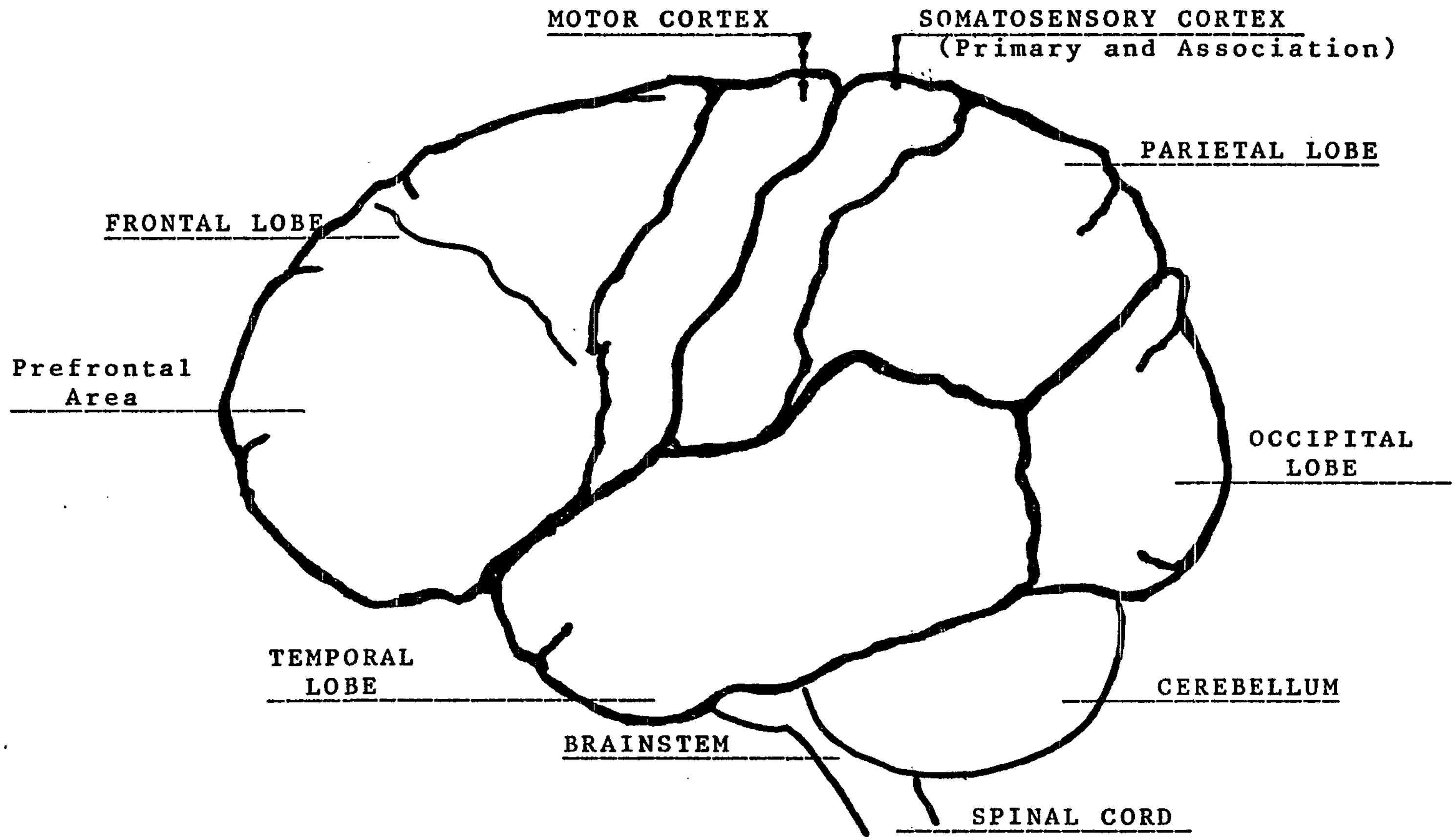

MOTOR CORTEX
SOMATOSENSORY CORTEX
(Primary and Association)
PARIETAL LOBE
FRONTAL LOBE
Prefrontal
Area
OCCIPITAL
LOBE
TEMPORAL
LOBE
CERERELLUM
BRAINSTEM
SPINAL CORD

PLATE I

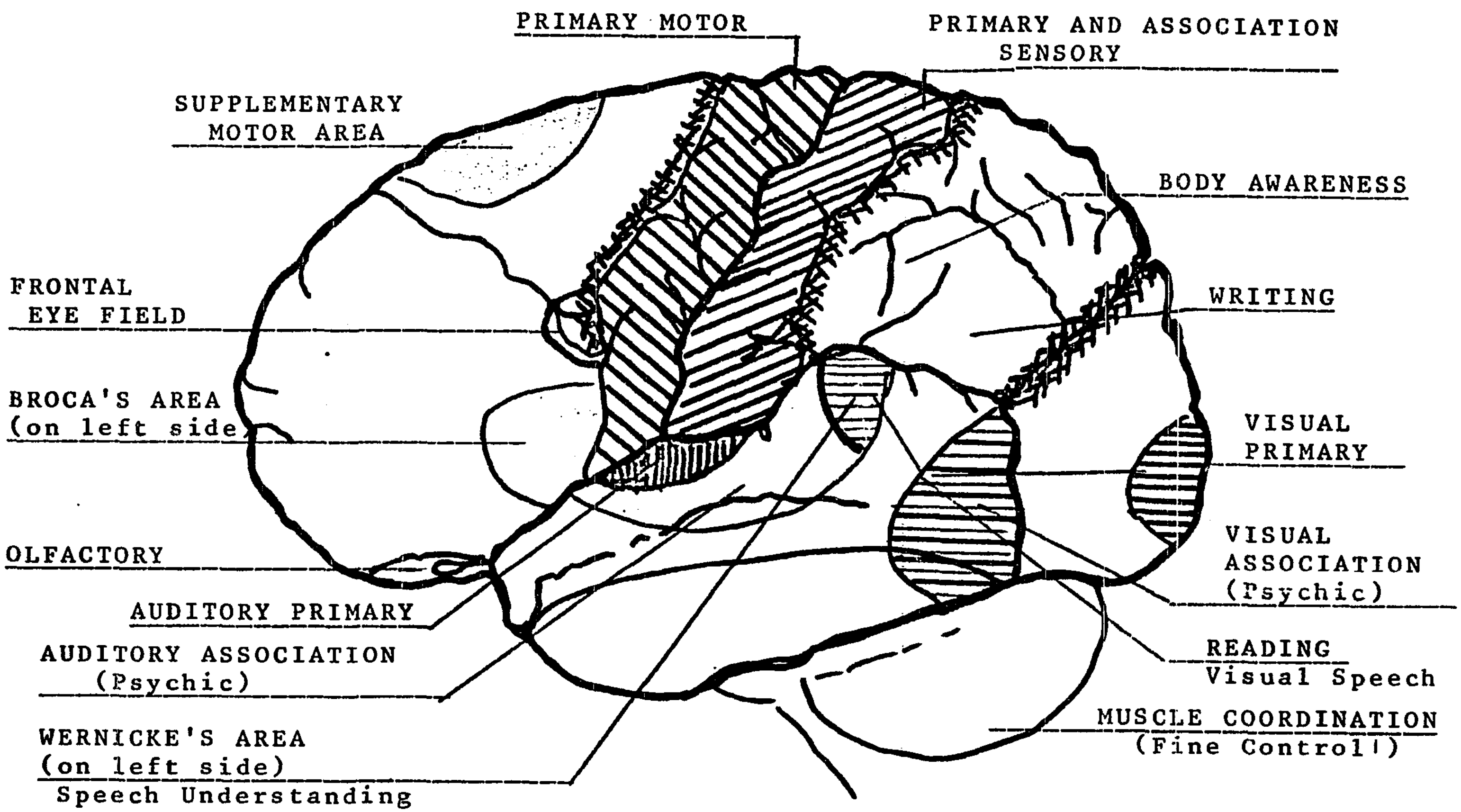
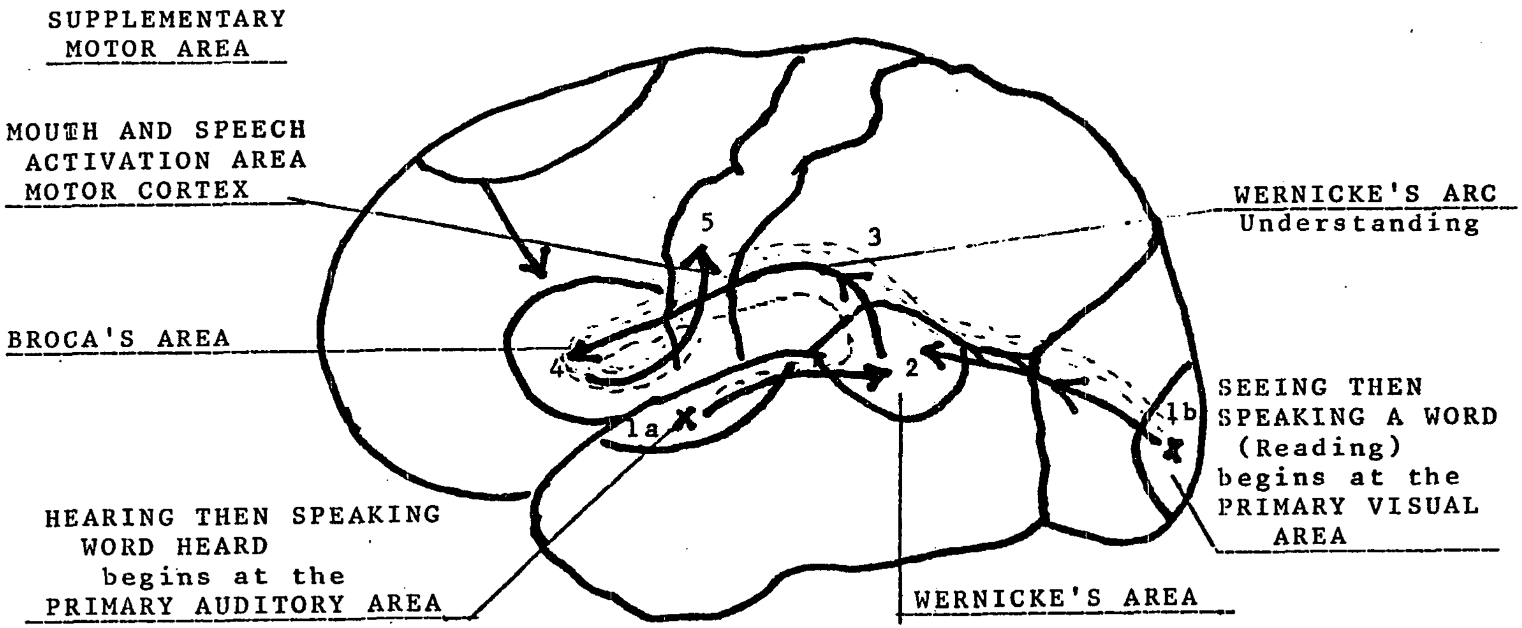
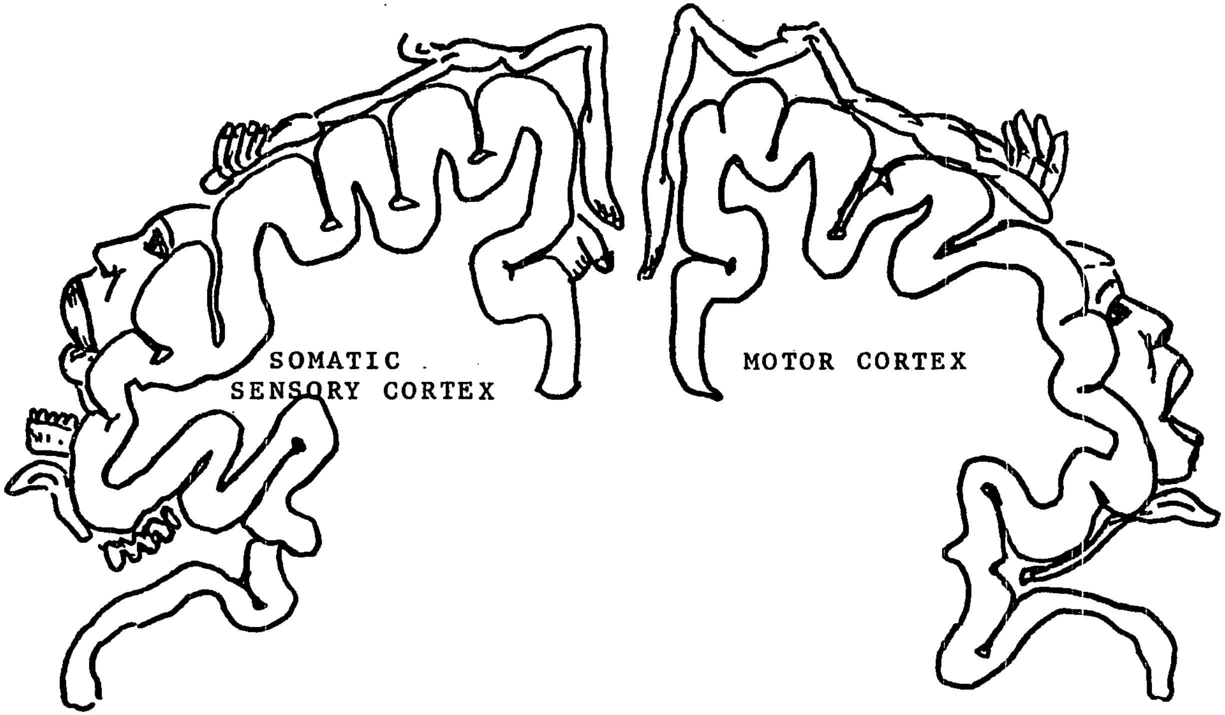

PRIMARY MOTOR
PRIMARY AND ASSOCIATION SENSORY
SUPPLEMENTARY MOTOR AREA
BODY AWARENESS
FRONTAL EYE FIELD
WRITING
BROCA'S AREA (on left side)
VISUAL PRIMARY
VISUAL ASSOCIATION (Psychic)
OLFACTORY
AUDITORY PRIMARY
READING Visual Speech
AUDITORY ASSOCIATION (Psychic)
MUSCLE COORDINATION (Fine Control)
WERNICKE'S AREA (on left side) Speech Understanding

PLATE II



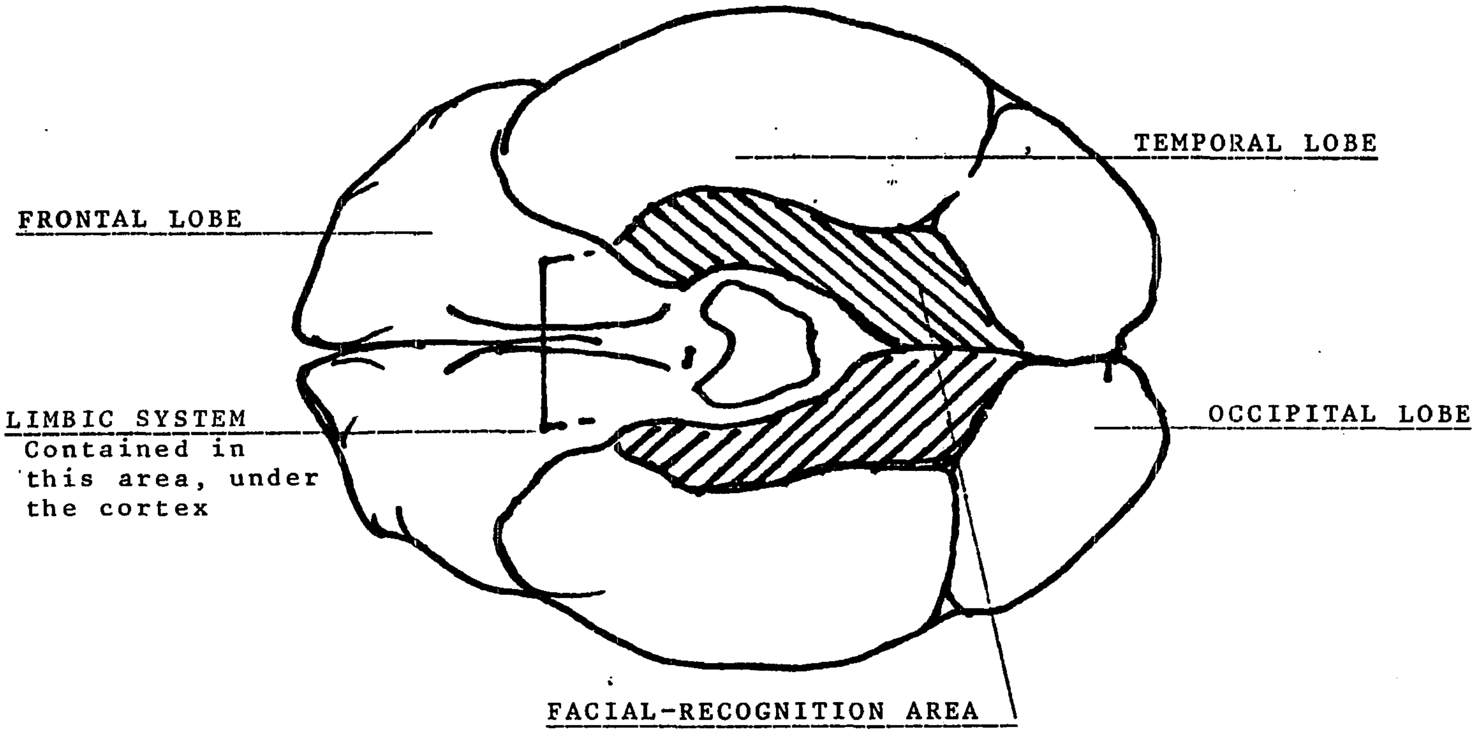
READING AND REPEATING WORDS
SEQUENCE OF ACTIVATION

PLATE III



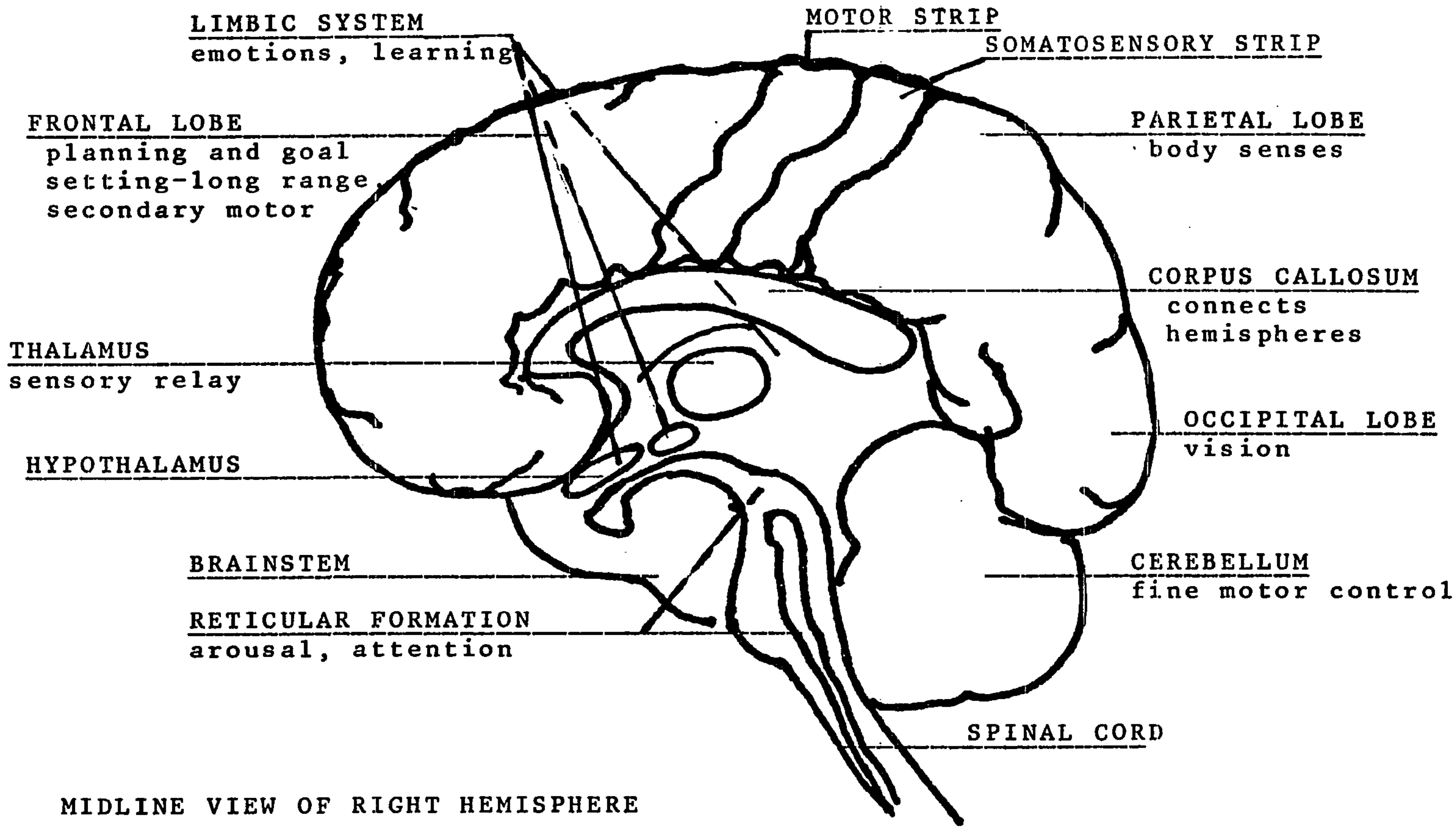
BODY MAPS ON THE CORTEX

PLATE IV



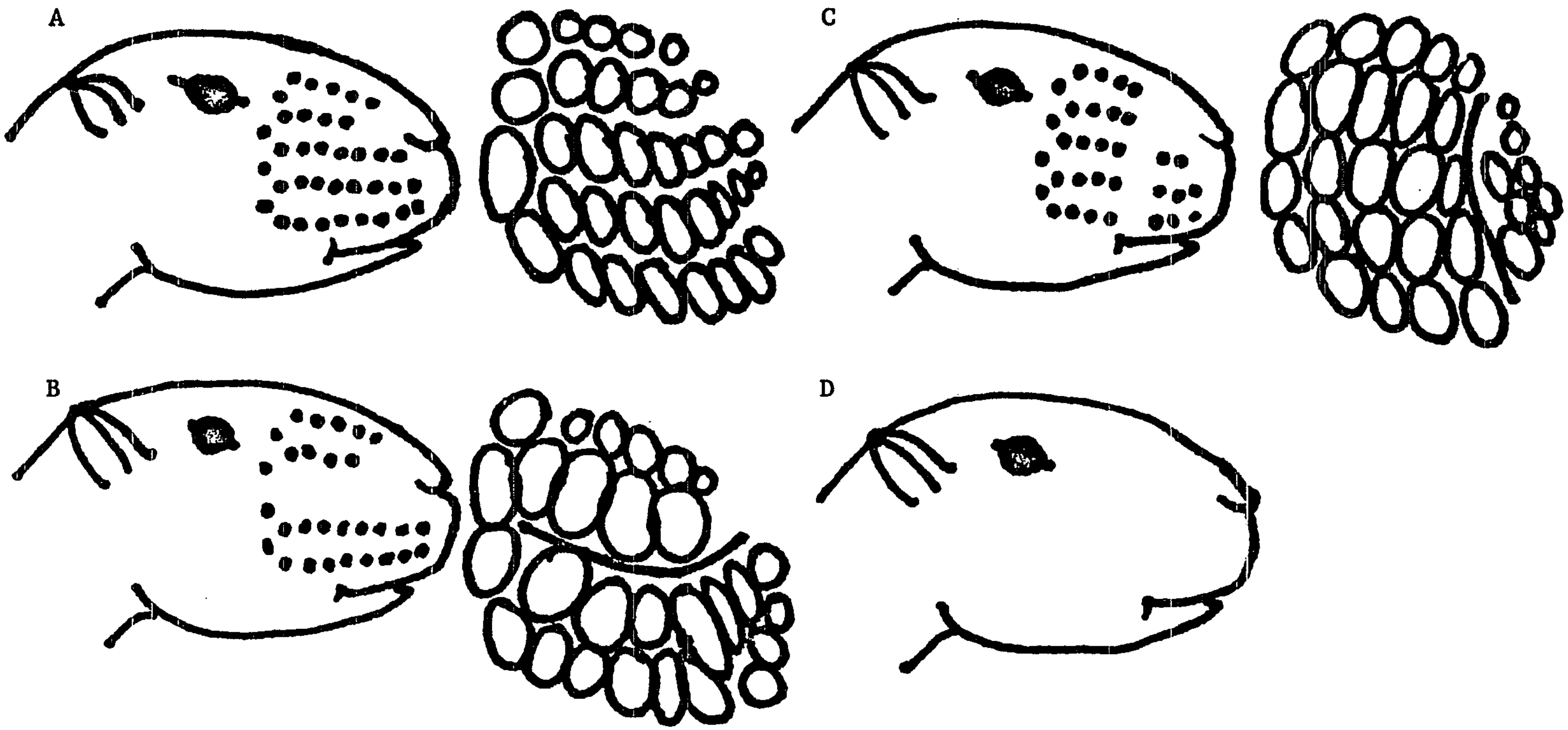
UNDERSIDE VIEW OF CORTEX

PLATE V



MIDLINE VIEW OF RIGHT HEMISPHERE

PLATE VI



GROWTH OF WHISKER SENSORY BARRELS IN CORTEX OF MOUSE

A. Normal Barrel Growth
All Whiskers Present

B. Horizontial Row Missing
Abnormal Barrel Growth

C. Vertical Row Missing
Abnormal Barrel Growth

D. All Wiskers Missing
No Barrels developed

Based on work by
Thomas A. Woolsey

PLATE VII

Washington University
School of Medicine

Glossary

These terms are defined for a layman's understanding of them. Most of these words have more precise scientific definitions.

Agnosia - The inability to interpret sensory input. The sense that is incapacitated is used with the word agnosia, (e.g., visual agnosia, auditory agnosia, etc.)

Amnesia - A loss of memory. This loss can be for a brief period or for all past memories.

Amygdala - A basal part of the brain. It controls aggression and other behavior often termed emotional. Amygdala means almond.

Aphasia - A disorder of the cortex of the central nervous system that impairs the ability to formulate and/or use symbols, usually written or spoken language production and/or comprehension. A disruption of sensory perception does not necessarily occur. The inability to speak correctly is called Broca's Aphasia. The inability to understand what is heard is called Wernicke's Aphasia.

Association Zones or Areas - Regions of the cerebral cortex that are not primary sensory or motor areas but do make a contribution to the adjacent sensory or motor function. They usually are adjacent to the primary area to which they contribute. Sometimes called secondary areas (e.g., secondary visual and auditory association).

Asymmetry (hemispheric) - A term used by neuroscientists to refer to the structural and functional differences between the left and the right hemispheres of the brain.

Autonomic Nervous System (ANS) - A subdivision of the central nervous system which operates without conscious control. It is divided into the sympathetic and parasympathetic nervous systems. It regulates breathing, heart rate, blood pressure, intestinal processes, hormones and other visceral functions. Many of the autonomic functions can come under some conscious and/or emotional control.

Axon - The fiber that carries nerve signals away from the nerve cell body of one neuron to some portion of another neuron. Axons are of various lengths.

Biofeedback - The conscious recognition of the biological signals that are returned to the brain to tell the brain how a particular part of the body is operating. Sometimes machines are used to translate the signals into sensory recognizable symbols in order that the person consciously learns how to recognize and exert some control over a particular bodily function. Biological feedback systems work within the body all the time to maintain its homostasis.

Brainstem - The lower portion of the brain which lies under the forbrain and cerebellum. It is a very complex region that includes among it's functions the carrying of sensory information to the forebrain area, conveying motor commands, regulation of sleep patterns, control of arousal, gross bodily muscle tone, regulating cardiac and respiratory centers.

Broca's Area - An area located in the frontal cortex of the left hemisphere in humans. It's function has to do with the syntactic and phonemic aspects of language. Damage to the area results in jerky, not well-articulated speech although content and meaning are normal.

Central Nervous System (CNS) - The brain and spinal cord. It coordinates all functions and behaviors of the body.

Cerebellum - A highly convoluted structure of the brain that is located behind the brainstem and below the cortex. It is concerned with the fine coordination and timing of movements and seems to play a role in maintaining symmetry between the left and right sides of the body. It is intimately connected to the brainstem and also has close interrelations with the cortex.

Commissure - A compact bundle of axons which originate in neurons from a structure on one side and terminate for the most part in the corresponding structure on the other side of the brain or spinal cord. Commissures carry axons from both left to right and right to left sites enabling the two halves of the system to exchange information and communicate directly with each other.

Commissurotomy - A surgical procedure that cuts the corpus collosum and the anterior commissure of the forebrain so that they can no longer pass electrical messages between the left and right cortexes. This operation was used to help control life-threatening epileptic seizures.

Consciousness - The state of being of the brain in which a person (or animal) is aware of his environment and can voluntarily react to it, experiencing, thinking, planning, reacting.

Corpus Callosum - The large commissure connecting the right and left hemispheres of the cortex. It is located under the midline division of the two hemispheres. When it is severed a large portion of information can no longer be communicated between hemispheres.

Cortex - The multilayered, convoluted tissue which forms the outer surface of the brain. It is divided first into the left and right hemispheres and then into four lobes, the frontal, parietal, temporal and occipital. The lobes are divided into zones that are sensory, motor or associational. It is critically involved in cognitive functions.

Dendrite - The short, branching projections that extend from neuronal cell bodies. They receive messages from other neurons. They are known collectively as the dendritic tree.

Dendritic Tree - A collection of dendrite branches that terminate into a trunk forming a treelike structure on a neuron. A neuron can have several dendritic trees.

Dyslexia - A disorder of the central nervous system in which the recognition and comprehension of written language is impaired.

Eidetic Images - Vivid internal images, both real and imaginary in origin.

Electroencephalogram (EEG) - The recorded pattern of the electrical activity of the cortex; produced by placing electrodes on the scalp.

Enzymes - A protein that acts as a catalyst for chemical processes in the body.

Forebrain - The top, the highest and most important portion of the brain. It includes the cortex, the limbic system, the thalamus and the hypothalamus. The forebrain is most highly developed in humans.

Frontal Lobe - The front or anterior lobe of the cortex, located behind the forehead and temple areas of the skull. It contains both the primary and supplemental motor areas and contributes a major portion of the abilities to plan and carry out a plan of action toward achieving a goal.

Glia, Glial Cell (spelled both ways) - These are glue like cells in the central nervous system. They far outnumber the neurons. It is believed that they provide structural support to neurons, guide the repair and regrowth of damaged axons, and perhaps regulate the chemical neurotransmitters.

Gyrus - The name of the outfolding of the convoluted tissue of the cortex. The major gyri have been given identifying names.

Hippocampus - A part of the limbic system, the hippocampus is shaped like a sea horse and is located on the underside of the forebrain. It is involved in the learning process, particularly long term memory.

Homostasis - A balanced, steady, state of the body and bodily functions which an organism strives to maintain.

Hypothalamus - A structure located at the base of the forebrain. The hypothalamus is involved in the modulating and regulating of eating, drinking, sleeping, sexual activity, aggression and controlling body temperature and hormone secretions.

Lesion - An area of bodily tissue that has been damaged.

Limbic system - A set of interconnected structures of the forebrain, including the amygdala, septum and hippocampus. The system is located in the lower, interior border of the forebrain. It modulates various behaviors such as eating, drinking, aggression, sex, rewards, learning and memory.

Lobectomy - The surgical removal of a lobe of the brain.

Midbrain - The uppermost portion of the brainstem. Its structures are concerned with processes for visual and auditory search and other motor movements. It contains the reticular formation and the hypothalamus. The midbrain structures have widespread and diffuse connections with many other areas of the brain.

Mnemonic - A system of mental devices that helps one to remember information.

Myelin Sheath - The fatty substance covering some axons. It helps to increase the speed of electrical messages along nerve fibers (axons).

Myelinization - The process by which the myelin sheath forms around the axons.

Neurons - Nerve cells found in the nervous system which carry out the activities of the nervous system by processing incoming sensory information, transmitting messages to signal and produce a response. The neuron is the basic functional unit of the nervous system.

Neuroscience - The science or study of the nervous system, its structure compostion and function. A multidisciplinary approach that relates specific scientific studies to the field of neurology. Neurology, neuroanatomy, neurobiology, neurochemistry, neurophysiology and neuropsychology are the basic neurosciences. Some of the other sciences concentrating studies on the nervous system are:

neuroallergy
neuroembryology
neuroendocrinology
neurochematology
neurohistology
neurohypnology
neurolinguistics
neuro-nography
neuronutrition
neuro-opthamology
neuro-otology
neuropathology
neuropediatrics
neuropharmacology
neuropsychiatry
neuropsychopharmacology
neuroradiology
neurosurgery
paleoneurology

Occipital Lobes - The posterior section of the cortex, located at the back of the head, behind the temporal and parietal lobes and above the cerebellum. It contains the primary and associational visual areas.

Parasympathetic Nervous System - One of the two subdivisions of the autonomic nervous system. It increases its activity during periods of rest by causing some bodily functions to slow down.

Parietal Lobe - The region of the cortex located directly behind the frontal lobe and above the posterior end of the temporal lobe. It contains the somatosensory primary and associational areas and is mostly concerned with bodily awareness. It makes a coordinating contribution to language.

Parieto-Occipital - The area of the cortex where the parietal and occipital lobes are adjacent to one another, the upper 1/3 of the back of the brain.

Prosopagnosia - The failure to recognize known people by their faces, even close family members.

Reticular Activating System or Reticular Formation - This system is also known as the R-complex and the RAS. It is a diffuse network of neurons running up through the base of the brain and ending in the midbrain. It's fibers are widespread and have diffuse connections with many regions of the brain. It is primarily concerned with arousal in action and sleep.

Somatic - Pertaining to the trunk of the body as opposed to the head or limbs.

Somatosensory - The part of the cortex that receives and analyzes information from the sense of touch or feel of the skin.

Split-Brain Operation - A common name for commissurotomy.

Sympathetic Nervous System - One of the two subdivisions of the autonomic nervous system. It increases its activity during times of stress or arousal causing the bodily parts required for action to increase their function.

Synapse - A bulb shaped projection from the axons of neuronal cells that transmit chemical and electrical messages between cells.

Synaptic Gap - A space between the two connecting surfaces of a synapse and the adjacent neuronal dendrite or cell body. It is about 1/50,000,000 of a meter across.

Synesthesia - A condition in which one kind of sensory stimulas invokes the sensation of another, such as hearing a sound and visualizing a color.

Synergism - The action of two or more substances, organs or organism to achieve an effect of which each alone is incapable of producing.

Temporal Gyrus - A prominent gyrus, or outfolding of the temporal lobe of the brain.

Temporal Lobe - A part of the brain located on the outside of the cortex just below the frontal and parietal lobes. It is largely concerned with hearing and understanding what is heard. It also contains regions concerned with emotions.

Trauma - Damage or injury inflicted upon the body or a part of the body.

Wernicke's Area - An area of the left side (usually) of the cortex, located on the posterior border of the temporal lobe adjacent to the parietal lobe. It is critical in understanding language.

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