Enriching Heredity
How Environment Impacts The Developing Brain

Marion Diamond, Ph.D.
A conversation with Michael Mendizza

Your work implies that the brain and nervous system is physically molding (adapting) itself to the environment moment to moment. What does that mean?

One can say that the brain is responding to the external environment and to the internal environment at all times. The nerve cells are designed to receive stimuli, store information and transmit information. And we've shown that we can (physically) change the brain by changing the internal and external environments at any age.

The brain is growing most rapidly right after birth. This explosive development of fibers receives stimuli and grows branches. The number of potential connections are vast. There are a hundred billion nerve cells in a brain and many of those make connections with thousands of others. A single nerve cell can receive input from 20,000 other cells. Just think of the computation that goes on in a single cell before it fires. The interaction of the environment with this system is extremely dynamic.

What is the relationship between the development of these connections and what we call learning?

Learning is essentially the formation of these new connections. We are growing these branches while we're learning. We've been able to show this in the laboratory with rats learning to solve mazes. We measure the cells afterwards and find more branches on those cells that have been challenged and are learning, versus those cells that are inactive.

One of the things that is most startling about your work is the implication that changing the environment can alter the physical development of the brain. This was a major emphasis of the book "Endangered Minds", by Jane Healy.

She's expressing some of our concerns with the modern day child who sits in front of a television for hours. Even though we know some learning is taking place, it's the passivity that is so detrimental. In the laboratory it's been shown that only the rats that are playing show changes in the brain that we can measure. The rats that are sitting and watching don't change. We think it's the total activity of the body, physical and mental, that bring about these changes.

Most of us think that our brain's capacities are hard wired and fixed.

When we first presented our work way back in 1964, I remember one man stood up and said, "I'm sorry, but the brain cannot change." And I said, "I'm sorry but we've been able to show that it does."

Now, most people in the scientific world say yes, the brain's like a muscle. When you use it, it develops larger nerve cells, including the cell body and all of its branches and connections.

What are the implications of your research when we look at the changes that are occurring in childhood today?

We live in a multi-sensory environment and the brain is designed to receive many types of sensations. When it is developing, we should give it the opportunity to utilize a wide range of input, rather than single tract. As technology enters that might focus children in narrow channels, it's very important that we develop whole factions. We are multi-sensory and we need the whole cortex so that it's ready to handle the problems of this complex world, rather than narrow focused learning.

The idea of nature/nurture has been around for centuries. What impact does your research have on the balance between our innate potentials and the external stimulus needed to develop them?

We've found certain parts of the brain to be extremely plastic and changeable. Other parts are not. Many of the older parts of the brain stem do not change. They're closer to what you call hard wired. We've looked into all 15 different parts of the brain to see what's moving and what's not and these older areas don't move as readily as the more recently evolved areas, such as the cerebral cortex. It seems to be the most plastic of all.

We do not find this basic brain stem to be very changeable. It's dealing with fundamental functions such as appetite, thirst, sexual behavior, temperature regulation, heart regulation, and respiration. But the higher cognitive processing is taking place in the newer mass and that's where we find we can change so readily. We can change this cerebral cortex structurally in our rats and measure the increase in dendrites in just four days.

We used to think of the brain as fixed and believed it would take centuries for the brain structure itself to change.

We have measured physical increases in the brain in as little as four days and this change also was reduced very quickly with disuse. It is important to stress the importance of use versus disuse.

What is use?

Pediatricians are concerned that modern parents are giving too much stimulation to the children and they are closing down as a result. The brain needs time for assimilation. Children and adults need time to associate. When I teach I always write on the board. When I say something the students may hear me, but they don't have time to put it into their association cortex. By writing on the board, it slows the process down, they can think and at the end of the lecture they know what you said.

The brain only grows if it's challenged, but over challenging it causes it to close down and atrophy as well. How did you explore this in the laboratory?

The question we've asked for many years is what is enough stimulation and does the brain have a stimulation ceiling? Will it continue to grow with stimulation or will it stop? We designed an experiment where we changed the toys for our rats much more frequently than normal and we found that their brains didn't continue to increase. The rats just didn't interact with the toys as much when we were changing so frequently. I think it's the same with children. When you get too much going on in a room they shut down and don't really interact with much of anything.

You give them one or two things to explore, they're hungry, they're curious. Our rat work has taught us a great deal in how the brain changes in response to the amount of stimulation.

Part of your work empathized that the brains capacity to learn transcends age.

We have measured increases in the brains of rats whose mothers had been living in enriched environments. So we've shown an increase prenatally and also early postnatal, as young-adult, middle-aged, and extremely old age, the equivalent of 90 year old people. 900 day old rats are very old rats, but we've still shown if we put them in enriched environments, roughly in middle-age, and then follow them to the equivalent of 90 year old people that we can change that brain. The brain has the capacity to learn and develop throughout your life, providing it's healthy.

We have this tradition dividing the body and brain into different parts when it may be more accurate to say that each part is interdependent on the other. We are a living system. We talk about the brain so much because it is this structure that is unique to each individual. I can get a liver transplant and survive. I can get a heart transplant, but if I get a brain transplant I'm no longer myself.

It's one of the best lessons in self-respect for anyone to realize that his or her brain is unique on this Earth.

We talk about a central nervous system, which is the brain and the spinal cord, but for this unit to talk to the rest of the body we have a peripheral nervous system going out to the limbs and the rest of the body, which are all working together. I have an autonomic nervous system, which is keeping my heart going while I'm talking, or my breathing taking place - things I don't have to think about. At all times, these are integrated and it is terribly important to appreciate that if you damage one, it influences the function of the other.

I once asked Ashley Montagu about the physical development of the fetus. He pointed out that there were different systems developing at different stages of pregnancy and that stress or trauma to the mother at that stage can physically impact the fetus.

There's evidence from UCLA that shows that adult schizophrenics have an abnormal appearance of nerve cells in this hippocampal region deep within the temporal lobe. As one goes back to development, those cells normally migrate into position during the second trimester. There is evidence from a Finnish study to show that women who had a certain virus during that second trimester had more cases of schizophrenia. This is giving some credence to the fact that such a disease as schizophrenia may be due to abnormal embryological development.

I'm very interested in the prenatal diet. When we were teaching in Africa, the mothers did not want to eat protein while they were pregnant because they did not want to have large babies, which would make birth difficult. After doing experiments with rats, one can show that if during pregnancy the mother has a low protein diet, those little brains that are formed do not respond to enriched environments.

If we're putting hundreds of millions of dollars into Headstart which begins at 3, 4, or 5 years of age, and haven't developed the appropriate brain to receive that education, it will be a waste of money. It is important to be sure that the brain has developed well in-utero. So when you start with formal education, you have the nerve cells and the dendrites that can respond.

Are you saying that an impoverished maternal environment may have life long implications for the child?

An impoverished environment during the development of the fetus is very detrimental to the brain for a life-time. If we don't form the nerve cells appropriately, they're not going to make the right connections. Then, when we try to educate and work with the child, we won't have the basic material to stimulate.

This has been shown very clearly with protein deficient diets, to say nothing of cocaine, alcohol, other more abusive substances that are reaching these brains of our unborn children. These are the children we will be educating in the future. Good prenatal care is critical if we want to give these infants a chance.

There's some evidence that boy brains and girl brains are different. What are the significant differences you have found and how do these relate to child development?

Nobody really thinks about brains. We don't really think about where behavior comes from. The more we understand about brains, the more we'll understand each other as a same sex, as different sexes. Researchers at Brigham Young University induced stress in pregnant female rats. The male pups from these mothers, baby rats are called pups, did not have the normal male right/left brain pattern. They had the female pattern. When those baby male rats grew up, they behaved more like females sexually.

There's a biological basis for our preferences which most of us fail to appreciate and how people cry out to be understood. Why the little boy prefers other little boys and keeps it quiet because he doesn't know why. The more we learn about sex differences in the brain, the more we can understand all of our types of human behaviors.

If we are hurt, physically or psychologically, we tend to defend against being hurt again. Is there a defensive posture built into the neurological patterning which causes us repeat patterns over and over again?

If we're in an automobile accident, we never forget it. The adrenaline is high, and somehow the adrenaline embedding that memory is stronger than if we have something very mild. The stress related to an experience seems to impact our memory of that experience.

What advise would you offer a new mother and father that just discovered they were pregnant?

Keep a healthy body and keep a healthy mind during this period. Protein in the diet is important. So is vitamin B for the development of the brain.

Exercise to keep the placental circulation active. Stay away from stress if possible. The Japanese have said this for over 2000 years. Tykio, think pleasant thoughts. It's not always possible but recognize that what you are doing will influence the development of your infant. Nurture as much loving care between the parents as possible.

I experienced bonding with my own children as a heightened sensitivity to what's going on in them, with how they are feeling. It's also very clear that children participate in the emotional states created by the parents. They are sensitive to things that are happening beyond physical touching. Is there any model for this sensitivity in current brain research?

This may be related to the electro magnetism of the body and some give off more of a positive essence than others. Animals and children pick it up but we don't understand how to measure it. We were talking about this at lunch today, how to measure the things radiating from us. We don't have the apparatus to pick these up yet, but our children sense them.

We know as adults which person we want to interact with. There is a lot of room for discovery ahead and the instrumentation will be refined so that we can measure these things in the future. We know they're there, but how and in what quantities and how they're received, we don't know.

Can children develop beyond the model and environment that they are given?

I think children can reach beyond the role model they're given. I always tell my students, take what's good from everything you see and combine it in yourself to be the person you want to be. I firmly believe that you can bring into yourself many different patterns through a life time. At each stage we see different kinds of role models, and if we don't see them, we can imagine or make them up for ourselves, and use that to become what we want

The word "imagine" adds a new dimension to this question.

I asked Issac Asimov how he got the idea I found in one of his books. He said, Much more can come out of a brain than goes into a brain. We have certain parts of the brain talking to each other. Once we get information up there, the potential to interact with it is tremendous. That's the thrill. This is also an area we can't measure very well. But once we get the information up there, it's having a lot more fun than the information just coming in.

In "Frames of Mind" Howard Gardener writes about the nature of the intelligence. How is it that we can encourage children's brains to move into more creative states, rather than defending old patterns?

If I were to start to help children have more creative brains, I'd get a group of them in a room and I'd hold a human brain in my hand and say that no two human brains are alike - ever. Each one is individual. Then I would give each a question and have them go into a separate room and tape the answer. Then I would bring them all back and hear how each handled this question.

We would look at the similarities and differences. Then we would use this experience to create new ideas. For some reason new ideas are some of the most satisfying experiences in our existence, and every child should have the experience of getting new ideas and knowing that it's his own or her own. This will continue for a lifetime if we establish it early.

In"Growing Young"Ashley Montagu deals with this issue of maintaining a creative spontaneous state, not getting rigid and fixed and bogged down. Is there any physical reason why we can't stay as little children our whole life?

I certainly think we can. This morning I got up at 5:00am to look at new data and found something brand new. It game me the same thrill I had 30 years ago when we did our first experiments. The thrill of discovery can last a lifetime and that's one of the greatest things we can teach children, to seek new knowledge, to retain curiosity, to keep asking questions.

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