What Cells Remember: Toward A Unified Field Theory Of Memory

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Abstract: The accepted neurological dictum is that memory resides in the cortical neurons of the brain. Evidence from studies on genetics, epigenetics, organ transplants, immunology, unicellular organisms, planarian flat worms, nano computers and clinical psychology is cited here in support of the hypothesis that memory can also be stored in all the cells of the body, not just nerve cells. The relevance of this theory to pre- and perinatal psychology is explored.

Key words: epigenetics, nanotechnology, immunology, unicellular organisms, cell memory

Learning and memory are two of the most remarkable faculties of our mind. Learning is the biological process of acquiring new knowledge about the world, and memory is the process of retaining and reconstructing that knowledge over time. Most of our knowledge of the world and most of our skills are not innate but learned. In large part what we have learned and what we remember and forget defines who we are. In this paper, I want to address the question: where is all this information stored?

Some years ago, after the publication of my book, *The Secret Life of the Unborn Child* (Verny & Kelly, 1981) I received the following letter:

> We have four children, the one I'm writing about is Ingrid, our third. Their ages are eleven, ten, four, and two. Ingrid is very bright and always has been able to reason well. At 15 months she was completely fluent and spoke in long sentences. One evening, when Ingrid was three years old, we were just sitting at the dining room table and remembering some pajamas I wore when I was pregnant with her. Just kidding we asked her if she remembered the pajamas and her answer floored us, "I couldn't see what you were wearing I could only hear what you were saying." We just couldn't believe it so we began questioning her. What was it like? "Dark and crowded." What else? "It was like a big bowl of water." What did you think when you were born? "I could stretch, it wasn't crowded anymore." This child could carry on a conversation without ever saying she saw things - only what she heard and how it felt. We said, "What was your favorite food?" "I didn't get any food." She never answered the questions wrong. I know she really knew what she was saying.

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I heard many accounts like these that supported the proposition I advanced in my books that a child's central nervous system is sufficiently developed by the age of six months in utero (end of second trimester) to be capable of laying down rudimentary memories (Verny & Kelly, 1981; Verny, 1987; Verny & Weintraub, 1991; Verny & Weintraub, 2002). However, in the course of these past three decades, other narratives have come to my attention which cannot be explained in the same fashion. Interesting examples of even earlier memories can be found in the famous Scottish psychiatrist R. D. Laing's book, *The Facts of Life* (1976). He reported that a few of his patients spoke of their body image or had dreams in which they would spin, revolve, float, fly; be dashed against rocks; be washed ashore and be washed away again, before journey's end (Laing, 1976, p 45). One can make the case, as improbable as that may seem, that this is what a blastocyst would experience as it is tumbling down the oviduct.

The next stage of the blastocyst's journey would be implantation in the uterine wall. There are people who have a lifelong fear of being sucked in, drawn in, dragged down or who long to be rescued, revived, welcomed, or who are preoccupied with getting into a club, a university or any place that is difficult to get into. Laing (1976) relates how one of his patients in a therapy session said, "I feel I am clinging to crumbling rocks liable to be swept away in the torrent. Hanging on for dear life, trying to get a foothold, never seeming as though I can get into what I'm doing" (p. 46). Again, one can see how a "memory" such as this may accurately reflect on the experience of a difficult implantation.

Graham Farrant, an Australian psychiatrist, said the following about such very early memories,

> I believe in the reality of conception experiences in therapy because I have been able to identify specific movements of the body, especially the hands, in relation to specific sequential biologic phenomena. These are consistently and spontaneously present in different clients who don't know each other. In their regressions they believe they are re-experiencing various aspects of conception, like implantation or floating in the womb, or descent in the tube, or conception and pre-conception. It is true [my clients] may know that my paradigm includes conception, but they do not know the various movements that I have previously correlated with different conception memories, and these physical movements come quite spontaneously, even uncontrollably. This is one reason I am convinced that their experiences are memories and not metaphors. (Farrant as cited in Raymond, 1988, p. 20)

For a long time, scientists discounted clinical findings such as these and thousands of other similar ones as simply "anecdotes" that were of no scientific value. They might as well have called them fairy tales. The accepted neurological dictum is that the brain does not function as a memory storage device before the third trimester (though I know many neurologists who would argue for an even later date). As my colleagues reported - and I experienced - our patients' recollections and reenactments of experiences not only from their first six months in utero, but going back to conception and even prior to conception, I began to wonder whether a scientific explanation could be found for these and other phenomena that to my mind had one thing in common: memories formed independent of and outside of the brain.

Organ Transplants

"My personality changed after my kidney transplant - and I started to read Jane Austen and Dostoevsky instead of celebrity trash," says Cheryl Johnson, from Penwortham, Preston in England (Narain, 2008, para 1). She is further quoted as saying, "Now I just want to read all the heavyweight novels from the 19th century when before I would have run a mile from such books, preferring instead a good celebrity autobiography" (Narain, 2008, para 5).

About ten years ago, I read a paper by Paul Pearsall and fellow researchers (Pearsall, Schwartz, & Russek, 2002) in which they discussed ten cases of heart or heart-lung transplants. Pearsall had interviewed transplant recipients, their families, and the donor's family, while Schwartz and Russek examined parallels between the donor and recipient. According to the authors the recipients experienced profound changes in their lifestyles "changes in food, music, art, sexual, recreational, and career preferences, as well as specific instances of perceptions of names and sensory experiences related to the donors" (Pearsall, Schwartz, & Russek, 2002, p. 191).

“The prediction is that the memory exists in every heart . . . the question is what percentage of people who receive a heart would become aware of that information, or be significantly influenced by it, compared to the power of their own memories that would be competing with the memories of the donor’s heart,” Schwartz says (as cited in De Giorgio, 2012, para 8).

Dr. Heather Ross, medical director of the Heart Transplant Program at the Peter Munk Cardiac Centre in Toronto, says there is no scientific evidence that such a thing happens. “It’s been out in the pop culture for a long time, for sure” (De Giorgio, 2012, para 15).

Dr. Ross and many other scientists have taken a dim view of reports such as these. They follow a long tradition of rejecting scientific advances that are different from their own. Think Galileo, Ignaz Philipp Semmelweis (an early pioneer of antiseptic procedures), Charles Darwin, Sigmund Freud, and so on. Scientists dismiss ideas they did not learn about at university or that are not taught at their academic institutions.

What I have come to realize is that the heart is not just a pump; kidneys don’t just purify our blood. Every organ and all body tissues are composed of individual cells that are in constant communication with each other. The hypothesis that organ recipients' personality changes are due to the memories stored in the cells of the organs they received from their donor seems rather convincing, though not proven beyond a shadow of doubt. Keeping that in mind, let us explore some other areas of research that may throw further light on this subject.

Cortical Memory

For a start, let’s look at how memories are formed in the brain itself. Eric Kandel, a professor of biochemistry and biophysics at Columbia University, who shared the Nobel in the year 2000 with Arvid Carlsson and Paul Greengard, officially for "their discoveries concerning signal transduction in the nervous system” (Nobel Media, 2000, para 1), has described memory as "the pattern of functional interconnections of cells" (Kandel, 2001, p. 567).

Kandel used the marine snail, Aplysia, in his studies as this creature has fewer nerve cells than the human brain - 20,000 nerve cells compared to 100 billion. By focusing on a simple reflex of the snail used for protecting its gills, Kandel was able to see how the snail learned and remembered stimuli. He discovered that “short-term memory involves increased levels of neurotransmitters at the synapses, the communication sites between nerve cells and long-term memory requires changes in the levels of proteins in the synapse” (Mirsky, 2006, para 3). Using the knowledge gained about memory from these simple animals, Kandel then moved onto studying the same nerve process in mice, which are mammals like humans.

Scientists are learning that DNA - normally tightly packed around histones - must be unwrapped in order for a memory to be formed and stored. The relaxing of the chromatin complex allows access to the genetic blueprint for making proteins. When experiencing an event - a celebration party, the smell of the air after the rain, or other sensory input - some chromatin relaxes which exposes regions of particular genes, allowing proteins to be produced in the brain that help store the memory (Gaidos, 2013).

Every time we look at an object, taste a food, or touch a loved one, signals pass from our sense organs, in these examples - the eyes, the tongue, the sensory cells in our fingers respectively, to the neuronal assemblies in our brains that specialize in receiving these particular messages (Gaidos, 2013). In the process of transmission, synapses grow stronger as a result of the incoming signals initiating the production of specific proteins in the cells. These proteins not only build up the synapse but also encode memories. Just as physical exercise leads to greater muscle mass through a production of new proteins, so experience builds memories in synapses, potentially whole neural networks and brain regions.

The frontal cortex can tap into the sensory information immediately for use as a short-term, or working, memory. New neural connections then grow in the hippocampus and areas of the medial temporal lobes. These new connections strengthen the brain’s existing circuitry - changing the number of synaptic connections - which leads to long-term memory. When permanent changes in the neural connections are maintained throughout the brain, the long-term memory remains (Gaidos, 2013). Information, depending on its type, takes up permanent residence in brain regions involved in processing the original experience. Which region of the brain is involved depends on the type of experience. If the information is spatial, then the hippocampus region will be involved; if the information is emotional, then the amygdala will have the primary involvement of processing (Squire, 2004). The hippocampus and cortical brain regions then help with long-term memory retrieval when sensory information or emotions trigger that memory (Gaidos, 2013).

The most current neuroscientific view is that memories are encoded in nerve cells and their synapses by the production of particular proteins. Both short-term and long-term memories reside in different parts of the brain. If you were to stimulate one area of the brain such as the occipital cortex at the back of the brain with a tiny electrical probe you would trigger visual memories; the left temporal area at the side of the brain might produce speech sounds, words, phrases, etc. Related memories are stored in adjoining synapses. The larger the area stimulated the more complete the memory becomes. So much for the brain. The question arises: are there other cells in the body, apart from brain cells, capable of retaining memories?

The Human Cell

Human body cells come in many different sizes - small ones, like red blood cells, measure only 0.00076 mm and the larger ones, like liver cells, can be about ten times larger. The average-sized human cell is so small that literally thousands could fit on the head of a pin (Farr, 2002). Though these cells are unimaginably small, there are no physiologic functions in our bodies that do not already exist in the single, nucleated cell. In our bodies these physiologic processes are associated with the activity of specific organs such as lungs, heart, kidneys, etc. In our cells, the same physiologic functions are carried out by several dozen diminutive organ systems called *organelles* (Lipton, 2001). Examples of organelles are the *mitochondria,* which are thought to function as *"cellular power plants"* because they generate most of the cell's chemical energy. These organelles are also involved in other tasks such as regulating the cell cycle, cell growth, cell death, cellular differentiation, and signaling. The cellular scaffolding of the cell is called the *cytoskeleton* which is contained within a cell's cytoplasm. The cell's largest organelle is the nucleus which contains almost all of the cell's genes (Lipton, 2001). For a long time, scientists considered the nucleus to be the cellular equivalent of the "brain," commanding and directing the activity of the cell. However, this hypothesis is now being challenged by a number of scientists who believe that it is the cell membrane of the entire cell that represents the brain of the cell and not the nucleus.

According to cellular biologist, Bruce Lipton (2001), one of the leading members of this brave new breed of scientists, the cell membrane contains receptor and effector proteins. Receptors function as molecular nano-antennas (nano refers to very small items) that monitor both internal and external states. The membrane's receptors function like sensory nerves, and the effector proteins like action-generating motor nerves (Lipton, 2005, p.79). It is therefore quite reasonable to compare, as Lipton (2005) and others have, the cell's membrane *with its gates and channels* to an information-processing *transistor* and organic *computer chip* or, microchip.

A microchip, as most of you know, is a small piece of semiconductor material that contains many circuits. Thanks to the low cost of manufacturing these integrated circuits, they are nearly ubiquitous in modern society. Traffic lights, mobile phones, computers, and nearly any digital home appliance all rely on microchips for their function. Billions of electronic components and transistors can be contained in a microchip less than an inch in size. As technology advances, the circuitry will be made even smaller.

The cell membrane has been shown to act like a microchip. In fact, in 1997, researchers from Australia "successfully turned a biological cell membrane into a digital readout computer chip" (Cornell, 1997; Lipton, 2005, p. 91).

More recently, Taiwan scientists created a new computer microchip - only nine nanometers in width - which broke manufacturing records for smallest device of its kind. Laboratory Director Yang Fu-liang said that “using this technology, a one square centimeter chip would be able to store one million pictures or 100 hours of 3D movies” (redorbit.com, 2010, para 4) on a computer that is smaller than a grain of sand. Even more impressive, a whole functioning computer has been built by a team from University of Michigan that measures less than a cubic millimeter (Templeton, 2013). Called the Michigan Micro Mote, or M^3, this nano computer “features processing, data storage, and wireless communication…the chips are designed to necessarily work as a swarm, and indeed the term ‘smart dust’ seems to have been a rallying cry for the researchers” (Templeton, 2013, para 2).

We live in an age where most of us understand microchips and computers better than the biology of cells. Over the last half century, we watched how computers that occupied enormous spaces in university labs and functioned with very little memory shrunk in size – some now as small as a grain of sand – while increasing their memory exponentially. So my reasoning goes something like this: microchips store huge amounts of memory in a very small space. The cell membrane has all the characteristics of microchips. Therefore, it is very possible that in addition to performing other duties, the cell membrane also directs the production of proteins that encrypt memories. This would apply equally to neurons (brain cells) and somatic cells (body cells). While the present scientific view is that memories in the brain are located in the synapses, there is good evidence presented here that memories are also stored in the cell membrane of all cells, including neurons.

The conclusion we can draw from this, of necessity, very cursory review of the structure and function of neurons and somatic cells, is that they both operate in very similar fashion, reacting to signals with chemical and electrical activity and changes in the structure of their proteins. As the fertilized ovum proves, just because the area within a cell appears small to our eyes does not preclude it from storing millions of bits of information. In some ways, the cell is like the earth. To an observer from far away in the universe our planet would appear as this tiny speck of dust in a galaxy surrounded by other galaxies stretching into infinity. They could not possibly conceive of intelligent life actually existing on such a microscopic level. I suggest to you there is at least as much space within a cell as there is in our galaxy. It all depends on your point of view.

Genetics and Epigenetics

In the last decade, genetic research has established that the DNA blueprints passed down through genes are *not* permanent and unchangeable from birth onward. As Lipton (2005) emphasizes, *genes are not our destiny*. Stress, emotions, nutrition - the environmental influences of a human life - can modify the genes we carry. Just as new directions have emerged in cellular biology so there has been a comparable revolution in genetics with the development of epigenetics. Epigenetics is the study of the molecular processes by which the environment affects and modifies genetic information (Pray, 2004; Silverman, 2004).

Thus far, the most surprising epigenetic discovery is that life experiences don’t just change us; they may affect our children and grandchildren down through many generations. One striking example of intergenerational epigenetic effects was studied by Dr. Lars Olov Bygren (Bygren et al., 2014). The study focused on an isolated town in Sweden which had kept meticulous records during the 19th century of the townspeople’s health, births, deaths, genealogies, and harvests. Bygren and colleagues found that if a girl was living in that town when a sharp change occurred in that town’s food supply from one year to the next, then her sons’ daughters were significantly more likely to die from cardiovascular disease. In other words, this study showed that it is possible for a grandmother’s *life experience* to have a substantial impact on her grandchild’s later health and susceptibility to disease.

Many different forms of long-term memory require gene activity that is clearly affected by epigenetic mechanisms (Gaidos, 2013). Disruptions of epigenetic mechanisms can lead to gene silencing, changing a neuron's behavior for months or even years. In some situations, genes needed for memory and learning are deactivated permanently as it appears to happen in the brains of Alzhiemer's patients (Gräff & Tsai, 2013).

Geneticists have discovered that these modifications can be passed from parent to child through germ cells (egg and sperm cells) - cells, I wish to emphasize once again - that are not brain cells (Reik & Walter 2001; Surani 2001).

Every new human being is formed by the union of an ovum, the only cell in our bodies visible to the naked eye – 100 microns in diameter, as large as a dot on this page - and a tiny sperm cell - about 55 microns long, little more than half the size of the ovum. One micron equals one ten thousandths of a centimeter or, to put it the other way around, 1cm = 10,000 microns. The fertilized ovum becomes what is called a zygote, which is one hundredth of a millimeter large. The fertilized ovum is at the very start a one-celled organism. The zygote contains the blueprint – the human genome – for building a person who will eventually be made up of 37.2 trillion cells (Bianconi, et al., 2013). It is hard to fathom how this incredible amount of information/memory can be stored in such a microscopically small space. Yet this is an incontrovertible scientific fact.

Single-Celled Organisms

Another way of studying the capacities of cells is by examining how single-celled organisms function. Possibly 3.8 billion years ago, unicellular organisms first appeared on our planet. They are believed to be the oldest form of life.

Learning and memory have been observed in most of these organisms and across a variety of experiences such as in "bacteria 'remembering' prior nutritional status and amoeba 'learning' to anticipate future environmental conditions" (Guan, Haroon, Bravo, Will, & Gasch, 2012, p.495). Researchers from the University of Sidney, Australia (Reid, Latty, Dussutour,& Beekman, 2012) found that the slime mold *Physarum polycephalum* avoids areas it has previously visited and by doing so, it constructs a form of spatial memory. This mechanism allowed the slime mold (which lacks a brain, of course) to solve a puzzle trap which is often used as a test of an autonomous navigational ability (Reid et al., 2012, p. 17490). They concluded, "Our data show that spatial memory enhances the organism's ability to navigate in complex environments. We provide a unique demonstration of a spatial memory system in a nonneuronal organism . . ." (Reid, et al., 2012, p. 17490).

Other experiments with the slime mold *Physarum polycephalum* reveal even more about the nature of learning and memory. The slime mold learned a pattern of shocks (delivered at regular intervals by scientists) and altered the way it behaved just prior to the next one. The slime mold was anticipating the shocks based on the learned pattern of intervals. Next, the scientists paused the shocks for several hours and when they began again with a single shock, the slime mold acted with accurate anticipation of a follow up shock, based on the pattern it had learned prior to the pause (Saigusa, Tero, Nakagaki, & Kuramoto, 2008). These findings "hint at the cellular origins of primitive intelligence" (Ball, 2008, para 2). Microbiologist James Shapiro of the University of Chicago, commenting on their paper said that if these results are accurate, "this paper would add a cellular memory" to the proven capabilities of cells (Shapiro as cited in Ball, 2008, para 3).

Flatworms Planarian

The planarian is one of the simplest living animals having a body plan of bilateral symmetry and head orientation. Several factors make the planarian flatworm's nervous system more similar to a vertebrate nervous system than an invertebrate one.

> Special sensory input from chemoreceptors, photoreceptor cells of primitive eyes, and tactile receptors are integrated to provide motor responses of the entire body, and local reflexes. Many morphological, electrophysiological, and pharmacological features of planarian neurons, as well as synaptic organization, are reminiscent of the vertebrate brain. (Sarnat & Netsky, 1985, p. 296)

The planarians have nearly every neurotransmitter that is also found in mammals. Researchers Sarnat & Netsky (1985) even suggest that this worm may offer a living example of what a vertebrate brain may have been like earlier in evolutionary history. For this reason and many more, this flatworm is an excellent research subjects for studies that seek to investigate more simple model of how the brain chemistry.

The planaria of the species *Dugesia japonica* were chosen by Shomrat and Levin (2013) for their study on memory. The researchers familiarized one group of flatworms to a textured floor of the Petri dish while a second group was kept only in smooth-floored containers. Both groups were then placed in a container with a rough textured floor that included food at a particular location that was also near a very bright light. This was especially significant because flatworms are typically averse to entering an illuminated area and so, to eat the food, the flatworms had to overcome their typical aversion to light. The researchers noted that the flatworm group who was familiarized previously with the rough-textured floor fed more quickly and spent more time feeding than the group that was not familiar with the textured floor (Shomrat & Levin, 2013; Thurler, 2013).

Then, the researchers decapitated the flatworms in both groups. Two weeks later, the heads had been regenerated in both groups of flatworms and the researchers put them through the same test. They found that after a brief re-exposure session of feeding on a rough-textured floor and then re-tested four days later, the flatworms who had been in the familiarized group fed more quickly than the unfamiliarized group. This demonstrated that the flatworms retained some recognition of what they had previously learned. The researchers conclude that

> memory of the original environment was not located exclusively in the brain, and had become imprinted onto the newly built brain during regeneration. . . we suggest that "some trace of memory is stored in locations distributed beyond the brain (because the place conditioning association survives decapitation)." (Shomrat & Levin, 2013, p. 3807)

Though future research will have to investigate the mechanism by which this memory is transferred from somatic structures to the regenerating brain, the finding of the study - that memory can be retained in areas beyond the brain - is noteworthy.

The Immune System

The immune system is a prime classroom for our investigation of memory. The immune system is made up mostly of the bone marrow, lymph nodes, and various kinds of white blood cells, some of which circulate throughout the body, while others reside in the various tissues of the body, including the skin. The immune system responds and reacts to antigens - which can be found on surfaces of bacteria, fungi, and viruses and can also be nonliving substances such as chemicals, foreign particles, and toxins. When a new bacterium or virus invades the body, the immune system mounts an attack by sending in white blood cells called T-cells that adapt to the molecular structure of that invader and attack it. Defeating the infection may take several days or weeks. However, once victorious, some of these T-cells, with their modified structures, remain in our system, remember the invader, and should the same bacterium or virus shows up again will quickly destroy it. Thus, the next time the antigen returns, the immune system responds more quickly and efficiently to the invader. In many cases it will prevent you from getting sick (Pert, 1997). For example, a person who has had chickenpox or has been immunized against chickenpox is immune from getting chickenpox again. This is not a theory but an accepted scientific fact and, as such, a perfect example of a particular cellular memory at work.

Cellular Memory and Pre- and Perinatal Psychology

The theory that is being advanced here is that the cells in our bodies function very much like the musicians in an orchestra. Take the New York Philharmonic, for example. It is made up of 106 musicians, plus conductors and associated staff. Sometimes, for example when performing Beethoven's 9th Symphony, it may also add a very large choir. The musicians sit in sections according to the instruments they play such as string, percussion, wind, etc. They all play together though, occasionally, one musician may have a solo part. Together they produce a complex alchemy of musical notes, which reaches the ears of the audience as one unified sound. I postulate that all our organs such as the heart, gut, skin, etc. and also, regions in the brain, function as repositories of specific memories = sections in the orchestra. Each cell = musician contributes its bit of information to the memory that emerges either consciously or unconsciously as a result of some trigger, from the environment or from the brain = the conductor. This is exactly how neurons and all the cells in our bodies work, namely in close cooperation with each other. In neurology we speak of neuronal assemblies, neural circuits and feedback loops. It's all about being part of an orchestra made up of 37 trillion musicians.

This hypothesis provides a robust scientific explanation for many phenomena that have been observed and documented in Pre and Perinatal Psychology such as children's and adults' memories dating back to early life in the womb – in rare cases reaching back to conception and before, as well as fears, phobias, predilections, and behaviors unexplainable by life events. Through our ancestry, by way of their reproductive cells, the things our parents and their parents ad infinitum into the past experienced, physically and mentally, may be passed on and potentially, affect us. It is postulated here that these memories, both personal and ancestral are hidden deep in the cells of our bodies from where they exert a gravitational pull on our lives, a pull most of us are totally unaware of.

Summary

All cells, be they nerve cells or somatic cells, respond to environmental signals by producing proteins that form memories. These proteins are stored at synapses of neurons throughout the brain but also in the cellular membrane and intracellular space of all cells. Cells act as microcomputers and although they are tiny, they are capable of amassing vast amounts of memory as demonstrated by the ovum and sperm cells, T cells, unicellular organisms, etc. Epigenetics has shown that at conception we inherit with our genes not only a blueprint for our future body and personality but also memories of our ancestors. The conclusion we can draw from the research cited here is that distinct bits of information are encoded in cells throughout our bodies. Complex memories arise from large numbers of these cells working in concert.

References

Ball, P. (2008). Cellular memory hints at the origins of intelligence. *Nature, 451*, p. 385.

Bianconi, E., Piovesan, A., Facchin, F., Beraudi, A., Casadei, R., Frabetti, F., . . . & Canaider, S. (2013). An estimation of the number of cells in the human body. *Annals of Human Biology, 40*(6), 471.

Bygren, L.O., Tinghog, P., Carstensen, J., Edvinsson, S., Kaati, G., Pembrey, M., & Sjöström, M. (2014). Change in paternal grandmothers' early food supply influenced cardiovascular mortality of the female grandchildren. *BMC Genetics, 15*(12).

Cornell, B.A., Braach-Maksvytis, V., King, L., Osman, P., Raguse, B., Wieczorek, L. & Pace R. (1997). A biosensor that uses ion-channel switches. *Nature, 387*, 580-583.

Farr, G. (2002, May 31). *The human cell.* Retrieved from www.becomehealthynow.com/mira2_front/printpage.php?id=709

Gaidos, S. (2013). Memories lost and found: Drugs that help mice remember reveal role for epigenetics in recall. *Science News. 184*(2), 24-28.

De Giorgio, L. (2012, March 28). Can a heart transplant change your personality? *The Toronto Star.* Retrieved from: http://www.thestar.com/news/world/2012/03/28/can_a_heart_transplant_change_your_personality.html

Gräff, J. & Tsai, L. H. (2013). Histone acetylation: molecular mnemonics on the chromatin. *Nature Reviews Neuroscience, 14*(2), 97-111.

Guan, Q., Haroon, S., Bravo, D.G., Will, J.L. & Gasch, A.P. (2012). Cellular memory of acquired stress resistance in saccharomyces cerevisiae. *Genetics, 192*(2), 495-505.

Kandel, E.R. (2001). The molecular biology of memory storage: A dialog between genes and synapses. *Bioscience Reports, 21*(5), 565-611.

Laing, R. D. (1976). *The facts of life.* London: Penguin.

Lipton, B. H. (2001). Insight into cellular consciousness. *Bridges, 12*(1), 5.

Lipton, B. H. (2005). *The biology of belief: Unleashing the power of consciousness, matter and miracles.* Santa Rosa, CA: Elite Books.

Mirsky, S. (2006, May 24). *In search of memory: An interview with Nobel Laureate Eric Kandel. Scientific American.* Retrieved from http://science.howstuffworks.com/dictionary/famous-scientists/biologists/eric-richard-kandel-info.htm

Narain, J. (2008, March 15). *My personality changed after my kidney transplant - and I started to read Jane Austen and Dostoevsky instead of celebrity trash.* Retrieved from http://www.dailymail.co.uk/health/article-533830/My-personality-changed-kidney-transplant--I-started-read-Jane-Austen-Dostoevsky-instead-celebrity-trash.html#ixzz2rpRVHzJl

Nobel Media. (2000). *Physiology or Medicine for 2000 - Press Release.* Retrieved August 28, 2014 from http://Nobelprize.org

Pearsall, P., Schwartz, G. E., Russek, L. G. (2002). Changes in heart transplant recipients that parallel the personalities of their donors. *Journal of Near Death Studies, 20*(3), 191-206.

Pert, C. B. (1997). *Molecules of emotion: Why you feel the way you feel.* New York: Schribner.

Pray, L. (2004). Epigentics: Genome meet your environment. *The Scientist, 18*(13), 14-20.

Raymond, S. (1988). Cellular consciousness and conception: An interview with Graham Farrant. *Pre and Perinatal Psychology News, 2*(2), 4-7 & 20-22.

Redorbit.com. (2010, December 14). *Scientists create world's smallest microchip.* Retrieved from: http://www.redorbit.com/news/technology/1966110scientists_create_worlds_smallest_microchip/

Reid, C. R., Latty, T., Dussutour, A., & Beekman, M. (2012). Slime mold uses an externalized spatial "memory" to navigate in complex environments. *Proceedings of the National Academy of Sciences of the United States of America, 109*(43), 17490-17494.

Reik, W. & Walter, J. (2001). Genomic imprinting: parental influence on the genome. *Nature Reviews Genetics 2*(1), 21-32.

Saigusa, T., Tero, A., Nakagaki, T., & Kuramoto, Y. (2008). Amoebae anticipate periodic events. *Physical Review Letters, 100*(018101).

Sarnat, H. B. & Netsky, M. G. (1985). The brain of the planarian as the ancestor of the human brain. *The Canadian Journal of Neurological Sciences. Le Journal Canadien des Sciences Neurologiques, 12*(4), 296-302

Shomrat, T. & Levin (2013). An automated training paradigm reveals long-term memory in planaria and its persistence through head regeneration. *Journal of Experimental Biology, 216*(20), 3799-3810.

Squire, L. R. (2004). Memory systems of the brain: A brief history and current perspective. *Neurobiology of Learning and Memory 82*(3), 171-177.

Silverman, P. (2004, May 24). Rethinking genetic determinism: With only 30,000 genes what is it that makes humans human? *The Scientist, 18*(10), 32-33. Retrieved from: http://www.the-scientist.com/?articles.view/articleNo/15678/title/Rethinking-Genetic-Determinism/

Surani, M. A. (2001). Reprogramming of genome function through epigenetic inheritance. *Nature, 414*(6859), 122-128.

Templeton, G. (2013, May 15). *Smart dust: A complete computer that's smaller than a grain of sand.* Retrieved from: http://www.extremetech.com/extreme/155771-smart-dust-a-complete-computer-thats-smaller-than-a-grain-of-sand

Thurler, K. (2013, July 18). Flatworms lose their heads but not their memories. Retrieved from: http://now.tufts.edu/news-releases/flatworms-lose-their-heads-not-their-memories

Verny, T. R. & Kelly, J. (1981). *The secret life of the unborn child: How you can prepare your baby for a happy, healthy life.* New York: Summit Books.

Verny, T. R. (1987). *Pre- and perinatal psychology: An Introduction.* New York: Human Sciences Press.

Verny, T. R. & Weintraub, P. (1991). *Nurturing the unborn child: A nine month program for soothing, stimulating, and communicating with your baby.* New York: Delacorte Press.

Verny, T. R. & Weintraub, P. (2002). *Tomorrow's baby: The Art and Science of Parenting from Conception Through Infancy.* New York: Simon & Schuster.