BRAIN SCIENCE PODCAST

With Ginger Campbell, MD

Episode #4

A Discussion of the Book, *The Great Brain Debate: Nature or Nurture?* by Dr. John E. Dowling

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INTRODUCTION

This is the *Brain Science Podcast*, Episode 4, and I'm your host Dr. Ginger Campbell. In today's episode we're going to be talking about John Dowling's book, *The Great Brain Debate: Nature or Nurture?* I'm going to be talking about how the recent research in brain development has shed light on the question of nature vs. nurture. Also, there are a few terms I use that I'm going to define now, because I realized I didn't define them during the episode.

First of all I assume everyone knows that the neuron is the main cell of the brain and nervous system. The neuron has some parts that I refer to in this episode. First there is the axon, which is the long outgoing tract from the neuron. Then there are the dendrites which are the little short, stubby, spiny-looking things on the neuron. This is where inputs come in. And also I mentioned briefly the hippocampus—which, if you missed the last episode, is the deep structure of the cortex that's involved in the formation of long-term memory.

So, let's get on in to today's episode.

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DISCUSSION

Today I'm going to talk about *The Great Brain Debate*, by Dr. John E. Dowling, who is a professor of neuroscience at Harvard University and a member of the prestigious National Academy of Sciences. This is part of the *Science Essentials* series which is intended to "bring cutting edge science to general audiences." In *The Great Brain Debate,* Dr. Dowling presents an overview of what he calls the neurobiological facts that we have about the developing, adult, and aging brain.

He points out that neurobiology is still in a very primitive stage compared to the rich tradition of psychological observations. Most of what is discussed in his book is based on animal studies because it is very difficult to study neurobiology non-invasively. Even now that we have new technologies like functional MRIs there are practical obstacles. For example, you can't really put a baby into an MRI machine.

The book is divided into a discussion of development, the adult brain, and aging. The largest part of the book is about development, because it discusses what happens before we're born and after we're born. For development the key question is how much of the brain is hard wired and how much is determined by experience: In other words, nature vs. nurture.

Here is a brief outline of what we know about how the human brain develops. The first cells that are destined to become neurons appear at about three weeks' gestation, which is when the neural tube forms; and most of our neurons have been generated by four months' gestation. That's the reason why the fetus is so vulnerable during the early parts of pregnancy.

After birth by the age of 6 months we have all of our neurons, but our brains continue to grow until we're about 20 years old. The growth of glial cells and other supporting cells, and the growth of the myelin sheaths—which are the insulating layers that improve conduction—constitute part of this growth. But early on the most important growth is the growth of the actual neurons themselves—especially the development of dendrites, which is where the incoming connections to neurons occur. 80% of dendrites form after birth.

Of course, there are different rates of growth in different parts of the nervous system. It occurs in a generally tail-to-head direction, so early on the brain stem and the spinal cord develop. When we are born the brain stem is well developed so we can breathe, etc. Then the cerebellum—which controls coordination—begins to develop. The cortex develops last.

Motor development occurs before higher levels of cortical development. This makes sense if you consider that babies learn how to walk before they learn how to talk. Some of the higher cortical centers don't develop until as late as age 18. That's the reason why it's relatively later that we learn how to reason and plan, and why adolescents are notoriously bad about thinking about the future. It's not just hormones; their brains just haven't fully developed yet.

How does all this relate to the question of nature vs. nurture? Dowling emphasizes repeatedly in this book that when it comes to neurobiological facts this question is largely unanswered. But we can use animal studies and studies with people to come up with some important principles. First of all, development is clearly a mixture of nature, i.e. hard wiring, and nurture, i.e. experience. For example, the visual cortex of cats and monkeys is ready to go at birth, but then there's also a critical period during which visual deprivation can cause permanent damage.

For example, if one eye is covered, binocular vision doesn't develop properly. And if a cat is raised in an environment where they only see, say, vertical lines or horizontal lines, if this is done during a critical period, then later on those are the only orientations that they're able to see. A similar thing is observed in children between the ages of six months to six years. If for some reason one eye is covered by a cataract or doesn't focus correctly, if this isn't fixed before a certain point they'll never have good vision in that eye.

Going back to the example of the cat, what we know is that there are areas of the cortex that normally show dominance stripes between the eyes, and if one of the eyes is covered during the critical period then that part of the cortex becomes almost entirely dominated by the unaffected eye. The implication of this is that there is a period during which the axons are competing for space.

Here is a summary of what we know so far. The basic brain circuitry is hard wired, but during maturation connections are pruned and development is based on experience. More primitive animals mature more quickly but they have less plasticity, or adaptability. Another example that he gives in the book is birds learning how to sing. It turns out that they have to be exposed to their bird song by the age of three or four months or they can never learn how to sing properly.

Also, since only male birds are generally the singers, testosterone is involved. If they are castrated before they learn how to sing, they can't learn how to sing properly. They've actually isolated various centers in the bird brain that are related to singing, and these all have testosterone receptors. Conversely, in people there seems to be a critical period during which language acquisition occurs. And I will come back to that in a little while.

In the adult the key question is how much plasticity does the adult brain have. It used to be—for over a hundred years—it was just assumed the adult brain was pretty much hard wired. But this has been challenged both by research and by the fact that baby boomers have challenged it by doing things like taking up new careers and learning new skills at ages that in the past people wouldn't have even considered trying to do such things. Clearly, if we are healthy we can continue to learn new things and make new memories until the end of our lives. Yet we also know that things like language become more difficult to learn, and skills we learned when we were young seem easier to maintain.

The issue of plasticity is also becoming more important because of several reasons. One is the aging population, and the other is that medical technology is enabling more people to survive injuries to the brain that used to be fatal. So far, walking after a spinal cord injury remains a distant hope. But the experience of thousands of people with strokes and other brain injuries suggests that surprising recovery is possible. Basic research is essential for turning these hopes into greater progress for rehabilitation.

In *The Great Brain Debate* Dowling reviews a little bit about what we know so far about plasticity in the adult brain. I mentioned axons, which are the key output tract from a neuron. In general a neuron has one axon and a large number of dendrites, or input places. We know that outside the central nervous system and the spinal cord, regeneration of axons is possible, both in mammals and in non-mammals. So, for example, if you have a cut on your skin you might have a numb area around that for awhile, but eventually the feeling comes back.

But inside the central nervous system, including the spinal cord, only non-mammals can regenerate axons. And, so far, how this occurs is not very well understood; except that it appears the regeneration is more related to the glial cells—which are the supporting cells—than it is to the axons themselves.

We also know that young mammals, including young people, have more potential for recovery from brain injury than adults. It seems possible that recovery and plasticity represent something of a trade-off, because cold-blooded animals can even grow back limbs and eyes but they're very hard wired and they aren't very adaptable. But in the long run, the better we can understand how regeneration occurs, even in lower animals, the better chance we have of finding a way to help people with brain damage recover.

One issue is that it has long been assumed you're born with a certain number of neurons and that's it—since neurons generally do not divide or reproduce. Recently it has been discovered that there are some stem cells—or neural precursor cells—in at least two parts of the brain, including the hippocampus. But we're a long way from turning this into anything that can actually be used.

When it comes to aging one of the challenges is sorting out what is normal in aging vs. disease processes like Alzheimer's disease. Also, determining mechanisms doesn't lead directly to cures. For example, in Alzheimer's disease we know there is a loss of the neurons that produce a neurotransmitter called acetylcholine. But giving people drugs that increase the amount of acetylcholine has very little real effect on their cognition.

This appears to be partly because there's more going on. There seem to be toxic processes that are killing neurons; and adding the neurotransmitter doesn't help this. One issue that he brings up is the question of whether or not there's a certain element of pre-programming in the aging of the brain, and whether or not this would represent an upper limit of practical life extension.

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I promised that I would talk about language some more, and it's a good subject because it demonstrates some of these principles and has been studied quite extensively. It appears that by the age of six months a baby has the ability to recognize the sounds of all the known languages. But this ability is gradually lost, until by school age we can only recognize or reproduce the sounds of our learned language.

We also seem to have an innate ability to learn the grammar of a language. It has been shown that children who learn to speak English as a second language prior to the age of six or seven can acquire grammar skills that are equal to those of a native speaker. What happens is, if you learn a second language—or even a third, or fourth, or whatever, language—before the age of about six or seven, you can speak it perfectly with no recognizable accent.

Then between six or seven and adolescence you can still learn another language fairly easily. After adolescence it becomes very difficult for most people to learn additional languages. Even though we have the ability to continue to learn new vocabulary, acquiring the grammar skills in particular seems to be difficult.

I'm sure if any of you have tried to learn, say, Spanish as an adult, you recognize the truth of this. When I read about this originally—which was in Steven Pinker's book *The Language Instinct*, a book I highly recommend if you're at all interested in how language develops—I had one of those 'ah-ha' moments, because I was at the time struggling with trying to learn Spanish, since I have quite a few Spanish-speaking patients in the emergency room. At least now I know that the fact I'm having such a hard time doesn't mean I'm stupid—it just means I'm over 40.

Another thing they've learned from studying young animals and children is that anything you learn while you're very young, even if you don't use it for awhile, you still retain it. For example, with owls whose vision and hearing are very closely related, they did an experiment where they put prisms on them that distorted their vision. The young owls were able to adapt to this and fly accurately. Older owls never could adapt. But the weird part was that if they taught the owl to fly with a prism when it was young, and then took the prism off and then later put the prism back on the owl, the owl could still fly with the prism—as long as it was the same prism that it had been exposed to during the critical period.

I think one of the implications of this is obvious, which is that we would like our children to learn as many new things as possible when they're young—especially foreign languages, even if they aren't' going to use them. If they learn them when they're young, then later when they're adults if they have need of that language they will be able to tap into that early language acquisition. Just like people who come from foreign countries usually don't forget their native language. If they came here when they were young and learned to speak English, they can still speak their foreign language.

Of course this is backwards from the way we actually do things, because we don't teach kids foreign languages until Junior High and by then our brains are really already not very receptive—even though this is somewhat variable from person to person. So, as we already know, kids are sponges. I guess it means we shouldn't be so much concerned about whether or not they can use the information in the short term, and perhaps take more of a long-term view of the value of things they learn when they're young.

The nature vs. nurture question is one that is very controversial when you get into behavioral issues. So, it is something that will come up more in the future. In fact, I'm reading several books related to this right now that I hope I will be able to discuss with you on future episodes.

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In closing I'd like to point out one thing that might not have been clear in my attempt to summarize the contents of *The Great Brain Debate*. Even though the neurobiology of brain development is a fairly young science, there is a great deal that has been learned. And I didn't really get into a lot of the detail. If you're interested in the detail, this book is a good place to start.

In the next episode, which will be in two weeks, I'm going to start talking about consciousness, which is probably the most difficult aspect of the brain to study.

Until recently it was assumed that scientists could not study consciousness. I look forward to starting this discussion with you.

Meanwhile, if you have time I hope next week you will listen to my *Books and Ideas* podcast. I'm going to be talking about the history of how early scientists began to unravel the mysteries of reproduction. The *Brain Science Podcast* is going to continue to come out every other week, and *Books and Ideas* will come out on alternate weeks.

Please visit my website brainsciencepodcast.com and leave your comments there. Or you can send me email at docartemis@gmail.com. I look forward to hearing from you.

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Transcribed by Lori Wolfson
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