Transcript of Cerebrum Podcast—The Skinny on Brains: Size Matters

Guest: Jon H. Kaas, Ph.D., is Distinguished, Centennial Professor of Psychology at Vanderbilt University, where he has been since 1973. He received a B.A. from Northland College and a Ph.D. from Duke University. Kaas was elected to the National Academy of Sciences in 2000, and the American Academy of Arts and Sciences in 2001. He received the Distinguished Scientific Contribution Award from the American Psychological Association, the Karl Spencer Lashley Award from the American Philosophical Society, the George A. Miller Prize in Cognitive Neuroscience from the Cognitive Neuroscience Society in 2014, Honorary Life Member, J. B. Johnson Club for Evolutionary Neuroscience in 2014, and the Palay Award from the Journal of Comparative Neurology, 2014. He has published over 540 papers and review articles, and edited many volumes including a four-volume series "The Evolution of Nervous Systems" in 2007 and 2017. In 2009 he received the Graduate Mentoring Award from Vanderbilt University.

Host: Bill Glovin serves as editor of *Cerebrum* and the *Cerebrum Anthology: Emerging Issues in Brain Science*. He is also executive editor of the Dana Press and *Brain in the News*. Prior to joining the Dana Foundation, Mr. Glovin was senior editor of *Rutgers Magazine* and editor of *Rutgers Focus*. He has served as managing editor of *New Jersey Success*, editor of *New Jersey Business* magazine, and as a staff writer at *The Record* newspaper in Hackensack, NJ. Mr. Glovin has won 20 writing awards from the Society of Professional Journalists of New Jersey and the Council for Advancement and Support of Education. He has a B.A. in Journalism from George Washington University.

Bill Glovin: What makes the human brain superior to other mammals? Do animals express emotion? Has the human brain reached its full potential?

These are just some of the questions we posed to the author of our recent Cerebrum article, "The Skinny on Brains: Size Matters." Hi, I'm *Cerebrum* Editor Bill Glovin, and welcome to the Cerebrum podcast, where we explore brain research with scientists who are leaders in their field.

With us today to discuss the evolution of the human brain is Jon Kaas. Jon is Distinguished Centennial Professor of Psychology at Vanderbilt University, where he has been since 1973. He's published more than 500 papers and review articles and edited a four-volume series on "The Evolution of Nervous Systems." Wikipedia credits him with "making discoveries about the organization of the mammalian brain, including the description of many areas of the cerebral cortex and their neuroplasticity."

Welcome Jon, and thanks so much for your work on the article. Let's begin with what motivated you to study the evolution of the brain?

Jon Kaas: I started off with sort of an idea that we could study basic things about brains that would apply to all brains and, gradually through my exposure to studies on different species of mammals, discovered *always* that there were very important differences. To look at it in another way, it seemed that if we really wanted to understand things in a broader sense, we should understand how brains develop and how they change development in different lines of evolution.

In other words, how the brains get to be different as a result of evolution of different branches of the mammalian trees. So, that seemed to be a rather imposing sort of goal. But it was one that allows you to do more traditional studies, which would be to say that you're using a model and the model will tell you what you need to know about a system.

And there are also studies that tell you how systems came to be and how brain specialization came to be. So, we can pursue both of those kinds of lines of research at the same time.

Bill Glovin: You write that the modern human brain reached its current potential, perhaps as long as 200,000 thousand years ago. Is that as far as we can go in your view?

Jon Kaas: No it's not as far as we can go. But people disagree on that very conclusion because, if you look at what's happened to humans that have been basically modern for a very long time (that time keeps going back to new data, but it's now in the range of 200,000 thousand years), anatomically modern (as far as you can tell from skeleton remains) existed that far back and tool use and so on goes back to that time. But the puzzle is that for most of those 200,000 years, people were hunter gatherers and had rather limited technologies. And only recently, in the last, say, 20,000 years ago or or less, did agriculture come in and domestication of animals come in, and the building of cities start.

And then, in more recent times, you have the changes in our culture and what we've accomplished in different regions of the globe that have just been tremendous and so varied. So, there are different ways. I've tried to explain this, these recent changes compared to why did it take so long for these changes to take place? And some people would speculate, "Well maybe early humans didn't have language or they didn't have a way of communicating and maybe significant changes did occur to brains over that time." The other explanation is that it comes about as a result of opportunities that gradually emerged. The ability to work with metals and so on, greatly influenced the next step.

But those early changes came slowly. So what makes sense to me is that early humans gradually dispersed across the globe and some of them got as far as Australia, 40,000 years ago. And those descendants of those people who got there 40,000 years ago (when modern society imposed on them and Australia got immigrants from Europe and became a modern country) could do everything that the immigrants did. They could become airline pilots, great tennis players, doctors, whatever.

So, even though the brains were capable of the same things for both of these branches of human evolution. Recent, because of isolation in different parts of the globe, their brains to me seemed to be highly similar. So, it forces me to think that language did exist with early anatomically modern humans. And their brains were very similar to the brains we see in humans who we meet and talk to today.

The differences in the brains are because they're plastic and they adjust to education, they adjust through the culture. So, we have a word area in our brain that is unique for only reading people. Before reading emerged, there was no word area in the brain. This is something ... a part of the brain that we've altered through education. So, I've sort of given you a reason why some of the conclusions that modern human brains existed that long ago: 200,000 years ago. That's not always accepted. But I'm also saying that modern human brains are different because of culture and education and learning than the early brains. Not because they lack the same potential.

Bill Glovin: Do humans have the largest brains among mammals?

Jon Kaas: Not the largest brain among mammals because, for example, an elephant brain is larger. Whale brains vary but they're all much larger than human brains. So, we don't have the largest brains, not at all.

Bill Glovin: So is it the most neurons that make the difference or …?

Jon Kaas: The work that Suzana Herculano-Houzel's done has led to the conclusion that, with a lot of evidence, primates have a neocortex with more neurons than any other mammal. And that makes this part of the brain very, very important for mammals in general. But it's especially important for humans. So, although we have a smaller brain than an elephant, the neocortex is responsible for most of our cognitive abilities.

We have the machinery for better and more extensive cognition, and I think behavioral observations bear that out. Although, as an aside, I would say that everyone who has a pet cat or a pet dog or a horse will always argue that those animals are extremely intelligent.

Bill Glovin: How does nutrition tie into the evolution of the human brain?

Jon Kaas: Well, this is interesting because Suzana and others have talked about this for some time now. That the brain itself is very costly in terms of maintaining it. That the metabolic cost is high and the development time is long. So, how do we make up for those costs? And one advance that took place, two to three million years ago in the in the evolution of our ancestors, was to start to prepare foods. Two ways you can prepare foods is that foods that are hard to digest and eat can be cooked and made very easy to eat and digest or you can pound them up or cut them up or process them in some way so that you have small pieces and don't have to spend all your time chewing them up to make them a suitable size.

So, the argument that comes from that, and a professor at Harvard has led this argument, is that early use of fire became a turning point in the evolution of our ancestors so that they could rapidly, or for the last two to three million years, increase their brain size from that comparable to a chimpanzee to the much larger brain of modern humans. So that change occurred with a change in the diet and calories became possible.

Bill Glovin: We've all heard the term "left brain and right brain." Can you explain the difference?

Jon Kaas: Well, that's one of the surprising things about the human brain; there may be slight differences in brains of chimpanzees and other mammals. And that they might be doing something a little differently in the right side of the brain or the left side of the brain. For example, there might be a slight tendency to be right handed. But mainly animals, other primates will favor one hand or the other, to do certain tasks but it will sort of be randomly distributed. It looks like they just initially, for some reason, maybe just a random choice, favored one hand and then they got more experience with that hand so that it became a favored one to do certain tasks.

But humans are unusual in that most people are right handed and other people, a small portion, are left handed. But it's not really a choice. It comes about because of some built in factor that would favor one arm or the other in the brain mechanisms for controlling that arm.

So, we have the left side of the brain controlling the right hand and that's one of the fundamental differences that you would be either right or left handed. But the other source of changes that occur in hemisphere are probably more important. And basically, we have the left hemisphere specialized for most of the things we consider to be language and the right hemisphere is be more specialized for having spatial sense, spatial abilities, and artistic abilities, perhaps. And there's a lot of data and a lot of interest in how these two hemispheres are different.

But what it does, it breaks up the symmetry that is found in almost every mammalian brain. That the right hemisphere and the left hemisphere deal predominately with contralateral space vision. More hearing and sound. It becomes, as the brain gets bigger, more costly to organize a brain in this way when which we have to have a lot of communication between the two hemispheres because they're doing the same job and only half of the job. So, they have to communicate back and forth what's happening in each hemisphere. That takes more connections, longer connections as the brain gets bigger and so on.

One of the ways out of that sort of problem is to start to specialize, at least for higher order, cognitive traits or abilities. Specialize them to be in one hemisphere or the other. Mainly in one hemisphere or the other, so that you can reduce the amount of communication between the two hemispheres, considerably. And that seems to be especially important, of course, in language, which is really an amazing ability and takes tremendous computational abilities to both formulate speech but to also to keep track of the vast meanings that are randomly assigned to sounds and make sense of this. And then to add upon this of course, modern reading and processing of written languages.

So to divide that up between the two hemispheres equally would mean a lot of connections between the hemispheres and that would be costly.

Bill Glovin: The part of the brain that's known as the amygdala is tied to emotion. Do other mammals experience emotion?

Jon Kaas: I think that emotions are broadly distributed across mammals and Darwin really talked about this when he talked about expressions of emotions in animals and man. He used examples from dogs and other animals that we're familiar with. Because emotions play an important role in almost all mammals, as far as I can see, and also a very important role in humans, as Steve Pinker would say when he talked about how the mind works. And, to put it in a simple way, emotions force decisions that are generally beneficial to the individual that is expressing them. So that you might protect yourself from injury better when you get into an emotional state where you're willing to take the risks involved that are necessary.

You might reproduce more effectively if you have an emotional attachment and affection. And you can go through the different emotions and see how they impact and help make decisions. But most mammals will have a strong attachment to their offspring for a period of time and take great risks to protect them from injury or death. And they seem to be doing this in an emotional way, such as being very upset when the infant is separated from them, and making every effort to come and rescue their offspring.

Bill Glovin: Korbinian Brodmann, the German neurologist in the early 20th century who became famous for parting the cerebral cortex into 52 distinct regions known as the Brodmann areas, considered these areas to be functional equivalents of the organs of the body. Without imaging, how was he able to determine this?

Jon Kaas: It was a time for being daring, I guess. And, of course, they had some evidence that the brain functions were not distributed equally or uniformly across the brain (From lesion studies in humans). So, when it was discovered that a patient had a great language impairment and the the lesion was in the left hemisphere in the frontal lobe, he could start to make some conclusions about the localization of structures that were necessary for language.

Other kinds of deficits were also very clear. If someone has had a damage to the back of the brain where the primary visual cortex is, they will have partial blindness, according to the size of the lesion, and this could be ascertained. So, the idea came about that there would be functional localization. And the evidence was accumulating. But at the same time, it became clear that the brain itself is not uniform in structure, so you had medical students seeing in a fresh human brain as they dissected a brain where a part of cortex was clearly different, just without any preparation or staining. You could see where the myelin is and line of geraniin line is in this primary visual cortex. It's clearly identified.

And then, when they started to get the stains, they could be used to stain neurons or white fibers, and they became, around the time that Brodmann was starting, you could start to see structural differences in different parts of the brain. And he took that and used it very effectively to identify and describe structurally different parts of the brain, without knowing too much about the functions of the parts that he was describing. He, of course, knew what was already becoming commonplace; that there were parts that were involved in touch, and parts involved in hearing or sight or motor intuition and so on.

But his knowledge about the functional roles was, probably because of the time and the lack of data, very limited. So he described the structural differences in some detail in the human brain and also tried to describe cortical areas in the brains of other animals, other primates and non-primates, rats, squirrels, and so on. They tried to identify the same areas because of matching structural appearance in different animals, and he was only partially successful. But because he did this early and he did it so extensively, they have been used in these designations ever since the time of Brodmann to refer to regions of the brain that likely have functional importance. And it turns out that some of the things that he identified weren't the same structures across different animals and they were misidentified in that sense.

And other areas that Brodmann didn't see in the human brain have been proposed since. So that number has gone up considerably to three or four times what Brodmann described. But his numbers are still in common use as a way of communicating to other people what part of the brain you're talking about.

Bill Glovin: You end your article by writing, *"For now the neuro mechanisms mediating the astonishing abilities of the human mind remain incompletely understood and this should motivate us to look further. It is an exciting time."* What else do we need to know?

Jon Kaas: Well, what we've learned about the human brain in recent years has been really astonishing. All of this, of course, especially early on, was guided by experimental studies on mainly other primates. But to have these imaging abilities, to see where blood flow changes in response to having a person take on some task, use some part of their brain, at a higher rate, therefore require a higher blood flow. You can start to identify these down to millimeter levels in the brain. It means that systems and regions of the brain can start to be assigned, with a lot of confidence, sets of functions. And that makes understanding how the human brain works and is organized. Much more great progress is made there and is continuing to be made there.

But the same methods now that can be used to image a human brain can be used to image say a Macaques monkey brain and direct comparisons can be made between the two brains. And we get a much better idea then of how the brains are similar and how they're different. As a result, we have an idea that there are many more areas in a human brain than in a Macaques monkey brain. But some of the areas, a good number of them are very similar, and they might be modified somewhat, or quite a bit in a human brain but they came from a common ancestor.

So these new methods have such usefulness and such power and it's a time of great discovery. This is added to by the fact that we used to have just a few ways of staining brain tissue to see how it's organized. And now you can have antibodies for almost any protein that can be expressed by a neuron or a class of neurons or a part of a neuron and you can start to look at the chemistry of a human brain or any other brain and compare them. And since these chemical cues can be related to function, often, and in some detail, you can start to make functional conclusions about how the processing is going on. It could be post mortem in a human brain, for example. So the potential for learning new things is at an all- time high.

Bill Glovin: I think that at least partially covers the topic. I'd like to thank Jon Kaas again for his wonderful article this, "The Skinny on Brains: Size Matters," which you can find at dana.org. I'm *Cerebrum* editor Bill Glovin. Thanks for listening and we'll see you next time.