BRAIN SCIENCE PODCAST

With Ginger Campbell, MD

Episode #34

Interview with Dr. Rachel Herz, Author of *The Scent of Desire:Discovering Our Enigmatic Sense of smell*

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INTRODUCTION

This is the *Brain Science Podcast* – the podcast for everyone who has a brain – and I'm your host, Dr. Ginger Campbell. On the *Brain Science Podcast* we explore how recent discoveries in neuroscience are unraveling the mysteries of how our brains make us who we are. For more information including Show Notes, links to previous episodes, and information about how to subscribe please go to the website brainsciencepodcast.com. We also have a Discussion Forum at brainscienceforum.com and you can send me email at docartemis@gmail.com.

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Welcome back to the *Brain Science Podcast*. This is Episode 34. If you're new to the show I'd like to welcome you. My usual format is to have either an interview with a scientist or author, or to discuss a recent book on neuroscience. Today I have an interview with Rachel Herz, the author of *The Scent of Desire: Discovering Our Enigmatic Sense of Smell*. Dr. Herz is on the faculty of Brown University, and she is a leading expert on the psychology of smell.

I'm going to get into her interview in just a minute, but I wanted to remind you of just one thing. And that is that if you subscribe to the RSS feed at

brainsciencepodcast.com you will automatically get all of the Show Notes, including links that are mentioned during the podcast, and you'll get posts that I put up in between episodes. You can also get this same information in email form if you prefer. As the number of subscribers increases I hope to increase the amount of content on the website in between episodes.

Now, you may be wondering why would I devote a whole episode to smell. A few weeks ago I talked about anatomy and I mentioned that smell is unique in the fact that it's the only primary sensation that goes directly to the cortex and does not go through the thalamus. Also it has very intimate connections with the amygdala, which is involved in emotion. So, it turns out that smell is a lot more important and even more interesting than you might have imagined.

So, let's get on in to the interview with Rachel Herz.

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INTERVIEW

GC: I'd like to welcome Rachel Herz to the *Brain Science Podcast*. Rachel, I'm really glad that you came on the show today.

RH: Well, thank you so much, Ginger, for inviting me.

GC: Could you tell us a little bit about how you got interested in smell?

RH: Well, the short answer is it turned out to be the perfect intersection between biology and psychology. And from my academic background that was really what I was searching for as a graduate student, and I stumbled upon the perfect way to analyze it. And particularly because smell really relates to evolutionary theory in terms of when you're trying to figure out how something in our sense of smell works, asking evolutionarily-based questions and thinking

from that perspective, I think, is extremely fruitful. And I had excellent training in that background and that, I think, enabled me to really pursue this and also to get excited about the topic.

GC: So, did you have a background in evolutionary psychology?

RH: Well, actually my undergraduate degree was in biology and then switching over at the end to an Honor's thesis in psychology. And then my Master's was in a psychology department but ostensibly was evolutionary biology and ecology. I was studying how Black-capped Chickadees store their food and find their food. The sort of psychological dimension of this was relating to spatial memory.

And then when I started my PhD work I had at that point decided clearly that I wanted to work with humans and that I was interested in the biological processes and psychological mechanisms, and so on, and that I was interested in emotion. And I wasn't really sure how to put this together. I actually started my PhD doing some sleep research, which I also am quite passionate about. In fact I've even collaborated with Mary Carskadon here at Brown, who is a sleep pioneer, and we've done a study about sleep and smell; and you cannot smell while you are in deep sleep or in REM sleep.

But, in any event, that didn't work out very well for me from sort of the politics of what was going on. This was at the University of Toronto in the late 80's, and at that point they did not have any kind of clinical program. And they saw what I was doing as being too clinical and I was told I had to change areas and make it fit into the program. And so, I did, and I started working with someone who was a social psychologist who worked in emotion. And that was interesting to me, but the social psychology part of it I really couldn't get too enthusiastic about.

And so, I read a paper, actually, taking a course in social psychology, where they used smell to manipulate mood, and the reason the authors gave for using smell

was that it was this basic biological fundamental emotional system. And I thought, 'This resonates very well with me.' And I said to my supervisor, 'Can I look at this?' I've also always been interested in memory, as my Black-Capped Chickadee work attests, and I was very interested in the process behind smell and memory and emotion.

And I said, 'I'm interested in this and I'm hoping that you'll let me.' And he said, 'Sure, you can go and do it, but I can't help you.' As it was, pretty much no one in the department had any expertise particularly in this area. I was able to put together a committee that had specific expertise in memory, or specific expertise in one case in animal behavior and olfaction, and then my own supervisor who was more of an emotion expert.

And then I actually went down to the United States. I came to Brown University where at that time Trygg Engen, who was really the father of the psychological study of olfaction, was then a professor. He subsequently retired. I met with him and he was very, very nice. And I called up some of the companies that make the fragrances that people use in all sorts of products. And I think they thought I was a little bit nuts, but they actually invited me to come down and see how they did things. And then they gave me samples to use for my research. And things went from there.

GC: Well, great. I have on this podcast talked quite a bit about memory, we've talked about emotions, and recently I did an episode about anatomy where I mentioned the fact that one of the things that's unique about smell is the fact that it goes straight to the forebrain and not through the –

RH: Thalamus.

GC: Thalamus. Thank you. I think I'm having one of those days, if you know what I mean. But, anyway, at the time I was recording that episode I was reading

your book, so I just said, 'And we'll talk about smell soon.' So, now we are. Maybe you could give us a little background about why smell is much more important than many of us might realize.

RH: Well, smell really is a sense that for humans doesn't have extreme survival value in the way that vision provides survival value for our species. For other species smell actually is the critical sensory system which animals need to orient to their surroundings, to find reproductive conspecifics, to find food, to find all the basics of species survival. With us we really rely on our eyes primarily as the fundamental informational source.

However, smell is still extremely important and linked to those fundamental survival needs, but in a more subtle way. So, for example, when it comes to food, without a sense of smell our experience of food is purely taste. And taste is actually a very simple system. There are only five basic tastes: salt, sour, sweet, bitter, and the fifth one is called umami, which is basically the taste of savory protein, or literally MSG. And everything else that we experience when we eat something comes from our nose.

It comes from our nose by both smelling what's on our fork as we bring it to the mouth, and then when it's in the mouth, chewing the food releasing the volatile chemicals which then go up the back of the mouth into the nose. And that's why when you have a cold and that passageway is blocked things don't seem to taste right. It's because we're not smelling properly. And so, everything that we experience as flavor—what people often actually call taste—is really flavor and it's really to do all with our nose.

So, again, all the sort of pleasurable aspects of food really derive from smell. And people who've lost their sense of smell often have quite a difficult time with eating, in the sense that they often overeat because they're trying to quell a craving for something which just is not happening because all they're getting is

salt, or sweet, or whatever the basic taste is, and they're not getting the wonderful aromatic quality of chocolate, or steak, or whatever it is that they really want. And what can happen is that they either overeat to try to quell that craving, or they become discouraged and just say forget it, and don't eat very much, and can become malnourished, and lose weight, and so on. And so, eating is definitely an area which is affected very much by our smell.

Our social relationships are also very affected by smell. For women it's actually very important how a man smells in terms of her sexual attraction to him. And in a sort of pure biology case, in the sense of women who are not on birth control pills and in a community where men are not using colognes and body sprays and so forth, the body odor of a man actually is a signal for his immune system genetics. And women who have complementary immune systems to a particular man will find his smell more attractive than a man whose immune system does not match well with hers.

And what this means biologically, and why this is so important, is that the union of their genetics will result in a healthier child and also the greater likelihood of actually conceiving when their immune systems are complementary to one another than if their immune systems are too similar. And so, this actually has major biological consequences. It also turns out that women's sense of smell is highest during ovulation—the very few days in the month when this is actually the most important thing; when actually intercourse will result in conception. So, there's a very fundamental relationship between smell and biology in that case.

And then when it comes to memory and our emotions, our whole emotional life is very much influenced by smell. People who lose their sense of smell actually often become quite depressed. It to a certain degree depends on their personality's basic state, and it also depends on how much they paid attention to smell and were interested in smell and how it effected their life prior to whatever injury resulted in their losing their sense of smell.

But our emotional system in our brain is interconnected totally directly with olfactory processing. And I have a theory that when one side of the equation is malfunctioning the other side suffers by consequence. That is to say when smell processing is not happening in a normal way because there's no activation to the system, then that's feeding into the emotional centers of the brain and that's actually causing some difficulty or problematic processing in that center, which is why I think you see depression.

You can also see some memory problems, because the part of the limbic system that's involved with processing declarative memory is also directly connected to the olfactory system, and visa versa. Interestingly enough, there are a number of clinical reports that when people present to psychiatrists or therapists with serious depression they also at the same time complain that they feel like they're losing their smell sensitivity. So, there definitely seems to be this bidirectionality, and in a very fundamental way I believe smell is completely connected to what it means to be human.

GC: I think you sort of summed up some of the things that we are going to hopefully talk about. In your book—and I'm just going to quote from what you wrote—you said, "The neurological interconnection between the sense of smell—olfaction—and emotion is uniquely intimate." You mentioned a little bit about this briefly, but could you go into a little detail about the interconnection between emotion and smell?

RH: OK. Smells are chemicals that flow through the air and enter the nose. They go into the nose, and at the back there are the receptors for smell that actually directly connect into the brain. There's no mediating barrier; unlike in vision or in hearing where there is a mediating barrier between the outside world and the brain. From here the receptors bundle together to form the olfactory nerve and go into the olfactory cortex, which is the first way station of where smells are processed.

Directly connected to the olfactory cortex is the amygdala, the structure that processes emotion and emotional experience; and directly connected to it is the hippocampus, the area of the brain that processes memory, and learning, and associations. And without going through any other systems, without being integrated in any other areas of the brain—which all of our other senses are before they go into this area—smell impacts directly into the neurologic substrates of emotion, learning, and memory. And so, it is unique in this capacity.

Another way that it's also very interesting, and I think unique with respect to its connection to emotion, is in neuroevolutionary terms, in that the brain's original tissue was primarily olfactory cortex. Organisms that do not have any other sensory system have a basic chemical detection system: go forward food, go away something that's going to eat us. So, the sense of smell is actually the most fundamental biological system.

And in the mammalian brain it is also the most fundamental and oldest part of the brain. Other structures like the hippocampus evolved from what was originally olfactory cortex. So, literally the part of the brain that processes emotion grew out of the part of the brain that processes smell. So, something I like to toss around is potentially we wouldn't experience emotion as we do if we did not have a sense of smell.

And finally, I believe there's a very fundamental conceptual relationship between what smells tell us and what emotions tell us. Because the fundamental message that smells give us from a sort of basic biological perspective is this is good or this is bad: this is good, I want to eat it, I want to approach it, I want to mate with it, whatever the case might be; or, this is bad, I want to get away from it, it's dangerous, and so on.

And our emotions tell us the exact same thing. Positive emotions tell us to go forward, to approach to increase our possible survival, and negative emotions either protect us or enable us to fight to defend ourselves and hopefully stay alive in that way. And so, from a conceptual fundamental perspective—the approach and the avoid connection—both the sensory experience of smell and the abstraction of emotion tell us the exact same thing.

GC: So, that's what you meant when you said not only do odors trigger emotions, but they also become emotions.

RH: Well, actually what I meant there is that there is through association, basically through simple conditioning, a smell when it's experienced at the same time as an emotion can become the sort of proxy for that emotional state. The emotion becomes attached to the smell so that the next time you smell that smell you feel that emotion. So, that's how smells become emotion: through association with an emotional experience. Because the premise is that prior to any past experience with a smell, a smell is nothing—a smell is basically meaningless.

Only when it becomes connected to something meaningful does it take on the properties of being liked or disliked, or being able to trigger memories, or being able to trigger emotions. And so, as a function of being connected to something emotional the scent can then trigger emotion. So, a smell that makes you feel really good, or a smell you really like and makes you feel happy, it only does that because of the connection you have to it. There's not a pharmacological truth to that, there is basically just a learned connection between the two.

GC: So, smells don't start out hard-wired to be good or bad.

RH: No. My position is that they do not; that basic smells have no a priori meaning. Now, there's a little bit of wiggle room in here in the sense that many

smells also have what's called trigeminal stimulation—that is to say that it triggers another nerve system in the face around the nose, the eyes, and the mouth—and that's what gives the feel to many smells. So, ammonia feels burning, menthol feels cooling, and many smells to a much lesser degree also have this component.

But when a smell is also trigeminally activating and to a high degree, that can be painful because ultimately high degrees of trigeminal activation are pain. It's the same system that when you're eating a hot pepper causes the burn in the mouth, what makes your eyes tear when you're chopping onions, and so forth. So, if you're experiencing discomfort at the same time that you're experiencing a smell, you're going to back away from the smell. But it's not the smell aspect that's causing the negativity, it's the burn aspect that's causing the negativity. So, if you were to separate the two the odor part of it would not inherently be bad.

And the other caveat to this picture is that more is beginning to emerge about some individual differences between all of us with respect to both the number of olfactory receptors that we individually express and potentially which ones we express. That is to say, there are 1000 genes that have been found for 1000 olfactory receptors that are possibly out there. Animals like mice have nearly all of them expressed as functional genes. And we humans have only between about 350 to 400 of them expressed as functional genes.

Now, this number between 350 and 400 is because different laboratories testing different individuals have found different numbers. And what this means is that people with a so-called normal sense of smell do not all have the same number of receptors, and it's therefore possible that if you just take the 350 they may not all also be exactly the same. And what we know about the numbers of receptors that we possess is that the more receptors you have, the more intense something is. That is to say, mice and dogs who have most of their olfactory receptors

expressed as functional genes can perceive smells at a much, much, much lower intensity than we can.

And so, how this ties into the picture with humans is that if you are someone who has, let's say, more than the average 350 or 360 receptors, or a particular set of receptors for, say, a subtype of chemical in a higher degree of activation than somebody else, you may be perceiving something that I perceive but you may be perceiving it as much stronger than I do. And the stronger something is the more aversive it is. The same goes for all of our systems. So, we could look at a color that we really like, but if the light is really, really bright that is going to be unpleasant. We could hear a piece of music that we love, but if it's played too loud it's going to be unpleasant.

The smell of chocolate could be great at a moderate intensity to someone, but at a really, really high level of concentration it can be aversive. So, if you naturally come into the system with, let's say, the gain turned up for certain chemicals, you may have a predisposition to have less of a positive response to them than someone who has less of that intensity relationship to those chemicals. So, there it seems that there may also be some differences. But fundamentally there's nothing hard-wired; there's nothing inherently bad about skunk and inherently good about rose.

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GC: I want to talk a little bit more about exactly how we smell, but I wanted to ask you one other anatomy question first. What is it about our anatomy that makes us so vulnerable to losing our sense of smell?

RH: Two things are the reasons why we become so vulnerable to losing our sense of smell. One is that, as I mentioned, the receptors are right out there exposed to the environment. And this means that toxins in the environment can

kill off olfactory receptors or damage them. And this is why smokers often complain that they don't feel that they have a very good sense of smell. That's actually because cigarette smoke is killing off their olfactory receptors. The good news is that—because the olfactory receptors normally regenerate on an approximately every 28 day basis—several months after quitting smoking someone can regain a fully functioning set of receptors and then they can smell perfectly well. But the other thing that tends to happen is people who develop sinus diseases, who get polyps in their nose which damage the inner passages of the nose or can damage the receptors themselves, that can cause problems.

But probably the reason why we are the most vulnerable to losing our sense of smell has to do with how the receptor neurons themselves actually go from being at the back of the nose to getting into the brain. And the way they do so is the axons of the olfactory receptor neurons pass through this bony plate called the cribriform plate—and I like to make an analogy that it's sort of like a Chia Pet—so it has little tiny holes in it. And this is where the axons pass through. And this plate is basically a horizontal plate right at the level of your eyebrow.

And if you get hit hard right at the level of the eyebrow—which can happen in football tackles; it's very common in car accidents—anyhow, the sort of hard jar to the front of the head will cause that plate to move, and in doing so it will shear off the axons. Now, what happens here, and why this becomes irreversible, is because when the axons try to regrow, that tissue is normally at that point scarred over and there's no basis for them to be able to pass through the bone again and get into the brain.

And so, what happens when people lose their sense of smell through this kind of accident is that they are probably in the worst case for not being able to regain their sense of smell because there's no possible way for the neurons to get back into the brain. And also as a function of the axons being sheared off where they are, they may not even regenerate. So, both of those two things together usually

mean that someone who's lost their sense of smell in that way is never going to get it back. And because we can get hit in the head so easily, and it doesn't take much, this happens relatively frequently.

GC: What about aging? I think you mention in the book that losing the sense of smell as we get older is very common. Do we know what the mechanism of that is?

RH: Well, it's believed that the mechanism with respect to aging—just like with our other senses, actually – Taste, it seems to be, is the only sense that does not deteriorate as we get older. But with respect to smell, what it seems is going on is that, as I mentioned, the olfactory receptors are normally regenerating themselves on basically a monthly basis, and it seems that what happens as we get older is the ratio of cell death to cell regeneration starts to fall off in favor of cell death. That is to say, regeneration is not taking place as often as it should or as well as it should, so there may be populations of neurons that aren't regenerating at all and the process may be taking much longer. And in essence what seems to happen is that over time that ratio just tips in the favor of there being very few functioning receptors, and therefore that's what leads to the loss of smell as we get older.

Now, there are again a lot of individual differences with respect to this. Some people throughout their life span have an excellent sense of smell. Other people may begin to experience this kind of loss in their 40's, as well as others not until their mid 60's or their mid 80's. So, there is definitely variation in this, just like there are people who will never need glasses or hearing aids. But it does seem that at least by the mid 60's on average people are beginning to lose their sense of smell as a function of the fact that the cell death to cell regeneration is tipped in the balance of cell death.

GC: I apologize, but since this is a brain science podcast I sort of want to concentrate on some of the how-it-works kind of stuff for my listeners.

RH: Sure, that's OK.

GC: Can you tell us a little bit about how the receptors work?

RH: Generally speaking the most accepted theory for how smell works and how the receptors process the chemical molecules that we then perceive as smells is that it's a shape-fit combination. And also that there is a code that a particular chemical produces in the olfactory epithelium as a function of which particular populations of receptors are activated, and potentially also the timing of the activation of those receptors. So that it may be the case that, let's say, the smell of eggplant—I keep using the same examples of rose, and skunk, and so forth—but let's say the smell of eggplant triggers a particular set of receptors. It may be the case that another smell triggers those same receptors but in a different order or with a different kind of spatial frequency. And we don't know quite yet how that might be playing into it.

But the basic story is that it is the array of receptors and that code that it produces that leads to the perception of a given smell. And what's interesting here is that chemicals that are actually very different in structure can lead to the same percept of a smell. And it's also the case that as a function of this structure ligand binding—the fact that a particular chemical has to fit into a receptor in a particular way in order to activate it—the chemicals that are extremely similar, just isomers of each other (which means the exact same chemical but just a different rotation of the chemical), because the rotation is going to affect its fit into the receptor, those two versions of a molecule can smell different. So, there are a lot of interesting features with respect to how the chemical and the percept are actually basically not predictable.

GC: So, that's why we can say that smells like something and it really could actually be something entirely different; because it just has maybe a code that's so close that that's what we think we smell?

RH: Right. And what's also very interesting about this code is it seems that our learning about what the smell means influences this code. So, as we understand that this is the smell of cheese, this particular chemical combination that triggers a certain pattern of firing will be interpreted as cheese. But if you were to interpret that, if you were to have learned that that sequence of firing actually were vomit, then you may never be able to get the cheese sense. Or you get both.

So, depending upon the context. Which is also something very interesting about smell: that the context that we're in when we are smelling something is extremely influential for what we think it is. And literally the exact same chemicals can be perceived in entirely different ways just as a function of the context that they're sitting in when they're being smelled; either positive or negative, depending upon what that context suggests they are.

GC: Backing up just a minute, in terms of what our receptors can detect, I guess you said as a general rule it has to be something that's of a low molecular weight and volatile, and you said it had to be hydrophobic so it would stick to the receptor.

RH: Correct.

GC: Is that the reason why we don't smell something like, say, carbon monoxide or the nitrogen in our environment?

RH: Yes. That's totally true.

GC: OK. So, when we eat and we're chewing our food, then volatile things off the food are then part of what we taste.

RH: Right. What happens when we're eating is as we're chewing we're releasing the volatile molecules from whatever the food stuff is. So, you're chewing on a piece of meat and you are tasting salt primarily, but as you're chewing you're releasing the aromatic compounds that are carried in the fat of the delicious, let's say, barbecued piece of steak. And this then travels up through the back of the mouth through the nose and then passes over the receptors there, and it's what's called retronasal olfaction—that is to say it comes from the back of the mouth in through the nose—as opposed to what we call orthonasal olfaction, which is when we smell the outside world that way. And there are some differences with respect to how we perceive smells when we perceive them through our mouth and through our nose, actually. But when it comes to food, the smell through the mouth is really important in terms of giving us a sense of what it is that we're eating. Because otherwise, as I said, it's just the basic taste of salt, sour, sweet, bitter, or umami.

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GC: Now, when Buck and Axel got their Nobel Prize, was that for discovering the odor receptor types or for the genetic aspect of the discovery?

RH: Buck and Axel got their Nobel Prize on the basis of the genetic work that they did on the mouse; discovering these 1000 genes which coded for 1000 different odor receptors. And that was the number and that was how it worked: that there was a one-to-one ratio between gene and receptor. And that was what their work showed, which led to an enormous explosion in the molecular biology and biochemistry of studying olfaction. And unfortunately the more psychological neuroscience perspective of olfaction has lagged somewhere behind that. But there are many people who are doing really excellent work in the biochemistry and molecular biology of olfaction now.

GC: I'm going to give you a chance to tell us a little bit about the psychology, but I want to talk about one other genetic thing because I thought that it was really interesting. In your book you were talking about the pseudogenes. Do we have basically the same genetic material for coding for smell as a mouse, but most of it's not turned on?

RH: That's correct. So, when I said there are these 1000 genes and then there are X number of functioning olfactory receptors, what that means is that the receptors which are actually doing anything in terms of perceiving molecules are only the number that are functional. So, in a mouse let's say 90%, or 900 of those 1000 receptors, are turned on and functioning. In the human it's only, let's say, 375 of those receptors that are turned on and doing anything, and the rest of those receptors are quiet, so to speak. And the genes that code for them, we call pseudogenes because they're not actually doing anything.

But what's very interesting also is it seems that through exposure, through repeated presentation of a chemical that someone initially can't smell – and what's interesting here is this brings up a topic which is also related to the individual differences in genetics for olfaction. Some people are anosmic, that is to say they cannot smell particular chemicals, where otherwise they have a totally normal sense of smell. It's like a blind spot just for a particular type of chemical, or just a chemical. Also it can be the case that somebody's sensitivity to a chemical is pretty poor. They can smell it but it's pretty weak to them.

It turns out—and this has sort of been discovered serendipitously—that by repeated exposure to the chemical that they formerly either couldn't smell or only smelled weakly, their sensitivity to that chemical seems to get activated. And in many cases where they formerly couldn't smell something—and this has been shown; the most common specific anosmias are to the steroidal musk compounds, and particularly one called androstenone, which is found in human sweat—and people who could not smell it, after being repeatedly tested ended up

being able to smell it. Not everybody, but most of the people in the sample who had that deficit then suddenly were able to smell it after months of being in this experimental paradigm.

And another thing that was recently discovered is that people with a weaker sensitivity to a particular chemical, through repeated exposure could increase their sensitivity to it. This seems to be something which is more so the case in women than in men. And I don't know why, but it could be the fact that women's sensitivity to smell is more biologically based in some ways as a function of the meaning of smell from an evolutionary and mate-seeking perspective, and that there may be endocrine-based reasons—as I mentioned, ovulation is the time of highest sensitivity—that women's sensitivity to smells becomes more activated through exposure than men's do. But in any case, just some recent discoveries.

GC: So, we don't really know whether perhaps the number of receptors is being up-regulated. That would be, I guess, difficult to test.

RH: Right. That has not been explicitly tested, but the guess is that it is: that the receptor that was formerly not activated is now being activated—rather the gene is being activated—and then that receptor follows suit. But it's not known.

GC: OK. I guess one of the big themes of your book—I was thinking when you were talking about the smell of cheese because that one sticks in my mind—you mentioned several times that Asians think cheese smells disgusting. So, an important theme in your book was the fact that our preferences for smell are both based on experience and cultural differences. Would you like to expand on that idea?

RH: Sure. Well, basically what I'm saying there is that because my premise—and it's not just mine, but many people agree with this; although there are still a few people who push for the innate perspective, or at least that there is more of

an innate component than I argue for—but because my perspective is that we come to respond to the odors that we respond to however we do, through learning, we learn about smells in two ways. We learn through our own experience and we learn through our own experience within the fabric of the culture that we find ourselves in. So, one way we learn is that the culture tells us this is food and this is not food, or this is good or this is bad, however the connotation of that particular smell is evaluated by the culture.

Or, that it means something different than it means in another culture. I was actually recently quite surprised to learn that in Latin America musk smells, the connotation actually is cleaning solutions, whereas in North America and probably most of Europe the connotation of musk aromas is sensuality. And there's nothing inherent about the reason why musk should be sensuous or that it should be in cleaning products—I was very interested to discover this—and whereas for us lemony smells and pine smells are what we connote as cleaning products, this is just totally random and arbitrary. The way our culture has presented these smells to us in various products then is how we learn the meaning of them.

So, in any case, you may have been raised in a particular culture that evaluates the smell of cheese as being disgusting, and therefore when you are presented with it that's how you'll respond to it. However, it could be that you have had a personal experience that goes against the cultural norm. Let's just say you originated in Asia but you spent a fantastic year in Paris and you had a great time, met wonderful people, and had wonderful meals. And during your wonderful meals you were exposed to cheese, and as a function of that exposure—which you actually had never had before, you just learned from your culture cheese was disgusting—you actually developed quite a fondness for cheese. So, that's how your own personal experience can intersect it.

Or, another example—and this is actually a true story that I mention in my book—is that a woman once told me she hated the smell of rose because the first time she ever smelled roses was at her mother's funeral. Here in North America the connotation of rose is very positive, but there was an individual with an experience that went against that. So, we learn through both the veil of culture and then our own personal experiences either conforming to that or not, depending upon what the specifics may be for us.

GC: Well, from an evolutionary standpoint is it different from other species? Are there animals that are more hard-wired for certain scents?

RH: Yes. That's a great question because one of the arguments that I base my, you know, there's no hard-wiring, on is the fact that we as a species are what are known as generalists. That means that we can live in any habitat the planet has to offer, and we can exploit whatever resources—and we do, as we well know—that particular habitat has. And this means that what is food is not known until we actually get there; or who or what may be our predators or what may be dangerous to us. And so, what this suggests is that the scent that could be, let's say, randomly associated with a poisonous mushroom in one locale could be associated with very nutritious food in another. Or, if we were hard-wired only to recognize fishy smells as food, then if we lived in a savannah we would starve to death.

And so, we as generalists—as rats are also generalists, and cockroaches are generalists as well—are hard-wired basically to learn the meaning of smells as soon as we have meaningful experience with them, but to not start with anything. So, we're very predisposed to learn the connections. And it is the case that once we do learn a connection to a smell it can happen just one exposure and that's it, and it can be set and very long-lasting.

Whereas animals that have particular ecological niches that they live in—and they are called specialists—it is shown that they do have hard-wired responses to knowing what is the scent of a predator, what is the scent of food, and so forth. And that has been demonstrated both in the lab and in the wild, that for instance a particular kind of gopher that has a certain species of rattlesnake as its natural predator, when exposed to the scent of that rattlesnake—even when it has never had any natural experiences; or gophers that are raised in a laboratory—they show an innate fear response. But not to other snake species that are not their natural predators.

So, it is definitely the case that animals that have very constrained ecological environments—and another example, the panda bear has to know that bamboo is food, because otherwise it's never going to survive—those kinds of animals are hard-wired to recognize what will maintain their survival from both the food and the predator perspective. But animals that can live anywhere, such as us, we do not have that hard wiring. Rather our brains are set up, like I said earlier, the connection between smell and emotion and learning and memory in that little triangle of interconnections is extremely potent, and as soon as the connection is made it's very hard to undo.

[music]

GC: Let's talk about the relationship between scents and memory. I think some people think that memories that are elicited by smells are somehow more powerful. Are they more accurate, or is it just the emotional component?

RH: Well, this is an area that I have been researching for almost two decades, and what I have found through this research is that smells do not trigger memories that are any more accurate than a memory triggered by seeing something, hearing something, reading something, feeling something, whatever the case might be. However, when we experience a memory triggered by a smell,

that memory is felt by us as more emotionally potent. And it's also more evocative; that is, we feel much more brought back to that original time and place.

I have demonstrated this both in the laboratory and naturalistic settings using neural imaging, and found consistently that the difference between smell memories and memories evoked in any other way is that smell triggers this emotional component of our experience much more intensely than the emotional component is triggered through other systems. And this can also lead to the, I think, false impression that these memories are more true. But it turns out that they are not more accurate.

And I believe that this is very similar to what we often hear about in eyewitness testimony where people are extremely convinced about some component of a crime or description of a criminal. And there's a lot of evidence that shows that what people say on the witness stand is often highly incorrect and that here is a situation where they're very emotionally involved in their recollection. They believe it's true—it's not that they are lying deliberately—but their feeling of conviction is augmented by the fact that they're experiencing a great deal of emotion with their memory. And I think the same thing goes for smell, where we experience more emotion with memories triggered by smell than in any other case, and therefore often feel that this memory must be more real.

GC: And this relates to the fact that the smell input is going almost directly to the amygdala.

RH: Correct. Yes.

GC: So, why is it that with most things we can imagine them but with smells it seems like it's hard to think about how something smells?

RH: Yes. That's a very good question. Now, I think this has to do with the fact—and again, this relates to the lack of hard wiring—is that in terms of being able to bring smell representations to the table, we don't really need to do this. As a species what we do with smell is respond to it when we encounter it. Now, there may be animals, because of the fact that they rely so much more heavily on smell in terms of their basic survival, that do construct sort of abstract maps, or visualization, or factoralizations based on smell, without there being any smells actually there. But for us the primary mode of operating with smells is when we smell it we do something; as opposed to thinking in smell.

And because we don't need to think in smell, I think is the reason why we don't image very well in smell—if we do at all. However, there is some argument with this, and certainly people who have smell as part of their trade will say that they are often quite convinced that they can perform this kind of imagery. Perfumers and some chefs I know have definitely told me that they can image in smell.

Now, I don't know whether or not this is true. Unfortunately there have not been neuroimaging studies comparing people who are experts like this who claim to be able to do this and people who are not, to see whether or not the same areas of the brain are activated when they're imagining the smell of apricot, let's say, as when they're actually smelling apricot. But what has been done with our other senses is that we know that when we're visualizing our car—or whatever the case might be—the same area of the brain is activated as when we're actually looking at that object; whereas in smell that has not really been demonstrated.

And the comparison between the expert and the non-expert has also not been looked at. However I would say that it could be possible that the expert has acquired this capability potentially because of the fact that they work so much with these sensory stimuli that over time they do get to form representations. So, it may not be only their egos talking when they say that they can create in their mind's nose the recipe, or the perfume, or so on. It may be truly the case that

because they are so exposed to these stimuli the brain is capable of producing some kind of representation. But it's not the natural state of the brain to do this, I believe, because the brain doesn't need to do this.

GC: Well, that would certainly be an interesting thing for somebody to study and find out if they make odor maps or something.

RH: Absolutely.

GC: And we can't smell when we're asleep.

RH: That's true. This is an interesting and actually a very important thing to know when it comes to smoke alarms: that you really need to have auditory smoke alarms or possibly very, very bright light flashing smoke alarms, or vibrating smoke alarms for people with certain sensory losses. But you cannot have an odor as a smoke alarm, because when you're in the deep stages of sleep—that is, stages 3 and 4, what's called slow wave sleep—or when we're in dreaming sleep—rapid eye movement, or REM sleep—my colleague Mary Carskadon and I found that you really do not show any neurological activation to the presence of extremely strong smells, even very strong trigeminal-activating smells, and you also don't show any behavioral response.

So, not only does the brain not even look like there's anything going on, but there's no rolling or moving or trying to move the face away. And we brought pyridine and peppermint—peppermint being the more pleasant and pyridine being quite a harsh smell that people associate also with spoiled milk—in four different concentrations, the highest concentration being really strong. And when people were awake they were highly responsive to these odors. But when we presented them to them right under their noses with Q-Tips while they were in either deep sleep or REM sleep there was no response at all, pretty much.

Now, in lower level sleep—what we call stage 2 sleep—we do see activation. So, if you were in not a heavy sleep it's possible that you could wake up by smelling something. But in the deeper stages of sleep—or our REM sleep which is actually more where we spend our nights in bed—we are not going to wake up if the fire is burning the house down. And we're also not going to wake up if the bacon is being cooked in the kitchen.

So, what's happening when we feel like the bacon woke us up, or the coffee woke us up, is it is the case especially towards the morning that we start to have what are called micro-awakenings; that is, these very, very brief awakenings where normally you wouldn't really have any consciousness of it and you would fall right back to sleep again. But if there's something very interesting in the environment, like the delicious smell of bacon, that may be enough to bring you beyond the micro-awakening into a greater level of awakening—the 'Mmm, yes, I'm going to get up now and have some bacon.' But that seems to be the way it works. When we are in deep sleep we are not capable of recognizing that there are scents out there, and this has serious implications from the point of view of being responsive to danger signals that are emitted by smell.

GC: Yes. I mean I think it's really important because it's not intuitively obvious that this is true. I think it might be easy to think, 'Well, if there was a fire I would smell it.' And I think that your work convincingly shows that that is not the case.

RH: Yes.

GC: I really enjoyed the chapter in your book about aromatherapy, and I would like for you to talk a little bit about this. Especially, does aromatherapy work? And if so, how does it work?

RH: What I feel is that aromatherapy can work, but the way that it works is through association, again, and that there's no pharmacological basis to odors

having abilities to alter our mood, change our behavior, or affect our health. And what I mean by this is that smells which have become connected to us with feelings of relaxation, stimulation, energy, happiness, or wellness—whatever the case might be—are capable of triggering those feelings because of the very direct connection between smell and emotion. And so, they can sort of feel instantaneously connected to those sorts of attributes. But that is through the connection of association and not through some kind of inherent drug-like process.

And the majority, in fact I would almost say all of the evidence—and I've just recently done a very extensive review of this literature—supports the fact that the basis for responding to odors is psychological through association and so forth, and also context and what people expect. It's actually amazing. There was one study done by Estelle Campenni at Marywood University, a brilliant experiment where what she did was she had water; neroli, which is often connoted as being a stimulating smell; and lavender, which most people consider to be a relaxing smell in our culture. She didn't tell her participants what the smells were. But what she did say was that they were going to be exposed to various smells including in the water condition—just maybe at a low intensity and that maybe they wouldn't be able to smell it but there was an odor there—and that either the smell in the room was stimulating or the smell was relaxing.

And what she found in each condition was that regardless of what the smell was, when people were told it was stimulating—and even when there was no smell there—their heart rate went up, and when they were told it was relaxing it went down. So, lavender, heart rate went up when they were told that there was a smell in the air that was stimulating; and their heart rate went up when they were told the air was stimulating when there was nothing there. And visa versa for the sedating component.

So, this really demonstrates how powerful marketing messages are also when people are expecting certain things with smells. But in any event, in addition to that leading that we are so susceptible to with smells, I think it's also because of the fact that smell is invisible and we tend not to trust our noses very much, we look to the environment to tell us what that smell is, and when it's convincing one way or the other we'll go for it. And the idea that smells can initiate feelings of health or even unhealthiness is also very much the case: that just people's beliefs about what the smell can do or not do will initiate responses along those lines; even the experience of having symptoms like stuffy noses, or sneezing, sore throat, headache, or dizziness when in fact there's nothing there.

So, it's really there's a tremendous degree of suggestibility with smell. But in addition to that with respect to how smells can actually truly make you feel energized, or happy, or calm it has to do with the connection that you have made with that smell. And if you have made the expected connection then the smell can have that effect, but if you haven't made that connection or if you dislike the smell for your own personal reasons then it will not have that effect.

GC: So, what you believe about a smell can actually make you sick also?

RH: Yes. Unfortunately that's true.

GC: I have seen examples of that, since I'm an emergency room doctor, and I've often suspected that was going on. So, when I read that in your book it stood out in my mind.

RH: Yes.

GC: Can you make smell illusions?

RH: Yes. Well, actually we did an experiment in my laboratory with this where what I did was simply by telling people that the name of the smell they were

going to be smelling was one thing or another I made people believe it was that smell. And I worked with odorants that were ambiguous. What I mean by that is that they weren't smells that would be very hard to move around. Like it wasn't as though I was giving them orange to smell and I was saying this was pizza, in which case it would be reasonably difficult to get people to believe me. I could with orange maybe get people to believe it was tangerine, maybe even lemon, but pizza was probably too far afield.

But I was working with smells that had more ambiguity to them. And some of them worked extremely well. One of them was a combination of isovaleric and muteric acid, and in one case I told people they were going to be smelling parmesan cheese, and in another case with exactly the same chemicals I told them they were going to be smelling vomit. And the very same people, given these two different labels, had totally opposite reactions to them, completely consistent with what the label was.

And they would not believe that it was the same smell on both occasions. I didn't give them to them right after each other; there was actually a week separating the two sections of the experiment. But they were completely convinced in each case that it was what they were told and that they were not the same thing; and in one case very positive and in the other case negative. And there were a series of smells that this worked with. That's sort of the most striking with respect to a contrast effect.

But definitely illusions like that can be created. Another great study that was actually done both on the radio and on the television in Britain almost 30 years ago, I think, showed that by actually making a suggestion that there was a contraption on the television set that was emitting a frequency that was going to be interpreted by the brain as a smell, made a number of viewers and/or listeners call into the station saying that they could smell something. And people were

listing all kinds of different things, but somewhat in line with what they were told it was going to be.

So, in one case they were told it was going to be an outdoorsy smell and people were listing things that were found outdoors. In another case they were told it was a perfume smell, so people were listing things that were more like that. But in some cases people called up the radio station and said they were having sneezing attacks, they felt sick, they felt they were getting an allergy attack or asthma. And this happened, not very frequently, but just by the fact that the suggestion alone could induce this was I think amazing.

GC: Do you have any ideas about the mechanism by which we smell things that aren't there? Is it just all psychology?

RH: I think so. I think that there is an inherent fear of smell because of the fact that it's unknown to us, and in terms of it's invisible, and we don't know necessarily where it's coming from. So, I think we have potentially a bit of a built-in wariness—which may be useful, because I think in general the approach of neophobia in the absence of information is more survival-oriented than not. If you're not sure about something, better not to leap in. And I think that this in combination with the fact that the emotional quality of the experience of smell and the whole mental experience of smell is so internal that when we're given a suggestion—when we're given an emotional suggestion like this is going to be bad or this is going to be good—we sort of feel it. And as a function of that we will attribute it to the environment however we do.

So, that's why I think that smells can become so easily associated to those kinds of suggestions, whereas when presented with something visually—if I were to show you a key chain and I were to say, 'Do you like my pencil case?' you'd say, 'Are you OK?' But you know I can do that with smell to a much greater extent

because most of us are very uncertain about what it is we're smelling and will go along with the environment much more so.

GC: And then there's the whole intimate wiring to the amygdala that probably has a role too.

RH: Yes, I think so.

[music]

GC: I guess we're almost out of time, but I wanted to talk about pheromones since I know that most people have heard of those. First, do you want to tell my audience the difference between smells and pheromones?

RH: Sure.

GC: They're not the same thing, right?

RH: No, they're not the same thing. It's a very controversial topic in humans, but pheromones are chemicals that are emitted by one member of a species that are picked up by members of that same species and that either initiate behavioral or physiological responses. And pheromones could be chemicals that have a smell to them, but they can also be chemicals with no smell at all. In fact, in animals that use pheromones as a mode of communication—because that's actually what it is—they have, in mammals at any event, and reptiles, another organ called the vomeronasal organ, which is actually what apprehends these kinds of chemicals because they're too big to be processed by the olfactory system. They don't meet the physical requirements for the olfactory system, so they're processed through a different organ, and they're also processed in a different part of the brain; a place called the accessory olfactory bulb. It's adjacent to the main olfactory bulb but it's not the same area, and there's this different organ that is involved with apprehending that.

Now, with humans there is the possibility of what is called a primer pheromonal effect, which is to say that it has a slow physiological response in us but there is something chemically mediating doing this. And in this particular case it's called the McClintock effect, or simply the fact that women who live together over periods of time start to get their menstrual cycles in sync with one another. And this seems to be something that has to do with chemical transference among the women living in the group, but whether it's actually something that happens through smell or through the olfactory system in some manner or other, or whether it just has to do with some other means by which the chemicals of one woman are getting, let's say, into the skin of other women who she's living with, or potentially some other mechanism, is not well known.

But unfortunately for the perfume industry there does not seem to be any evidence of any smell-based, or even non-smell-based chemical that can initiate any immediate behaviors. In particular what we see in the animal world which has become so fascinating to the fragrance industry, is sexual behavior that's initiated through this kind of chemical communication. And the Holy Grail is to be able to uncover whatever that chemical would be in humans. And there doesn't seem to be such a chemical.

The point is that people have made the argument that in humans we could be using the olfactory system in some other way to process pheromones since they could have smells to them, and maybe this is where humans are different, when it comes to pheromones, than other animals. But the bottom line from the sort of basic perspective is that it has only been shown in very restricted cases; like I said, from the point of view of menstrual cycling is really the only one where it's well demonstrated. And even that there are people that critique this argument and say that it's a statistical artifact. But from the point of view of behavior or anything else that happens, there really is no evidence that chemicals are producing changes in behavior.

And so pheromones as a definition—a chemical emitted by one member of a species influencing other members of the same species—it doesn't seem that there is much effect, if any really, going on in humans. And it's certainly not from a behavioral perspective. Potentially is does seem to be that there is at the physiological level, but only in very specific sorts of cases.

GC: I just wanted to make that distinction, because I think a lot of people have heard about the study with the men's T-shirts and how women will pick out the one with the different immune system. But that's smell.

RH: That's smell, yes.

GC: Right.

RH: So, smells do influence us from a sexual perspective, especially for women. How a man smells is very important for her attraction to him as a function of the complementarity of her immune system and his immune system. And our body odor it turns out is the external fingerprint of our immune system. Every single one of us has a unique body odor, unless we have an identical twin. And this is the reason why certain women will find a couple of guys' smell attractive, whereas another group of women or another woman will not find those same men's smell attractive. Because everybody's different, and there's going to be a different set of men that are going to be smell-attractive to each woman.

And it turns out that when you are smell-attractive to a woman this correlates well with having a complementary immune system. But the caveat to this, or in the study that this was looked at, women who were on birth control pills did not show this response. In fact they showed the opposite response: having a preference for the smell of men who were more similar to them, which in a biological situation would not be desirable.

And also what it seems to be is that men can mask their true identity genetically with colognes and body sprays and so forth, and that colognes and body sprays are also something women are attracted to, and that once a relationship is established it doesn't really matter what the guy smells like anymore because you've already formed your emotional attachment to him. And as a function of that maybe the body sprays don't get used anymore or the cologne doesn't get used anymore, but because of your emotional connection to this person now being so positive, however he smells will be positive to you. And that can also potentially lead to, let's say, biological mistakes.

And the way that it seems, though, that people may be doing this is not some sort of strange innate sensing system—this person is the right smell, this person is the wrong smell—but rather that what we are inherently doing is avoiding the familiar. This is like a smell-based incest avoidance mechanism. If you smell like family you're not fit to mate with.

And the reason why this seems to be the case is that in one experiment that demonstrated this with mice—and this has been well examined in mice, much more so than in humans—they did a really clever experiment where they took the pups after they were born from one litter and they cross-fostered them in another. And then when they reached maturity they were given the challenge of do you want to mate with your biologically same siblings but you haven't ever smelled them before because you haven't grown up with them, or do you want to mate with your non-biologically same house mates, as it were, who you've grown up with. You know their smell, but they're actually not biologically related to you.

And the mice make the biological mistake: they choose their siblings who are unfamiliar to them by smell. And therefore it seems that potentially what's going on in humans is that we're avoiding smell of brothers and dad as opposed to having some more basic biological sensing system that may be attributed to

determining this. But that's also speculation at this point based on the animal research.

GC: Yes, I was thinking that the whole thing could be kind of tricky if you were using birth control pills and you met somebody you really liked, and then you were like, 'Well, should I quit taking them to see whether or not I still like the way he smells when I'm off the pill?' But I couldn't really figure out the practical way exactly to approach that problem. It seems almost like a piece of information you might not even want to have.

RH: Right. Well, what I've said to people is just sort of as a general strategy if you're in that stage of life where you're looking for the man that you want to have as your life partner and to father your children, that it may be better to go about this general approach to things not being on the pill. And also maybe asking your dates not to use too much cologne and so forth, so that you can get a better sort of biological assessment in this regard. But, as you said, if you're already on it and you meet someone and you really like them, do you want to go off the pill just to find out what happens next?

And you know certainly the changes in your hormonal system don't occur instantaneously after being on the pill for awhile. So, from a practical perspective at that point it may be hard to do anything. But if you're sort of setting out in that point in your life—you know I'm on a mission and I want to meet a man and I want to have a family—then you can use, I think, the approach of not being on the pill and trying to get their natural smell as part of the information you gather about your possible partners.

GC: Well, we've used up a good amount of time and I really appreciate you taking so much time to talk with us today. Is there anything else you'd like to share that I've left out that you think is important?

RH: I think that we've covered a lot, as you said, and I think that my book also goes into more detail about social relationships; also relationships concerning mothers and children, parents and children, other kinds of social relationships where negativity about smell has been discovered, and other areas which I may not have talked about so much in this interview. But I think that we've certainly covered a lot in this interview. Unless you have a burning question.

GC: I highly recommend your book, and I think there's an awful lot of good stuff in there about the consequences of the loss of smell, because we didn't really have a chance to get into that today. But, you've got a lot of wonderful examples from real life that I think communicate those ideas better than I could just by summarizing them.

RH: Well, I hope so. I hope that people will be interested in the book. That's certainly a hope of mine.

GC: I will link to your book on my website and in my Show Notes, but is there any website in particular that you have?

RH: I have two websites. I have one which is just www.rachelherz.com, and then I have another www.scentofdesire.com. Both of those websites could be used as links.

GC: Do you have links at your website to academic studies and things like that for my more academic type listeners?

RH: In the one that's mine—www.rachelherz.com—under one of the pages which has to do with my academic history I have a list of references of certain of my papers. But I don't have an extensive list of the general topic. In terms of trying to find the specific references, my book has a whole lot of references in it to the particular experiments that I've mentioned in this interview and also that I

cover in the book So, I don't have one that links a whole set of downloadable articles other than listing some of mine.

GC: OK. Well, that sounds like a good place to start, because it seems like this area of research is a very new one and has lots of questions that are unanswered.

RH: Yes. Like I said, unfortunately although it's been almost two decades since the discovery of the genes for olfaction and how, like I said, the molecular biology and biochemistry really revved up in this area as a function of that, the psychological side of things and the neurological side of things has lagged behind, and there are still only a handful—maybe larger than a handful—but certainly nowhere near the number of people studying olfaction from a psychological or neuropsychological perspective as there are in the more molecular fields. And as a function of that there's just less information out there.

GC: What burning question do you want to answer before your career is over?

RH: Well, I am currently really fascinated about the individual differences in genetics and how that influences our predispositions to smells. I think partly because I've made such a case about us coming to all our hedonic responses to smells through learning, I'm very curious to know more about the potential for there to be something more hard-wired or more sort of biologically fundamental about some of our responses. So, I'm very excited about the research that's coming out with respect to what those individual differences may be.

And there also seem to be, in addition to there being individual differences, that there could be some racial differences. And this may also tie in potentially with why Asians think cheese is disgusting. It may be more than just a cultural affectation. It may be somehow based in the fact that maybe Asians have more receptor activation to some of the chemicals that are found in cheese. So, this is

something that would be very interesting to know and it would complete the picture. And I'm very fascinated by this.

GC: Well, I will look forward to seeing what else we learn, and I will keep track of what you're up to. So, I will let you know when everything's up and give you the links and everything.

RH: OK, great.

GC: Thanks a lot.

RH: Thank you, Ginger.

GC: I enjoyed it very much.

RH: OK, good. Great. Thank you.

GC: OK. Bye.

RH: Bye bye

[music]

I want to thank Dr. Herz again for coming on the *Brain Science Podcast*. I hope you enjoyed her interview as much as I did. I highly recommend her book, *The Scent of Desire: Discovering Our Enigmatic Sense of Smell*. It's highly readable and there's a lot of information in there that we weren't able to get into during the interview.

Before I do my closing announcements I want to thank those of you who have sent in contributions to help support the *Brain Science Podcast*. I occasionally mention that I am trying to build this into a full-time job, but of course at the

present time I'm a long way away from that and still working my full schedule as an emergency room physician. But every little bit helps.

I also want to thank those of you who have mentioned me in your blogs, and thank everyone for sharing the podcast with your friends and family. I also appreciate your reviews on iTunes, Podcast Pickle, PodcastAlley, and even Digg. Word of mouth is extremely important to bringing the *Brain Science Podcast* to new listeners.

The *Brain Science Podcast* has been recently fairly consistently ranked at #3 on the Medicine Page of iTunes, but I can't seem to get it onto the main Science page. I don't know what it takes to do this, but if you are listening to the *Brain Science Podcast* and you use iTunes but for some reason you haven't subscribed in iTunes, it might help if you just went in and subscribed.

One other thing that I keep forgetting to mention is that I've been using del.icio.us to tag articles on the Internet that are related to brain science, and the way I am tagging them is I'm using 'brainscience' as one word as a tag. This is an idea I got from listening to some the *This WEEK in TECH* shows. The idea is to pick a tag that won't get randomly used by other people, so by making brain science one word it tags it as being related to this podcast. So, if you see an interesting article that you want to share with others and you use del.icio.us, try to remember to go in and tag it as 'brainscience' with one word. And I have an RSS feed for this del.icio.us tag on the website, so that is one place where other people will be able to see it. And I'm going to try to start getting into the habit of monitoring that feed because I know there are some of you who are constantly putting up good ideas on the Discussion Forum and I'd like to have a way to get these links into the main website.

The Discussion Forum at brainscienceforum.com is a great place to go if you want to talk about the ideas that we have discussed on this show with other listeners,

as well as share your ideas. And there's also a place on the Forum for you to share a little bit about yourself and links to your blogs or websites, even if they aren't related to brain science.

We also have a *Brain Science Podcast* group on Facebook and one in Flickr, although the one in Flickr has not been as active as I would have hoped; because I'd love to see more pictures of where everyone is from, since I get email from all over the world. You can find links to all of these places on the website at brainsciencepodcast.com. And, as always, you can send me email at docartemis@gmail.com. When you send email it's a good idea to put 'Brain Science Podcast' in the subject line so that your email doesn't get put into junk by my spam filter.

The next episode will be out in a couple of weeks and it's going to be about mirror neurons, which is one of the most exciting recent discoveries in neuroscience. I'm also working on scheduling some follow-up interviews related to Episode 31, which was a somewhat controversial episode about language evolution.

Thanks again for listening. I look forward to talking to you again soon.

[music]

Transcribed by Lori Wolfson
All errors or omissions responsibility of the transcriber