Transcript of Dr. Ginger Campbell's
Brain Science Podcast #22
Interview with Dr. Christof Koch of Cal Tech, October 8 /07

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GC: *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**, I explore how recent discoveries in neuroscience are unraveling the mysteries of how our brains make us who we are.*

(music)

*Welcome back to the **Brain Science Podcast**. This is episode 22. Today I have an interview with Christof Koch, who is one of the pioneers in the scientific study of consciousness, and the author of the well-known book, The Quest for Consciousness: A Neurobiological Approach. (snip) Let's get right into the interview.*

Interview

GC: Dr. Koch, I'd like very much to thank you for being on my podcast - I know you've had a very long day today. I know that not all of my listeners are familiar with your work, so I thought that maybe you could start out by telling us a little bit about yourself, your background, and how you got involved in neuroscience research.

CK: I'm a professor at the California Institute of Technology, and I'm there since 21 years. My background is in physics - I have a PhD in physics - but then I moved from physics into neurobiology studying the computations performed by the brain. At Cal Tech now I specialize in vision, visual perception, visual attention, how do animals see, how do people see, visual consciousness. At the same time I'm also a professor of engineering; we're trying to build machines that can see based upon principles that we find in the thalamic brain. This is called neuronopic engineering, taking something from the brain and adapting it to engineering purposes.

GC: And you originally would you say that Francis Crick was your mentor, or...?

CK: Well he was my PhD mentor - I met him.. in fact I met him during my PhD but then when I moved to California he at the time was at the Salk Institute in La Jolla... we met early on once a month at a club called the (unintelligible) Club with other physicists to discuss questions of mind and brain and how the mind relates to the brain. And then in 1988, 1989, I got to talk with them a lot about consciousness and how the mystery of consciousness and how that consciousness relates to the brain. And then we talked in 1990 our first tape on the topic and ever since then we've collaborated virtually until the day he passed away in 2004.

GC: I've heard other scientists say that he was a wonderful mentor because he always encouraged people to ask the big questions..

CK: That's correct. I never shied away from asking the big questions. And the other thing that was remarkable, he was willing to talk to anybody with an interesting story to tell him, undergraduate, author, graduate student, professor, an employee, it didn't matter as long as the person had some interesting question and some interesting point of view. And he, very early on, people, scientists, particularly brain scientists, confronted them with the fact that the system they were studying, the brain, actually feels like something to have a brain. It's very funny - you can read a modern textbook on neuroscience and nobody ever mentions the fact how it feels to be an owner of the brain. Because when I have a brain I don't just move, I don't just act in the world, I actually feel - I have sensation, I

have pain, I have pleasure, I remember things, I feel things, and so how do feelings come into this? How does consciousness come in, enter in this? And that's the big question he asked people. He poked - he sort of - he poked fun at neuroscientists who were studying the brain without asking this very simple question obvious to sort of.. any child; how can a brain exude feelings? Where do these feelings come from? How do they relate to the brain? Do they relate to the entire brain? Do they relate to a particular area? What part of the brain do they relate to - do they relate to the neurons in the brain? Which type of neurons? These are the sort of questions he asked and then we jointly asked for a span of nineteen years.

GC: I guess attitudes have changed - now the neuroscientists are finally willing to actually look at the question of consciousness.

CK: Yes, now it's a much more popular topic at this point. Now there are big meetings organized on the topic of the neuroscience of consciousness, the psychology of consciousness, that's right.

GC: Now, I've been doing the ***Brain Science Podcast*** for almost a year, and I've only devoted one episode explicitly to consciousness, but it's a subject that probably gets more discussion on my discussion forum than any other subject, and in fact there was a bunch of postings on there today, which is the reason why I'm going to ask you to start out by giving us a working definition of consciousness.

CK: OK..that's not easy, and by the way people think, well..how can you do any science if you don't define things? So if you go back in the history of science, people almost never define things. It's sort of very ad hoc and I like it that what you say working definition - it's sort of very ad hoc definition that we were constantly ready to interpret change. You may note even today when something like a planet if we just redefined a planet and we all grew up learning there were 9 planets, ... well Pluto just, you know, was defined.. you know, isn't a planet anymore - they redefined what a planet is. So even something as planet which surely are big and sort of you know you should be able to notice them, they should be noncontroversial, even there the definition changed.

For consciousness there are at least two different definitions; well, OK there are different definitions depending who you talk to. When you talk to philosopher, or philosophy well, the phenomenal aspects - it feels like something to a pain, it feels like something to be me, it feels like something to be angry. And when I'm dead, when I'm in a deep sleep, when I'm in a coma, I don't feel any of those things.

(music interlude)

(GC: Unfortunately I accidentally turned off the recorder for part of Dr. Koch's answer to this question about the working definition of consciousness. Rather than take away from what I did get I'm just going to rejoin the recording. I just want you to understand why there's a discontinuity and I apologized to Dr. Koch for that. I think you'll be able to get the main thoughts that he's putting forth.)

CK: You know after a bad traffic accident the person may be what is called a (unintelligible) vegetative syndrome. The person looks almost like they're dead, or sometimes the person may open the eyes - remember Terry Schiavo a couple of years ago? The patient down in Florida?

GC: Yes..

CK: So there she opened her eyes, she looked like she was smiling, sometimes she was sort of grimacing, but as far as we can tell there was all zombie behavior - that was all automatic reflexes. So there we would say .. again that is a different definition of consciousness. So it really depends on your point of view - there's no universally accepted definition of consciousness. In fact I claim that you really have to be conscious in order to know what consciousness is, because otherwise, I mean if you look at books, for example in the British standard Oxford dictionary you find seventeen different definitions but most of them are circular, most of them are something like, "consciousness is when it feels like something to be conscious", you know, which is not very useful. So somehow it relates to this feeling aspect, to this phenomena, to this subjective, this ineffable aspect.

GC: Do you think that awareness is any part of what consciousness is at least when you're trying to figure it out in your work? Is awareness a part of your..

CK: Yes, so this now begins to get a little bit more technical. Some people say awareness is just a different word for consciousness, it's just something... today even among some scientists, amongst polite scientists, sometimes you can't - you still can't mention "consciousness" or you'll sort of evoke sort of, you know, snickers. But "awareness", it's OK, so to many, particularly to me, awareness and consciousness are usually interchangeable. Some philosophers and some scientists distinguish between awareness, which is sort of a little bit more low-level compared to... you know, "I'm aware of you" compared to "I'm conscious of you." I think it's a linguistic convention and for me it's the same.

When I'm aware of you, when I'm aware now looking - I'm sitting in here in Seattle in a hotel room overlooking downtown Seattle and I'm aware of the sky, I can see the sky, I'm conscious of the sky. I treat these terms as interchangeable.

GC: I do too. In your book, ***The Quest for Consciousness***, you describe your work along with Francis Crick in trying to discover what you call the neural correlates of consciousness. Is it possible to define what you mean by neural correlates of consciousness?

CK: Yes so the technical definition is it's the minimal set of neuronal mechanisms that are jointly sufficient to give rise to a specific conscious percept. What that means is the following: that if you see blue, let's say I'm putting you in front of a model - you come to my lab, and you're sitting in front of a computer screen, and I show you a blue screen. Where are the mechanisms in the brain that give rise to "blue" compared to when I show you a red screen? Because then you're conscious of "red" which is different than "blue".. blue definitely doesn't.. I mean it's similar, in both cases you have a visual feeling, you don't have a toothache, but they're different visual feelings.

Or you sit there and suddenly your little toe really hurts because somebody just stepped on it. Again, that's a conscious feeling. What are the pathways of pain that are specifically necessary to mediate this painful feeling in your toe, or the feeling of red, or the feeling of being angry - it feels like something to be angry. Where are the neurons that are responsible for that? Now we know from patients like Terry Schiavo there's some neuronal mechanism that has to be in place for you, in order for you to be conscious at all. For example, if your heart isn't beating, it's not pumping blood into your brain and you'd be unconscious. So clearly the heart is necessary for you to be conscious but it doesn't..the heart doesn't mediate any conscious sensation.

Likewise we know there are many structures in the deep brain and the brain stem that are necessary for you to be conscious at all. And assuming now, you're conscious, I'm conscious - now you're conscious of my voice, where are the neurons that are responsible for generating the conscious percept of my voice? Probably not the neurons in your eye or your retina. Probably not the neurons in the cerebellum. Probably neurons in your auditory cortex. But, all of the neurons in your auditory cortex? Just a subset of the neurons? And furthermore is there something special about the way the electrical activity of these neurons... maybe it's just not .. maybe for lots of processing - unconscious processing - you have one type of electrical activity but for conscious processing maybe you have a different type of electrical activity like... people have proposed that neurons oscillate, that they... you know, they fire in certain rhythmic discharges - so those are all questions of the different character of the neural correlates of consciousness.

GC: You have chosen to concentrate on the sensory aspects of consciousness and vision in particular. Why did you choose vision?

CK: As the leading philosopher Arthur Schopenhauer noted a long time ago, vision has lots of illusions. Vision is a sense that's very powerful - it's a long distance sense for us... and it's very powerful but you have lots of illusions that we can exploit where we can dissociate, where we can cut the simple relationship between the outside world and the world in my head, my mental world. So for example when you go to a magician, the magician will distract you, so you are looking at the magician but you will not see him moving his hand very quickly and doing a sleight of hand. So here... and there are hundreds of illusions like that where you're looking at things but you're not seeing them - even though I can tell you ahead of time, "look at this", particularly in the lab, and you don't see it. So why is this interesting? Well, this is interesting because now we can study the part of your visual brain that responds just to the visual stimulus.

To give you a concrete example, there's a proper illusion we discovered called continuous flash suppression, continuous flash suppression. It works in the following way: I put in front of your left eye,

let's say an angry face, OK? So into your left eye using a computer monitor or something - a mirror, I project the image of an angry male face. Usually that's very... I mean usually that immediately catches people's attention. In the right eye I flash a series of colorful splotches - a square, a rectangle, red, green, blue, whatever, but very quickly, all right? at the same location. In the left eye and the angry face I have a series of colorful flashes. Now the colorful flashes totally attract the attention. Now, though both of the eyes are open you will never see the angry face, unless you blink - unless you close your right eye, then immediately you see the angry face in the left eye. But if you keep both eyes open, and we can make sure of that using controls, you don't see the angry face. But physically it's present on the retina. So that's cool because now we can track the footprints of consciousness in your brain. How do I do that? Well, I can ask the question - first of all I close the right eye and clearly I see in my left eye, I see an angry face, and I can see approx - I can put you in a magnetic scanner while you do this, and I can see where the part of the brain that respond to the physical image of the angry face and to your subjective conscious percept of the angry face.

Now, I flash - I keep the left image on, the angry face, but now into your eyes I flash a series of colorful rectangles and squares, and the left image will be suppressed. It's wiped from visual conscious. You don't see it at all anymore with your eyes still open. So now I can ask, now, instead of the same physical input, your left eye still sees exactly the same stimulus - it's still gonna excite your eye, it's probably still gonna excite nerves in your visual brain, and at the back of your head, but somewhere in the brain, the neurons that are responsible for the conscious perception of the visual face, they're somehow not active anymore - they're suppressed because I don't see the angry face anymore. Right? So this way I can see.. now I can compare the brain - if I put you in a magnetic scanner I can compare how does your brain look when the face is present in your eye and you see it compared to how does your brain activity look when the face is present on your eye but you don't see it, you don't see consciously anymore. Using this contrastive, subtractive strategy I can now see where the pathway degraded specifically to respond to the conscious percept of the face. So this allows me to track the footprint of visual consciousness for the brain. And I can do the same thing in the brain of a trained animal, once in awhile I put electrodes into its brain to sample how the evolution the neuronal activity. And I can do this much better in vision than any of the other domains like olfaction, like feeling of sense, all these other conscious sensations - I can't fool them as easy as I can fool vision.

GC: So it's partly because you have these visual illusions to work with to tease apart the parts and also the fact that you can use the animals to do experiments about vision - isn't that also a part of why vision is such a good experimental ...

CK: Correct - because we know a lot about vision, and there are very good animal models of vision, so for example the monkey - the macaque monkey- which..it's not a rare species, they breed very well in captivity, they adapt very well to these experiment.. I mean they're very curious creatures and they like to play video games just like humans do, so essentially you can train them. You put them in a little chair and you train them to respond you know for example to do similars - for example I tell the monkey, I tell him indirectly, I train him to, every time he sees an angry face, he pushes the left lever, and if he sees these colorful squares and rectangles he pushes the right lever, and if he does it correctly he gets some orange juice or apple juice. And so now I can train him to do this, and at the same time I can put electrodes into the brain - the brain doesn't have any pain perceptor - although the brain is the organ ultimately that generates pain the brain itself doesn't have any pain receptors so, just like in a patient with deep brain stimulation you can put electrodes into the animal's brain if you are very careful and clean and hygienic about it. And so now you can record the activity of individual neurons - you can listen for the chatter, you can listen to the way neurons talk to each other, try to decode the language used by the neurons.

Ultimately what we can do with partial brain imaging that's very cool and very exciting - we can do it - lots of people do it - what's very cool is you're tracking power consumption of the brain - that's essentially what we're looking at. Ultimately, if you want to understand consciousness or memory or such then you need to go to the "atoms" of perception or the "atoms" of consciousness and those are the nerve cells - you have to understand what is "vision" in neurons, how they talk to each other, how they communicate with each other, and what code they use. And *that* you can primarily only do using electrodes that you can implant into animals or sometimes also into the brains of patients.

GC: Because the limitations of MRIs it's really an indirect measurement of what the neurons are doing since it's really a reflection of blood flow or other metabolic...

CK: Yes, that's correct. As I said they reflect ultimately power consumption - the neurons in my visual brain are very active, they require lots of oxygen, and the demand oxygen goes up, and you oxygenate the blood rushes in, oxygenated blood compared to deoxygenated blood has slightly different magnetic properties - that's essentially what you can track using the technique of magnetic resonance imaging. It's very cool because you can do it again and again in normal healthy people without any lasting side effects. It's slow, it's sluggish, because the blood flow takes a couple of seconds to increase and five to ten seconds to decrease so it's fairly sluggish compared to the time scale of nerve cells. They switch at a time scale of a thousandth of a second, and it's also very cool in terms of spatial resolution since the smallest volume you can image in a magnetic scanner tends to be, you know, like a pea maybe, like the size of a green pea, you know like about two by two by two millimeters. This little voxel, this little volume element of brain tissue contains maybe on the order of half a million neurons. So here you're looking at the average bulk activity of half a million neurons and we have to decide what is this one telling this other neuron.

(Musical interlude)

GC: Dr. Koch's book came out in 2004, so one of the questions I asked him during the interview was what key discoveries have been made since his book was published.

CK: Well nobody, I mean the field has really exploded over the last several years, over the last 5 to 10 years - there are all these cool techniques now, so for example you can show something very new. So for example the output of the eye, of the optic nerve, goes through a way station in the middle of the brain in the thalamus to the back of the brain. So you should feel this - everybody can feel this, so if you're listening to this podcast you should put your finger on the back of your head - you should feel a bump there. You may want to try this Ginger - you can feel a bump at the back of your head? At the base of the head?

GC: Mmm-hum...

CK: And your visual brain, the primary recipient of the output of the eyes sits just let's say a finger's width or centimeter above that bump. It's called the occipital cortex at the back of the brain. For example if you get whacked with a baseball bat or if you fall backwards onto, you know, hard cement or something - don't try this at home, it's very dangerous - you can see flashes of light, because it's directly stimulating the tissue.

For example some remarkable functional imaging experiments in England have shown that activity in cortex - this is to do with cortex, so cortex is what we think makes us different from, makes us more powerful, or you know, more intellectual, you know, having more cognitive ability than for example monkeys or closest.. or chimps, our closest relatives. Cortex is sort of this sheet of neurons at the top of the brain. But there for example experiments could show that you can have actual brain imaging activity in the visual part of the brain although you yourself are not conscious of the activity. It's interesting, because it tells us what Francis Crick and I surmised many years ago, that it's just not true that any activity in cortex automatically becomes conscious. It's not just to.. again it's very easy the question of NCC - is it true that any activity in your cortex proper - now that always give rise to conscious sensation. And that's clearly not the case. Animal experiments have shown and now human experiments have shown that activity that you can see in fMRI, or that you can see in animals when we're using electrodes, it doe not give rise to consciousness. So it can't just be any neural activity.

Something else people realized over the last five years is that by having very clever psychophysical experiments where you manipulate what people see and what people attend to, that attention and consciousness are closely related but they're really separate processes. In fact really cool experiments have shown that you can attend to something but still not see it. Conversely you can be conscious of something without attending to it. So these processes very often they are related - usually when you attend to something, you know, when your teacher says, "Attend to me", usually the student will become conscious of the teacher. But at least under laboratory conditions often you can dissociate this very strong link between attention and consciousness. You can show they are actually different processes. And any evolution of any science, that's always a common process that you try to isolate what's actually... you know, what is actually core concept of consciousness. Is attention actually, really.. it's related to consciousness but it's actually separate thing from consciousness, so you really want to isolate consciousness - now if it's visual consciousness, to really be able to study, isolate, identify, and

then ultimately what we need, we need a *theory* of consciousness - we need to understand why certain systems, certain biological systems, not only biological systems mind you...

So you may know, Ginger, in your intestines you have a complicated nervous system called enteric nervous system, sometimes referred to as the second brain in your gut. It has roughly a hundred million nerve cells - it's quite complicated - it's responsible for all sorts of things that you'd rather not want to know about, down there, you know, in the plumbing.. but it's not *conscious*.. it does all of its work, day in, day out - usually you have no idea what goes on.

There's another very complicated system called the immune system, and it fights off invaders, viruses, bacteria, every day, but there's no sensation associated with it. You don't feel anything. It does its work without consciousness.

So, what is it about certain parts of the brain, in us and in other species like, probably all mammals, maybe many other species, that gives rise to consciousness? We need a theoretical understanding. Does it relate to brains? Could it also happen in other systems? Could it happen in bacteria? Or could it happen in the internet? Is my MacIntosh maybe conscious but it's not telling me? Those questions people have raised - you know, machine consciousness, and to answer them we need a theory of consciousness - we need to understand at the principle level which system will have this ability, will have, you know, these feelings and why do they have them and does it relate to brains? - Or can other systems have it etc. Or maybe it's so complicated that maybe it will never be a theory, I mean not everybody wants a theory about consciousness - some people think it relates to, you know, to "soul" and some people believe.. it relates to a physical category that the scientists were unable to grapple with. We don't know the answers to those questions yet.

GC: Now one of the things I enjoyed about your book was that you really took us through the various parts of the brain that relate to vision and explained why we know that most of those parts are *not* the neural correlates of consciousness - for example as you just alluded to, the retina's not, since we really don't see what's coming in on our retina - a lot of processing occurs before it reaches consciousness, and on my podcast I've talked a lot about the things our brain does that we're not conscious of, and we've talked about the frontal lobes, and one question that came to my mind as I was reading about the different areas of the brain - I sort of thought to myself, well, how come the frontal lobes are *not* the neural correlates of *visual* consciousness?

CK: Well, that is controversial too, and in particular Francis Crick and I have a proposal, that we did in '95, that says that in order for you to be visually conscious of something, you have to have neurons essentially in the back of the brain, the visual brain, that establish a two-way communication with neurons in the front of the brain, in particular the prefrontal cortex. The neurons in the back of the brain that sit in the higher-order visual cortex need to project into prefrontal cortex, need to fire, then the recipient neurons need to feed back this activity, back to the visual brain, then you establish the loop, you establish a reverberant loop, and properties associated with those neurons, whatever those neurons represent, that's what you become conscious of.

So we specifically do believe that pre-frontal cortex will include part of the, will be essential for part of consciousness, that if you remove prefrontal cortex, you could maybe still, the patient could maybe still do certain automatic visual behavior, just like if, you know, you just walk on the street, you know, you automatically avoid running into people without thinking about it.

All of those behaviors are probably all what we call "zombie" behaviors. They're probably all automatic, behaviors that needn't become conscious at all, or you're only conscious of those behaviors after the fact, and there are lots of experiments that speak to that.

But for conscious visual behavior, when I really look at you and recognize you, for that we say that neurons in prefrontal cortex have to be involved.

GC: OK, so they are involved but they're not the whole story.

CK: No, you need neurons in the back of the brain that provide you the visual input or that provide you the auditory input if it's a, you know, if I can give you voice or podcast, or that provide me the tactile information, you know if I'm conscious of something touching my leg - it's sort of, crudely speaking, you could say the back of the brain is exceptional for ... special case, smell - the back of the brain is

essentially sensory, it represents sense information - tactile, visual, auditory information. The front of the brain is looking in some way at the back of the brain, it's interpreting that, and in this dialogue, it has to be a mutual dialogue between the back and the front, you establish these reverberant circuits, and your networks, and that's how conscious, we think, and a number of people think that's how self-consciousness happens.

GC: And that's the reason why you would say, I think, that consciousness is an emergent property? That involves the entire nervous system or at least most of the brain?

CK: I mean, "emergence" is sort of a fuzzy concept that means, can mean almost anything. I mean it's "emergent" in the sense that there's no evidence that a single neuron is conscious. And so in that sense, you know... what's "emergence"? What kind of democracy emerges out of a society of individuals? Like, it definitely makes sense to talk about democracy at the level of one individual but then you take, you know, a few million people like New York, and you have a certain political system and it's a democracy, so you know, a democracy "emerges" out of a society.

But likewise clearly consciousness is a systems property in the sense individual components of the system probably don't have it, the neurons, and you need many many neurons - how many neurons? We don't know. You know for example there's one of the simplest animals, it's a *C. elegans* little roundworm, very famous in biology, people got Nobel Prize for it because we understand it quite well. It only has 300 neurons. It's a little worm. Is this worm conscious? Well.. we don't really know, we don't really know how to answer the question. Now is it some magic number of neurons that you need? We don't really know. So in some sense, yes, conscious is an emergent property. But that still leaves totally open is it a property of entire brains? Some people say, you know it's a holistic property of the entire brain. You take any small part of the brain away and you'll lose some aspect of consciousness. Now I think that's wrong. I think you know, if you take my spinal cord away, maybe I can't move anymore, but I don't see any evidence that that's going to influence my visual consciousness. Likewise you take my cerebellum away, you know, the little brain below the cortex, and yes I'll have trouble maybe running, or maybe playing violin or piano, or playing you know a fast video game, but again, I don't think it's going to interfere with my consciousness. So, I don't think it's true that it's a holistic property. It is a property that involves probably many neurons, across many parts of the brain.

GC: That makes sense.

(music)

GC: Do you want to talk a little bit more about the idea of the zombie? And in particular could you tell me about the difference between the kind of zombie that you talk about in your work and the philosopher's zombie?

CK: Sure. A philosopher's zombie is a person just like you and me, in fact you could be a zombie in the philosophical sense, because this person looks and talks just like you, and just like me, just like any other person - the person has a brain etc., but this person, I mean it's a fictitious experiment, right? This person has no inner life. It doesn't feel like anything to be a zombie. So a zombie's just a total automaton. Now, philosophers are the first to say that this person doesn't exist, but they think the area's a useful, methodical... devised to sharpen your intuition about consciousness. We'd beg to differ for various reasons. Now either we say there are zombie systems in your brain - as I mentioned before there are many systems in your brain that work without you being conscious of them - or, you're only conscious of them after the fact. So, for instance, when you move your eyes, you can show - there's some very nice experiments to show that your eyes are sensitive to things that you don't even see, that they can - the eyes can adjust to very very minute changes, where you look at, for example, that you are not conscious of.

There's lots of evidence that a lot of sensory-motor system - when I play soccer, when I run, when I climb, particularly when you play violin, dance, when you play tennis, any of these things where you train for many many months or years, what you execute very very fast - you're training - and while you train you train so you don't need to think about them anymore so you just *act* - you just *do* it. Right? In fact, you know, if you just listen to certain training or if you read certain training manuals they will emphasize that - you just act you don't think anymore - you act. And if you train up enough there's this effortless merging of sinew and nerve and muscle and it just flows out. But now if you actually think about it, if you say, wait a minute, I move my hand this way or that way, then it's interrupted. Why?

Consciousness is very powerful, but consciousness takes half a second or a second, so then that effortless flow's interrupted.

The advantage is I can do many many more things than it seems I've just trained for. But for those things I trained for, which includes moving my eyes, running, walking, adjusting my posture... every time you go shopping, you know, in a busy mall, there are hundreds of people that come at you but you never collide - you effortlessly move aside, and you do all of that without ever thinking about it. You move your eyes a hundred thousand times a day - you move your eyes as often as your heart beats a day. In fact you can do the following experiments: you can look tonight in the bathroom mirror, you look at your eyes, you look at them in one position, and then you move into another position. You can never see your eyes in the transition. Now if you do this while looking at me I can see the transition but you can't because your brain shuts down briefly while you make this fast movement called a saccade.

So, again, you could show this is a complicated behavior because your eyes can still be controlled during this time, but you don't see, and it doesn't look like you don't see - it's not that... it's not like you have these... it's not like a movie where every time you move your eyes which is roughly three times a second there's this little gap called a millisecond. Because the brain very cleverly interpolates, just like in a movie, in Hollywood, it's something is cut out, but then something else is interpolated to *suggest* that you actually see the world continuously when in fact in control there is this gap in vision when you actually move the eyes. All this machinery - this complicated machinery- is in place, works all the time, effortlessly, automatically. So we call those, "zombie behaviors". And most of your day to day actions- when you brush your teeth, when you tie your shoes, when you drive quickly, when you shift gears, all those things you do all the time without thinking about it, highly trained things - maybe early on when you first learned to drive you had to be *exquisitely* conscious of it, but now after awhile you can do, you know, it's amazing when you live in LA and you see what people do while they drive. So these are all zombie behaviors, so the interesting question is at the neuron level, what's the difference between zombie behaviors and conscious behaviors? Are they in a different part of the brain? Probably not. Do they invoke different circuitry? Probably yes. This is another experimental avenue - you can look at the difference in architecture between when you have a person or animal doing zombie behavior compared to when the same person or animal does a behavior that gives rise to conscious sensation.

GC: And you can tell the difference...

CK: Well, certainly I mean the zombies are usually very fast, they're effortless and usually like I said you're not conscious of them.. the arm is up or the fact I mean of course you can know that a message you carry conscious that you move your eyes. It's not that you cannot be conscious - certain things you can't be conscious at all. Like you can't be conscious of the content of your stomach - you just don't have introspection there. You're not conscious how you understand my words, you're not conscious how you speak - when you think about it, you know we're talking - I have no idea how I speak.. I have some vague idea that I want to communicate to you and the next thing I hear these words come out of my mouth. But I don't have direct access the parts in my brain that generate the syntax that put the verb and the noun together that maybe translate it from German to English, I don't have, you know hell no - it just happens somewhere in my brain.

So most of the things in your brain you don't have conscious access to, in fact you only have access to very few things in your brain. Those things we are incredibly proud of. And as you get older, you may experience this particularly if you go through life tied to something very emotional, you try to understand why did he do that or why did she do this - very often you have no direct idea. You can try to - you can try to sort psychoanalyze yourself or try to analyze your friends or, you know your loved ones - why did they do this, but at best you've a very imperfect understanding even about yourself - why did you do this, the mostly for certain of your actions they all happen unconsciously for the most part. And so we have to agree that most of our brains we don't have access to. Most of the brain is zombie. Most of the brain happens unconsciously.

One of the leitmotifs of western philosophy, one of adages of western philosophy is "know thyself." This is very very difficult. If you go back to the old Greeks, you go to Kant, you go to even modern philosophers, it's trying to know yourself, trying to understand what makes you tick. And that's so difficult because most of the things we do and most of the motivations for the things we do remain hidden from us, from our own conscious introspection.

GC: And I think that's one of the things that maybe people are threatened by - that the more that we

uncover in neuroscience, the more it supports the fact that that really is the case.

CK: Why should that be threatening? I mean..

GC: I'm not threatened by it either but I think there are people that are threatened.

CK: For me I can see how they would be threatened from a religious point of view maybe, but I don't see - I mean I find that intensely frustrating - when I do things that I don't understand why I just did that, I mean why did I say that - it was totally unnecessary, just provoked this person, I mean why did I say that? You know I'm not trying to psychoanalyze myself, you know, maybe this maybe that, but the fact is I said it without really thinking about it without really wanting to in hindsight, so it kinda feels frustrating - I wish I had more insight into why I have things and have feelings I do have for people.

GC: If we do so much zombie stuff, why do you think we need consciousness at all?

CK: Remarkable. That's a very controversial question among philosophers, or among scholars in general. We - there are different schools. So people who are biologists, the driving philosophy is natural selection, evolution right? Selection, the act of natural selection over thousands of generations. And so, since we have this exquisitely formed consciousness my very strong supposition is that this has some evolutionary function. For instance - and people have surmised many different functions, for instance the need for us to do planning, complicated things, for example, where am I going to be tomorrow? You know, what happens if I - you know, I've never been in this particular hotel room - what happens if there is a fire? Then I have to think about it you know, I have to think where is the exit, if there is an earthquake, should I go under the table or should I exit into the hall - those things I have to think about. I have to play to different scenarios - I think that is a prime function of consciousness. Once I've done this action a hundred times, once I train it like a special process, soldier or something, I don't need consciousness I can just act it out. Or playing to different scenarios, I'm confronted - I've a very complicated sensorium of all sorts of different senses, all sorts of different actions, I can put them together in very complicated forms, and to properly think about them and contemplate the future, contemplate different scenarios, different futures, I think - for my mind, that's one of the key functions of consciousness.

But other people argue, well, consciousness is real, but it has no function. It's epiphenomenal. Yes, it's real in the sense that we really have these sensations pain and pleasure and all that, but they don't serve any function. They're sort of straw on the sea - I don't see how they could have arisen through natural selection if they don't have any function.

GC: I agree with you. *(music) One of the questions that I wanted to ask Dr. Koch was about subjective experience or qualia. But then we were having some problems with our Skype, so we decided to bring our conversation to a close. I asked Dr. Koch to tell me what he thought the most important idea he wanted to share with you was.*

CK: The - I mean the general point to get across is that consciousness is not any more a truly philosophy problem. Philosophers still have important things to contribute and continue to do so, but it's not just a problem anymore for philosophy. It's fastened to the empirical realm. We can do experiments, we can study people with all sorts of, you know, disturbances of consciousness, there are all sorts of interpretations, Oliver Sachs writes about them, for example who may have lost part of the visual brain, they can't see, yet they can still have visual behaviors. It's called blindsight. Blind sight - you know, implies a contradiction in terms. You can still "see" but you're blind, I mean, it's true there are some people that claim they have no vision and you can show they don't, I mean, they lack feelings for vision in this part of their visual field, but yet they can still do visual behaviors, you know, so there are lots of interesting phenomena in people - in normal people in patients and in animals that we can study and there are people now who are making attempts at theories of consciousness, so it's no more philosophical problem but it's passed into the realm of empirical and you can study it, and hopefully thereby answer some of those age-old questions you know Aristotle and Plato first posed 2000 years ago.

GC: It seems to me that that's the history of philosophy if you look at it - things go from being philosophical questions to being parts of science..

CK: Yeah they start off being from metaphysics, they start off being metaphysics and physics, yeah,

that's correct, yeah.

GC: But science keeps stealing stuff from...

CK: Well I don't know "stealing".. I don't know whether "stealing".. you know, it's like stellar - you know, 200 years ago, 150 years ago a famous French philosopher (unintelligible) made this claim that we shall never know what stars are made out of. But at the time you could only speculate about stars. Then they discovered the spectral graph - you can take the life of stars and put them in the spectral graph, spectrum, and actually analyze it, and see what elements are contained in the stellar atmosphere. At that point you pass from pure philosophical speculation into the realm of being empirical, and that has happened to consciousness over the last 50 years or so.

GC: And I think as you mentioned in your book one of the contributions philosophers make is giving us questions.

CK: Yes, they sharpen, they give a question and they sharpen the debate by sort of conceptualizing, you know, what's my attention and consciousness, are they really the same thing, are they different, how are they different.. by introducing things like the zombie, you know, zombies, is zombie possible, you know, if not, I mean, is it possible to imagine a world where you have zombies? Or is there some principle reason why you can't have zombies? I mean that is an interesting question. So, yeah - there's no question that philosophers have played a useful role, although almost never in answering the questions. I mean the answers are usually inadequate, I'm talking historically, but the questions they pose are very often questions of the sort that the scientists would not pose.

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***GC**: Since Dr. Koch and I are about the same age I asked him whether or not he thought that we would see artificial intelligence become conscious during our lifetimes.*

CK: We don't really know. Very often you don't really know the solution until you stub your toes against it - we don't really know. For instance it's really interesting - you never hear people in AI, artificial intelligence community talk about the impossibility of making intelligent machines. Right? The only question is will we get truly intelligent machines ten years from now? You know, very soon as ... says, or 20 years or a hundred years? And developmental biologists, we still don't know how an egg develops into a full grown human or adult or whatever, but you don't hear people saying, well there's some fundamental issue why we should not be able to understand how an egg develops into a full-grown organism.

With consciousness we still really have no idea - we still do not understand even in principle how any brain no matter how constituted, no matter how complex would give rise to consciousness. I mean, consciousness is not in the foundational equation of physics, it's not in the periodic block of chemistry, it doesn't seem to be inside cells, it's somehow you put some bunch, you know, a couple hundred billion of neurons together with a couple of trillion synapses in a healthy human being, and you get consciousness. And we don't understand how that comes about. Will we ever understand this one question? And if so, how soon? To both questions we don't have answers. All we have are plethora answers. Everybody who studies this has a different answer. Me, I'm agnostic. I really don't know. What I do know, is if we don't study it, for sure we won't know the right answer.

GC: So what's the question that's driving you forward in your work?

CK: Well, Francis Crick and I, we've been... a tactic for this is with an opportunistic approach. We say, right now we don't think we're in a position to solve the really hard problem like, so in philosophy there's a term, the hard problem. The hard problem is, OK, how can *any* physical system - the brain, synapses, neurons, even quantum mechanics, no matter what, how could any physical system have subjective qualities? Have qualia, have pain and pleasure and feelings? People have speculated endlessly about that. Right now we would think there aren't any really good answers to that. However, what we do think we can do about it now is, with molecular biology, with electrical biology, with

imaging, is try to find neural correlates of consciousness, in the brain. What is it in the brain that gives rise to our feeling of pain? And what is it in my brain that gives rise to our feeling of pleasure? Are there commonalities between them? Between your feeling of pleasure and my feeling of pleasure? Surely they are probably really similar. And we believe, just like with molecular biology, once Francis Crick and James Watson saw the double helix they realized that it would be a perfect mechanism for transmitting and storing and copying information. So likewise here's a belief that once we understand neural correlates of consciousness in the brain, we'll be in a much much better position to devise a theory of consciousness. So that's sort of what I've dedicated my life - my life pursuit.

Plus it is, you see if you think about it, consciousness is the only way we experience the world. In fact to experience the world is to consciously - I mean, it's synonymous. You experience - that means you consciously experience the world. That's the only way I know there's a world out there. I mean, the most famous deduction in western thought is the one by René Descartes , "Je pense donc je suis" - he said it first in French, you know, Cogito ergo sum. I feel that ultimately it's an affirmation - I'm conscious therefore I am. And that's still ultimately what's true. We experience the world because of consciousness. Therefore if we do not understand how consciousness fits into the natural order of things, science will forever be incomplete - we'll just have this huge hole there. We'll - you know, unless we understand how consciousness fits into the world.

GC: You have lots of exciting research left to look forward to then, right?

CK: There's no lack of interesting questions and experiments and there are lots of interesting people now who want to study it, and there's lots of funding - it's a very exciting time and place to be. No question about it. It's a golden age of neuroscience, no question about it.

GC: Well I really want to thank you for taking the time to talk with me tonight.

CK: It's been a pleasure Ginger - it's been a pleasure.

Music

***GC**: I really enjoyed talking with Dr. Koch. He was a very gracious guest. His book is The Quest for Consciousness: A Neurobiological Approach, and it's a pretty technical book, but I know that some of you are going to want to go ahead and read it.*
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