THE QUANTUM MIND DEBATE
Proceedings

José María Gómez: My question is, the collective excitation of the electron's spin is structured in the hydrophobic pockets, exciting these magnons. Demokritov experiment on condensate material and the Bose-Einstein condensate are grouped in better to explain this with the possibility of the stability, the excitations of magnons in the tubulins?

Stuart Hameroff: Yes. I don't know. That's a good question. I'll have to look into that. I hadn't heard about magnons, but I will say that initially everybody said, well, biology's too warm, wet, and noisy for significant quantum effects. Now they've found in mesoscopic scale, in photosynthesis in the Collini paper that you mentioned; Anirban's finding it in microtubules. So I suspect people are going to start finding it everywhere. There's quantum biology meetings popping up all over the place, I was… Google had a workshop on quantum biology, the American Physical Society, and next… in March is having sessions on quantum biology. So I suspect now that it's more or less accepted that it's possible, people will start looking for them.

Stuart Hameroff: Right. It was thought to be impossible. And now, once it's been found, I think… I'm hopeful, and suspect they're going to be everywhere.

Manuel Béjar: I don't think that the future of the consciousness research will be on magnons because the main source of magnetic in the human body is the heart. It's not the brain. The magnetic field on the brain is very low. I think it is 10^{-6} teslas. And I would like to say some few words about microtubule-associated proteins, because in the Penrose Hameroff hypothesis, MAPs plays a different role than in the Bohm Penrose Hameroff model. And I would like to make the difference.

Because when Penrose and Hameroff thought about MAPs, they were thinking about the Planck scale. And as you know, that Planck time and the length Planck… the Planck length are very, very short. But the mass… the Planck mass is not short. It's only 10^{-5} kilograms. And Penrose thought that the movement of MAPs, of microtubule-associated proteins, could produce the objective reductions due to some gravitational perturbation. When Professor Hameroff showed before this light in which he saw the uncertainty principle of Heisenberg, e multiplied by T is more or less a Planck constant.

Stuart Hameroff: E equals, yes.

Manuel Béjar: Planck constant. The mass of MAPs could be strong enough to produce the quantum objective reduction. But what would I ask to Roger Penrose and I would also do to you, Professor Hameroff, is that when you showed before this light in which there… it was plotted on the graph of the consciousness, low coherence to the high coherence and then the objective reduction, it's always the same. You showed before some different fields between activated conscious state, or some affected states, whatever. But the pattern on the graph is always the same. So how could we distinguish that… now I am conscious that I am talking to you, or how could we distinguish when I am just thinking in fantasy, for example?

Stuart Hameroff: Yes, so what you're asking is the shape of the curve is the same, but the content of consciousness is different, right? That's what you're asking. And I think

the content has to do with the particular patterns of tubulins that are involved in the superposition and what they collapse to. So the overall shape of the curve is going to be the same no matter what. It's like a DVD comes in a box, but each DVD can be different. But I don't… and the shape of the curve, we showed is slightly curved and straight, but we don't know. It could be jagged. I just think it's definitely negative. It's definitely vertical when it collapses because it's instantaneous.

In fact, the instantaneous reduction is important because that's how the small energy from the Planck scale has significant effects at the nano-scale, because it's energy over time. So the time is very short, the power is high. So it needs to be instantaneous and Roger always made the point that the collapse was instantaneous. So that part I think is important, but whether it's like this, or like this, or something like that, I don't know. I don't think that matters in particular. But I think the content of consciousness is at a much finer-grained scale, and that's going to be in the pattern of tubulins that get collapsed, too. Get reduced, too.

Manuel Béjar: I like the metaphor of the DVD, because what I'm trying to say on the Bohm Penrose Hameroff, is that the fields of reality, external fields, can guide MAPs to couple to microtubules to produce a concrete conscious state. So it's like… It will be like to burn a DVD with a code.

José María Gómez: Inside the human gene, genome, there are many genes coding for connexin. Connecting the protein. Different connexin are associated with deafness in many cases. In this individual have problem in consciousness, the gene, the people… deaf have any problem with consciousness, realise the gene connexin genes. And then they're deaf.

Stuart Hameroff: Well, I didn't quite get all that. Maybe Manuel can answer, too, but when I proposed the gap junction model, Christoph Kolk came back and said, well, they have these knockout mice where they've knocked out the genes for connexin 36, which is the main gap junction protein in the brain. And yet the animals survive and it turns out they're cognitively impaired, they're not. They are retarded, basically. But they're viable, they survive. However, they do have some gamma synchrony, suggesting that there's some other connexins, and there's a lot of different connexins, and there's also pannexins, so different types of proteins that mediate gap junctions.

I didn't know about the deafness, that's new to me. But in knockout mice there's often compensation. So you knock out one gene, and in the course of development, some other gene takes over, some other protein takes over. So in the case of a knockout mice, they must have had some functioning gap junctions because they had gamma synchrony, and although it was attenuated… but it was still there. Otherwise in my response to Christoph, I said, well, maybe they're zombie mice. maybe they don't have consciousness, but they're acting on autopilot, which would explain why they're slow. They're a little cognitively impaired, but they're still functioning. But they… maybe we've created… or they've created a zombie mouse by taking out the connexin. But I suspect that there's some functioning connexins in there.

José María Gómez: I remember the DNA has also superpositions. This support the mutability of DNA. The superposition the computation with DNA. Why is not DNA the super-tool for this model instead of tubulin?

Stuart Hameroff: Yes. Well, first of all, I think there are quantum effects in DNA. Vlatko Vedral and Elizabeth Rieper just published a… DNA requiring entanglement to

keep physically together, to keep from flying apart. And if you look down the core of DNA, I think Steen talked about this yesterday, the purines and pyrimidines stack up and you get this hydrophobic pi stack, it's called. So that's all quantum London forces down that stack. But DNA's not in the right place the right time for real time control of what's happening in the cytoplasm. By the time like in a neuron, the information gets from the receptor to the DNA and back, we've already acted and done all kinds of things.

So microtubules are right where they need to be for real time conscious control. We know there's a genetic code, but I think there's also a molecular code in the microtubules that I showed with the CAMK2, that we need to figure out so we can intervene medically in a variety of therapies. That would be very helpful. But microtubules I think have a code, do the real time information processing, without going to the genes. For longer term, you can go to the genes and have gene expression and so forth.

JAVIER MONSERRAT: This is a question about visual perception. As you know in neurology, the traditional explanation of visual perception is according to the model of constructivism. For example, according to this theory, the image is inside my head. The world in my head. But I think that any case in this… let us suppose this theory would be correct. We would need quantum effects and quantum states in the brain to make clear how this is possible, this interior image. But as you know also there was a very important, at least in my opinion. A very important psychologist in America, James Gibson, and he was defending the theory of direct perception. We should apply this theory, for example, to the perception of our body.

We have the perception of our body as a unity, biological unity, and also division. I have a unity with the world through light, through the pattern of light. For example, called into this… following these ideas, Gibson develops the concept of physical resonance. In his time, he couldn't give any physical explanation. Because in his time, the reductionism was dominant in physics. But this is a very important position of… because this direct perception is according to our psychological perception. We are feeling that we are in the world. We are not the… the world is not in our brains. But the contrary. We are in the world.

And in this moment, for example, I am having the sensation that I am having a visual perception of the objects. I am in the light, could we say? And my question would be, how would you see your model and your ideas about this quantum coherence, and all these phenomena you and also Manuel Béjar, have described. How would we… you see the connection with… of all these ideas to explain visual perception? Could it be a way to understand that we are in the world, perhaps that our brain is in coherence with these electromagnetic fields of light, because light photons are bosonic particles. In the free space they are building a, we could say, field of resonance. And our brains could be in resonance with this. For that reason that I think that your ideas could be a way to explain a very important psychological experience we have.

STUART HAMEROFF: It goes back to the Greeks, that the world is in our heads, and Descartes said that. That's constructivism, basically. But I think entanglement might be the answer to what you're asking for, and that we become entangled with the scene out there. And right now, I'm entangled with you because I'm seeing you and I'm communicating with you, but also the photons that enter my eyes bounce off you and I see you, go through my retina and before they get to the rhodopsin, they get absorbed. They go through a cilia which is made of microtubules, it's a mega cylinder. And it's the same structure as centrioles.

And we know from a variety of experiments that they're sensitive to photons and that they're actually the right wavelength to be optical resonators. They're about 700 nanometers

long and about 150 nanometers in diameter. They're made up of nine triplets of microtubules. And the light goes through them to the get to the rhodopsin. So the light bouncing off your face that is hitting my rhodopsin and is going through these cilia. And I thought for a long time that there's quantum information that can be extracted from the cilia through some kind of different pathway so that I'm getting a direct quantum entanglement with the visual scene, in this case you.

Which I think would speak to what Gibson was saying, and also what people like Alvin Noe and other people, embodiment, that we're actually directly interacting with the environment. So I'm sympathetic to that view, and I think a quantum entanglement of some sort, possibly through the cilia and the retina, might be the way to do it. And get us out of the problem that everything's in our head. Certainly we do have representations in our head, but we could also be more directly involved with the outside world, which is I think what you're saying.

Óscar Castro: So once we've got the idea of this going on in microtubules, we need to actually start looking for these quantum things in all other sorts of sensory perceptions?

Stuart Hameroff: Yes, but the centrioles or the cilia in the eyes are made of microtubules, so… but they're mega cylinders, the walls of which are nine triplets of microtubules. And when you make that cylinder, it's exactly the right size to be an optical wave guide, and it's got a helical twist, so it's going to be able to pick up angular… orbital momentum and what's the other? There is another quantum property that comes from the angular momentum or angular something, I forget. So that these quantum properties can be detected in some way that is outside the normal visual processing that we get maybe subconsciously, I don't know.

Manuel Béjar: Yes. I would like to say some things about this and I'm going to mix the last two questions and make a combined answer. To David Bohm, the whole universe can be described by a hold quantum function. So in this land, it could be possible to understand the coupling between the physical fields with the inner brain. But when one gets conscious about someone or something, the conscious state is classical, so we have to have an objective reduction from the quantum to the classical. And I think that what it's doing, the brain, is just decoding the physical fields into some cognitive patterns. But I do also agree with Stuart Hameroff that the representation of this decoding is personal and I couldn't share my own vision with yours. So the fields will be the main point that could link the external reality with the inner reality, but the decoding process in the brain could be only personal.

And answering your question about the DNA and in the cells, I have to remember one is light that we saw before in your presentation about the paramecium. And you said before that paramecium could be conscious. It's for me a bit heavy to believe that because I cannot communicate to it. I can't feel to the eyes and feel that it is conscious. And it is interesting to notice that the paramecium is one closed cell, some biological deterministic system that works with the DNA code. And if you hit with a knife to the membrane of the paramecium, the paramecium gets away. He doesn't like to be open to the reality.

But the neuron that is also a cell behaves in a very different way. What neurons like is to be open to the world. You say before that a neuron is like a string. The big action of the cell is just the physiological evidence that the neuron wants to be open to the reality. So the combined cells about the determinism of DNA and the undeterminism of probabilistic properties of quantum microtubules could combine or mix them, could we solve the emergence of consciousness in the frontier between determinism of DNA and undeterminism of quantum microtubules.

GIORGIO INNOCENTI: During my lifetime, I've seen the emergence of molecular neuroscience. So people have been putting molecules and general proteins into the brain, and these became very important. And I was suspecting that at some point that we'll go into some kind of atomic or subatomic neuroscience, and here we are. We are right at this point and I think it has to be taken very seriously, that there may be atomic or subatomic phenomena which are important for the way the brain functions.

Now, having said this, one of the difficulties is I'm sure there will be a lot of quantum phenomena which will be discovered affecting all kinds of molecules in the brain, and you were mentioning quantum synapses. Quantum synapses would be a good, for example, target for quantum events, because there you have a complicated cycling of proteins, which will take vesicles and you will transmit this in and out of the synaptic cleft, opening, closing, etc. So you might expect there would be a lot of quantum events, and then if you go in the receptor side, where you have essentially proteins which are going to change their configuration and they will bind or let the ions go through, and the other proteins, etc. You can expect a lot of quantum events there, too.

So now why should we favour microtubules? And here we have a problem of mapping, which is rather formidably bigger than what I was trying to talk about yesterday. Yesterday I was talking about the difficulty of mapping brain states into mind states. Now here we have the difficulty of mapping subcellular events, say, state of microtubules which could be computers in the sense you have said. And actually I would even like to complicate that, because these cytoskeletal proteins are heavily phosphorylated proteins, very often with several phosphorylation sites, and I've been looking a bit on filaments, and there the phosphorylation site is like playing a piano. Depending on where the phosphorylation site is, you can have changes in the information contact, etc.

The problem now that I see which is how are you going to map, or can you map, or can you give ideas on how to map the microtubule states into states of the neuron where the microtubules are? And if you can do that, then you can achieve the mapping the state of that neuron and the state of the network, say network of gap junction inhibitor, interneurons connector, by gap junction etc. Can you think of how doing this kind of mapping, because in my opinion. I may be wrong, it may be a kind of critical step if we want to give credibility to all this.

STUART HAMEROFF: I think you gave the answer, because let's say there are quantum states in all the ion channels, and MacKinnon's Nobel Prize work suggested that there's superposition of ions as they go through an ion channel and receptors and so forth. So you have this neuron with 1,000 dendrites, or ten or 20 dendrites and thousands and thousands of synapses spread out, and what's the common mediator is the microtubules in the dendrites and inside the cell. So what I'm thinking is all these outposts on the…

See, you're thinking from the outside in. I'm thinking from the inside out. So you have all these receptors and channels, and all that information needs to be integrated. There needs to be some kind of common information system, like computer cables built into a building, or computers built into a ship or something like that. That's running everything, so all the peripherals are mediated through the central processing systems.

So I think the microtubules are the central processing system in the neurons so that quantum information or classical information from the synapses and the membrane proteins and the ion channels are all integrated and processed via CAMK2 and other mechanisms into the microtubules, which is the clearinghouse for all this information. Which can then be communicated to all those other peripherals and also other

microtubules via gap junctions. So I think that microtubules are the answer to the question that you're asking.

GIORGIO INNOCENTI: But transmission along that microtubules is slow, because it is going to take dynein, it is going to take movement of MAP molecules. It's slow transfer of information.

STUART HAMEROFF: Yes, that's for synaptic plasticity. But for pure signalling, it's very fast. In fact, it's ballistic conductance. It's almost instantaneous if it's going to use the quantum mechanism.

GIORGIO INNOCENTI: What is the evidence for that? Do you record the neuron. Can you map activity of the neuron and activity which is reflected down in its action? Can you map it on microtubule states? That is the question.

STUART HAMEROFF: That hasn't been done yet. But we know from individual microtubules that you have this ballistic conductance. And also there's this phenomenon of isopotentiality, where if you record cortical neurons in the brain at two different places that are separated by microns and measure the membrane quote-unquote noise, they're identical. So here's two transmembrane potentials separated… on the same neuron, separated by microns, and they're perfectly synchronised, which is too fast for any normal conductance. And Christoph Kolk published that, and I asked him how he could explain it, and he said, the inputs coming in from somewhere else must be perfectly synchronised. But that really doesn't make any sense, so I think that's evidence for internal. It is some kind of internal rapid conductance.

JENS DEGETT: I am a little perturbed or mystified. I don't understand exactly what the connection between these microtubules and the firing of potentials in neurons is. I would rather think it would be much easier to explain, and even in quantum mechanic terms, if we talked about transport over cell channels of single molecules. So we talk about opening and closing channels, that would be much easier to work with and much easier to explain.

Whereas the build-up and breakdown of microtubules and their different states, and their connection to the firing of potentials in nerve cells, that's a much more complex process which I have more difficulties in following. Therefore my question is, has this connection between microtubules and the opening and closing of cell channels in the cell been shown? Because I think we can easily design an experiment, we can show this. Has this been shown?

STUART HAMEROFF: Yes. That's a difficult question. There's some circumstantial evidence. So I'm sympathetic to your objection, but you were implying that the role that I'm suggesting has to do with assembly, disassembly of microtubules, which is slow and takes a while. In dendrites, microtubules are quite stable. Because unlike all other cells where they grow at one end and shrink at the other, or grow and shrink at both ends, they're capped at both ends, so they stay fairly stable. So I'm not saying they assemble, disassemble as a means of signalling. That's how they work in cells that are growing and probing and retreating, but they stay fairly stable, so that they can take incoming information, for example, from CAMK2 and integrate it to in terms of axonal firing.

Now, what you said at the beginning is that neurons communicate by axonal firing, and they do, but I don't think that's the only way they communicate, and I don't think that's how they… I don't think that's how consciousness works, as I was making that point to Giorgio yesterday. Because dendrites are where EEG comes from and that's the best marker of consciousness. Now, we know from some work from Naundorf, Fred

Wolf's lab in Germany, maybe some of you know him, but they did a study on… they studied cortical neurons in vivo, neurons in cell culture, and then neurons in simulation, and inputs and integration. And what they found was only in the neurons in the brain that the threshold for firing for a given neuron varied from spike to spike.

So the standard dogma in neuroscience, correct me if I'm wrong, is that you take inputs, you integrate the inputs to a threshold, and that fires the neuron. So it's very linear, it's very deterministic. There's no room for anything other than inputs. Inputs drive outputs. But what actually happens, it turns out, is that the threshold from the membrane potentials to trigger the firing varies from spike to spike. So there's some other factor that influences firing, which I think is coming from the microtubules in that neuron, and also other neurons via gap junctions.

MANUEL BÉJAR: Yes. We have no problems with classical information and classical communication. Of course the brain is continuously communicating one cell to others between classical channels. What I'm proposing is that there are new ways of communication. When Hameroff showed before in the slide about quantum teleportation, quantum teleportation, it is transferring information, not matter, just only information to one side to the other.

And quantum teleportation is not purely 100% quantum. Quantum teleportation does need a classical channel. So the brain has both, has classical channels and quantum channels. So to compute the reality, a classical computer, it will be very difficult to decode all the information that is contained in the physical fields. It's… that's the reason qubits can rapidly compute information of the fields. So why not the brain that is in the borderline between deterministic and indeterministic, could use both channels, quantum and the classical, to decode information?

STUART HAMEROFF: Yes, that's a very good point. And as many people may know, you need a classical channel and a quantum channel because the quantum channel only gives you correlations. So to actually do useful information, you need both, and that's apparently what you're describing.

CARLOS JOSÉ CASTRODEZA: I want to refer myself to a more general topic. I have two short questions, and one comment. The questions are, according to both presentations, there are two realities. About mind and matter; at that level there are two realities. So Descartes was partially right. That's the first point. So is there room for dualism in our world? My first question; the second is related to the deeper reality that you mention. This is hard, because you are pushing away explanations.

But if there is a deeper reality, our world, monism is the right approach. There is just one reality. Now, the second question is, could deeper reality be the cosmic consciousness we are talking about? That's the first point. So consciousness is produced in both mind and matter, and my comment is that Amit Goswami says that cosmic consciousness is another word for God. Of God is cosmic consciousness.

STUART HAMEROFF: If you remember the first early slide I showed, the consciousness, did it emerge from evolution? Has it been there all along? Or a combination? And been there all along would be Goswami's view. And it's also Deepak Chopra's view, and he and I have had dialogues on this. And we disagree on this point, because he said consciousness is everything. It's idealism. It creates everything. Matter doesn't exist or is illusion, depending on how you look at it.

And I don't go that far, because I think reality is really out there. And I take Penrose's view on this, and this goes back to Einstein versus Bohr, actually, whether there's a reality

out there or not. And so I think there is a reality, and I think consciousness is built into the universe. And I like neutral monism, where there's one entity, which would be spacetime geometry, which can give rise to matter or mind depending on how the collapse occurs.

MANUEL BÉJAR: Yes. I think that Cartesian dualism is not possible today according to the scientific results, because they are psychophysic interactions between matter and the mind. If you are talking about a scholastic or some Thomistic or Aristotelian dualism, it is maybe possible because some of the things that those people say about the soul could be understandable to a scientist like emergent properties. But they don't think we could solve the problem of the mind, and they prefer to be in a steadier state of the matter. And David Bohm would answer you that of course the mind, the conscious mind, the cosmic mind, is everything and it is everywhere. I'm a bit bit more pragmatic. And I wouldn't say that everything is conscious and everything is the mind.

SARA LUMBRERAS: I've got a question for both of you. How do you make sense of what is happening outside of the brain? In relation to Javier's question, Javier's comment, if we are in some sort linking our consciousness to the outside world through that… retinal impulses to whatever is happening in the retina. If we extend it a little bit and we think there are more neurons apart from the ones that we have in our brains.

We have the nerves. Do we have any evidence of coherence happening in the nerves? And another step, we have tubulin in every cell in our body. And we've seen how smart unicellular beings can seem. So if we have that sort of proto-consciousness happening at the level of each individual single cell, how do we make sense of what's happening in the whole of the body? Can it be that we are conscious mainly in the brain, but we are conscious with each bit of our body?

MANUEL BÉJAR: Yes, a qualification. When you said that we have microtubules in every cell of the body, I have to say that although that is true. The function of microtubules are different in the cell bodies than in the brain cells. Because other brain, what does not have a nerve cell, a neuron, can divide itself, can spread into more other neurons, due to the microtubules process that mitosis. But brain neurons, brain cells, neurons, do not divide into other new neurons. So it can be that the function of the microtubules that there still are in those cells can be used for another kind of things. For example, to process information.

STUART HAMEROFF: Yes, I'll answer that, too. Go back to the paramecium, single cell, and somebody just asked if it was conscious. By e=h/T, the number of tubulins in a single cell is very low compared to the number in the brain that might be in one. So, for example, a paramecium, whereas we have 40 conscious moments per second by… because e is fairly large and T gets small. Assuming you could avoid decoherence, might have a conscious moment every couple of minutes. And similarly, other cells with microtubules, assuming they could avoid decoherence, might have conscious moments every once in a while because e is so small, and T would be very long.

Somebody once asked me after a talk, I got, you got microtubules in your rear end, is your rear end conscious? And I go, I don't know. I don't think so. But they don't have the number of microtubules together, connected by gap junctions, to reach or to get enough e to reach T in a short period of time, and before that happens, decoherence will set in and will avoid it. On the other hand, we have a lot of neurons in the heart and microtubules in the heart, and some people think the heart's conscious or might have conscious, and maybe it's connected to the brain. I don't know, that's another topic.

But I think anything in principle can be conscious if it satisfies e=h/T. But to get a big enough e for T to be small enough to happen quickly, you have to avoid decoherence, and then you need isolation mechanisms. So somebody at the break, we were talking about, it's a fairly rare occurrence to have this balance between isolation and a large enough system in superposition to reach threshold quickly enough. So a single cell could be, but I doubt it. The interesting thing about a paramecium, and I showed a picture of sex, is that the only time that they're absolutely still is during sex for a couple minutes. So maybe they're conscious at that time.

RASMUS WINTHER: I have a question for you, Manuel, which ties the question about DNA and the mapping from Giorgio. So I would like to ask you about two huge continents of discourse about science. One has to do with consciousness, the other one has to do with DNA and genetics. Here we focussed almost entirely on consciousness. I am not going to ask so much about the model, but I think it is related. It is actually more a comment. I'm confused. Whenever we talk about information processing, there's a lot of people that say DNA is an information processing mechanism or sequence, and other people, like here we talk about how neurons and neural patterns are information processing. And I'm just wondering how to relate them? Yes? And you made this claim about that DNA was closed off to the world, and neurons were open to the world, which I think is a fascinating claim.

But isn't there a sense in which neurons wouldn't be there unless there were DNA? In a causal sense, neurons require the genetic information in order to even be constructed during ontogenesis. It may be the case that once that instrument, call it the brain, is produced, that that's like the only antenna we have to detect or produce everything that we're talking about here. But in order to even have the brain we do need the gene… the genetic information.

MANUEL BÉJAR: Some guys say that 90% of DNA is just information because they don't know what they're used for. And I don't know if there is some speculation about that DNA could process information. I don't really know but I have to remark again that we are not opposing to transmit classical information. We are not opposing to the good work that neurons are doing in the brain. What we are looking for is, as Penrose would say… are looking for shadows of the mind. Shadows of the mind. So we have to look into the neurons to look for some kind of biological structure that could be compared to those condensate matter structures that are being made in good universities and good research institutes about qubits.

Why do smart people research on qubits? Because qubits could process that information more rapidly than classical information. And now that I am talking to you, I am being conscious of thousands of states of consciousness. My brain is rapidly decoding the information. I don't think that a classical robot could do the same as I am doing now. Why not? Because they are processing in the classical regime. So they are using the neuron at a whole system. What we are looking for is some kind to implement quantum computing into the brain. And now this is the reason we are looking for the microtubules as processing information.

First of all, we must be honest. There is no scientific last result that shows that there is coherence or that there is quantum superposition states in the brain. We have to be honest. We are just proposing that other alternative modes of consciousness are not good enough to explain the consciousness phenomenon. The model that those guys Penrose and Hameroff have made about consciousness, is for me the best, because the Penrose Hameroff model could explain a lot of phenomenological events of consciousness. But

we are not sure that it is completely right. We have some new evidence and I am very happy that the last few years there are some biological quantum results, but they are not definite.

STUART HAMEROFF: As I said before, Anirban's experiments are, I think, are the brightest light. And he came over for a series of seminars, one at Google, one at Paul Davies' centre at Arizona State University with a number of very prominent physicists, who just hounded him incessantly, were so sceptical and questioned everything he said. And it was painful to watch but in the end, he had them I wouldn't say convinced, but begrudgingly acknowledging that the experiments might be right. And they were trying to dismiss it out of hand because it seems outlandish that a protein can be a superconductor at room temperature, and also these resonances and so forth. He also tends to give, like me, too much information in one talk.

Except he's giving data, unlike me. So but at the end I saw him give three different talks over a six-day period, and it clarified in my mind, plus a lot of talks at night, so For me to understand what he was saying. And in e-mail exchanges with some very prominent quantum physicists afterwards, they acknowledged that he was on the right track. And if his experiments show up, then they should be if his experiments continue to turn up, then they should be believed. In other words, they couldn't rule it out, dismiss it out of hand that they were… as they were trying to do from the get-go. So if he finds topological qubits in microtubules, I, for one, will be very happy.

LUDOVICO GALLENI: I am working on Teilhard de Chardin. And now, in the talk later in the afternoon I will present a translation from my brain of one of the main points of Teilhard philosophy, so the fact that there is an inner side of matter, which is with some seat of consciousness. For this is a particular, peculiar quality of matter. I make a translation for the Darwinian part of my brain, I don't know where exactly it is, but it is a big part of my brain and as a general law, explaining and moving towards consciousness.

But perhaps this is the question in some way, these theories… in some way shows that perhaps also the original interpretation of Teilhard's ideas could be correct because there is some inner part of consciousness at the very beginning of the matter. I don't say of the wow, of the big bang, it took some theology fiction. But anyway, perhaps this interpretation of consciousness links to the first matter condition could be a way to recover also this part of Teilhard de Chardin. So perhaps when you said about Buddhism and perhaps Teilhard could also be an opening for a Christian interpretation of this theory, perhaps? And on back of the other question, perhaps this is a dualistic interpretation or still a monistic interpretation because consciousness is anyway… quality of matter?

STUART HAMEROFF: Right. Well, I look forward to your talk. If you think of matter in terms of tubulin, I think of those quantum channels and the quantum channels inside with the aromatic ring. So I think that's a phase space, going back to the whole body, if… that solubility parameter. I think that's the quantum phase inside the microtubule. And as far as Teilhard de Chardin or Bohm, or any adaptation of what we're doing I think is great. And I welcome it.

MANUEL BÉJAR: Do you remember the first slide of his conference? In which there was painted a smart brain inside the big bang? So we can say this, the big wow, you said before? So I would say that mind to matter share the same ontology, but they are different manifestations of the inside properties of matter. We have physical manifestations, physical activity, that have physical research study about that. And we have, on the other side, psychic properties of matter. They are not opposed one to each other because they

are linked with new matter. We need, I think, complex adaptive systems to make the psychic activity of matter to resonate and to be emergent from the quantum background.

When I was watching this slide in which the smart brain appears in the origin of our universe, now, Stuart, we have to rethink this slide. Because Penrose has proposed a new model on cyclic cosmic times in which there was not only one big bang. There were many, many big bangs. Maybe there was indefinite series of big bangs. So where have we put your smart brain? In the first big bang, in the second big bang?

STUART HAMEROFF: Yes, we actually had an e-mail discussion about that, Roger and I and whether consciousness… there's consciousness left over from the previous universe or not, and obviously we don't know. But then we got into the anthropic principle constants and whether they change also. And there's all kinds of… obviously we don't know, but it's going to be a lot of interesting discussion about that in the future.

LLUIS OVIEDO: You suggested, Hameroff, at least twice or three times in your presentation that Buddhism was the religion of sorts for… more akin to the paradigm you are representing. I'm not surprised because I am quite acquainted with consciousness studies and I know that the religion of sorts. Also who are looking for similarities or acquaintances or affinities is Buddhism, especially some kinds of meditation and Buddhism. Well, but the problem for me is that it seems that if the result of this quantum model of consciousness points to Buddhism. But the kind of Buddhist consciousness is not the kind of consciousness emerging from Augustinian understanding and Cartesian. Which is the one that renders possible this kind of science and observation and so on.

So I am not sure whether you are aware that here we are playing with a big paradox. So the kind of consciousness in Buddhist meditation. Buddhists would never allow for this kind of science which has led us into this deep scientific knowledge. So it seems to us to pretending to have the best of two different worlds, and I am not sure that it will work.

STUART HAMEROFF: Well, I wouldn't want to exclude Christianity or Christian thought from consciousness or anything like that. And the Buddhist connection to quantum goes back a number of years, those books. The Tao of Physics and Fritjof Capra and some other, Dancing Wu Li Masters. And so those books go back 30, 40 years probably. I'm not familiar with… I was raised Jewish, and I gave up organised religion, so I'm not that familiar with Christianity. But I certainly welcome any application or involvement of Christian thought in this, because I think it's compatible.

I myself personally don't make a big distinction among religions, I just call it spirituality. And I honour all of them. And so we've had a number of people come to our conferences and talk about Buddhism and then some people say, well, why don't you have Christian speakers? And I say, well, I just don't know. We would welcome them, and maybe you should come and talk, I don't know. But I think anything's possible, and I certainly wouldn't exclude Christian approaches at all. And I look forward to the Teilhard de Chardin talk.

MODERATOR: The texts of some religions would be phrased in ways that are more compatible with the kind of language you're using now.

STUART HAMEROFF: Yes. And you're talking about St. Augustine, and I know I quote him in descriptions of time, because he has some very interesting things to say about what time is. And I know what it is until somebody asks me, and then I don't know what it is. And I think that that's very wise. And so I'm a little bit familiar with that. But overall I'm not that familiar with Christian doctrine and writing, so it's my own shortcoming.

JAY FEIERMAN: Something that you said, Stuart, is just counterintuitive for me. And that is that you said that consciousness is, from your perspective, the same as awareness. But we as human beings understand our consciousness, and if anybody's ever interacted with a bonobo or a chimpanzee on a one-to-one basis, you just get the intuitive feeling that these animals also have consciousness. And then we can go down a little bit lower to mammals, and they probably have consciousness. And birds probably have consciousness.

But as we get down to reptiles, and amphibians, and fish, and even the invertebrates, it's hard to understand that what we call consciousness exists at that level. So one question, other than gamma synchrony which requires an EEG, are there not behavioural criteria for consciousness other than simple response to stimulus? So for example, strategy, where you identify resources for acquisition through tactics. That requires what I would call consciousness. And it also addresses the function of consciousness, which is to make our behaviour more adaptable. So one question is, are there behavioural criteria for consciousness that can apply across taxa? And then the parallel question is, how far down in phylogeny do you see gamma synchrony?

STUART HAMEROFF: I don't know the answer to that last question, but the early slide I showed hinted at my… what I think is that consciousness arose with the simple organisms at the beginning of the Cambrian evolutionary explosion, with the urchins and worms. Now, I don't think they had self-consciousness, but I think they had awareness. They were conscious of their environment, and why that would accelerate, and this speaks to function, why that would accelerate evolution and cause a Cambrian explosion, was because they were going to have better behaviours in terms of strategies. So if two organisms are in a predator-prey relationship and one of them has consciousness, he may have the non-computable affect that Penrose talks about. He may have the backward time effects that's going to allow him or her to anticipate, and he's generally going to win predator-prey relationships.

Plus if the creature knows that it hurts to get eaten, he's going to run away when something comes at him. If he knows it tastes good to eat something, he'd going to be more prone to find food and survive. And if he knows that it feels good to have sex, he's going to have sex and procreate the species. So consciousness would be good for evolution. I think if I had to guess, and obviously just a guess, I'd say consciousness happened in those simple creatures. And the axoneme I showed has… I was astounded to read this, a 3×10^9 tubulins in one of those things, which would give you Orch-OR in about 50 seconds, something like that.

One of those creatures could have a moment of consciousness whereas we have 40 per second, they would have one roughly a minute. One per minute, something like that. And you'd say, well, that's pretty boring having one conscious moment per minute only, but on the other hand, they'd be unconscious in between so they wouldn't know the difference. It'd be like the electron that had one every 10 million years. He wouldn't notice. It wouldn't notice the difference because he would have been unconscious during that time. So that's where I would put my money, early in the Cambrian evolution explosion, a simple form of conscious awareness.

ROLAND CAZALIS: In some cultures, people seem to perceive some realities with not only the brain but the zone between the heart and intestine. But anyway, could you extend almost the quantum effect or the quantum addition to the little brain if possible?

STUART HAMEROFF: Yes. Well, as I said… you want to answer that? Well, some people… we talked about this yesterday. Some people would argue that you… we have consciousness

in the ganglia of the heart, or in the intestine, elsewhere in the body. But again, you have to have enough microtubules in superposition, isolated from decoherence, long enough to reach threshold. So it's possible we have moments of consciousness, maybe rarely, not as much as in the brain. So it could be.

And there's also this business about… this isn't necessarily quantum, but heart… patients who get a heart transplant sometimes report memories from the donor. And there's been some recent TV shows about that. And they asked me about it on TV and I said, well, there are microtubules in the heart, so maybe memory is stored in the heart and the new recipient gets those memories. Because there have been some very strange reports about people who get heart transplants get memories, and new tastes, and new drives that match up with the donor, the deceased donor.

So I think memory might exist. Whether consciousness can exist, it's possible, just like it's possible it could exist… it could happen in anything that satisfies e=h/T by our criteria. So we have that one criteria, and we have to bite the bullet and say wherever that happens, that's going to be… that's consciousness. But the criteria are pretty strict against it.

MANUEL BÉJAR: Do you imagine talking to your intestines? It will be a great question.

ROLAND CAZALIS: What I mean by little brain is the nervous system of the intestine, because I think it is like more of the same cells. Because you said before, it's not possible to extend the quantum addition to the whole body, because microtubules don't have the same function. But perhaps, I don't know, if the microtubule have the same function in the nervous system in the intestine or in the brain.

MANUEL BÉJAR: Intestines need to reproduce many times each week, for example, because the walls of the intestines must be well-prepared for digestion, for example. And the neurons in the heart are also complex, because the heart must do complex movement. As your intestines must do complex movement to digest. So maybe those neurons are specialised in motor movement and neurons in the cells, microtubules in the cells, get adapted by evolution to compute information.

IGNACIO SILVA: I thought we were going into some kind of a multi pineal Cartesian gland, because of all the bings, bing bing bing, but then you said, no. And when you said no, you said that there is a collapse and it depends where the collapse goes, we have matter and mind… when you were answering a question over there. And I wonder what collapses. That's one thing. And then related to that, you both… the basic question is to make sure is, who or what is the subject of consciousness, Because you were saying consciousness is in these collapses, and then you were saying that it's a personal experience, but at the same time you say it involves, is it a connection between brain activities and then although I know it's not the same mind, you define it as a neural system. And the felt state of consciousness as a felt state of matter, who or slash what is the subject of consciousness? Or is it a subject?

STUART HAMEROFF: Well, that depends on who you ask. Deepak Chopra would say that subject-object split, there isn't anything. It's all one

IGNACIO SILVA: Yes, but when I say subject I mean, where it resides. The subject of my hair is my head, in that kind of sense. Not the distinction of subject-object.

STUART HAMEROFF: Well, the conscious pilot model I was presenting basically says that wherever that envelope is at that particular moment, that's what is conscious. If it's

involving the visual cortex, you're having visual conscious experience. If it's in your smell, olfactory cortex, you're having smell, or some combination. If it's in your thalamocortical motor system for driving, where you're conscious of your driving, that's where it is. If it's eating, it's in your taste buds. So it can basically move around, and it moves around. The gap junctions open and close and it moves around. So that whole model was designed to allow for gap junctions to let tunnelling occur so that the quantum state can spread. But also the mobility, moving around the brain, I think is an important concept.

And I'm working with a computer scientist in Germany named Marc Ebner, who's been modelling this type of conscious pilot in neural networks, moving it around. And he shows he can recognise figure to ground and stuff like that with this type of model. So that's a biological model basically showing how the conditions that would support consciousness can move around the brain, and wherever it is, that's what you're conscious of. That's the mode of what you're conscious of, anyway.