Interview: Sean Carroll

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On January 23, 2011, Expositions's *Noël Falco Dolan interviewed Dr. Sean Carroll, Senior Research Associate in Physics at the California Institute of Technology, on the occasion of his lecture "The Origin of the Universe and The Arrow of Time." Carroll's lecture expounded on ideas he put forth in his 2010 book* From Eternity to Here: The Quest for the Ultimate Theory of Time.[1] *Both Dolan and Carroll attended Villanova University as undergraduates in the late 1980s, one studying the arts and the other the sciences, and both (separately) took the interdisciplinary core humanities sequence, an Honors seminar that was team-taught by members of different departments to offer multiple perspectives on the great questions of the human experience. It was in this spirit that Dolan and Carroll discussed the connection of science to the humanities, using as a touchstone Carroll's own work and the collected writings in* Science Is Culture[2] *(a collection of discussions on how science drives today's culture organized by Adam Bly, editor of* SEED*).*

Dolan: Looking at *Science Is Culture*, the first [discussion] … was between Edward O. Wilson (biologist) and Daniel C. Dennett (philosopher), and they were talking about evolutionary philosophy. They agreed on the importance of knowing the history of philosophy. Dennett felt that that helps you to avoid "falling into the same old traps," and Wilson felt that it was better to give you a sense of examining the great questions and the creative process. So, I was wondering, in what ways is such a connection important to you in your field, and is it important to have a sense of historical connection, is it important to consider the humanities in your field or sciences more broadly? Did the humanities in some way play a role in your training?

Carroll: I think that if you were to ask many different scientists, you would get many different answers to that question. I don't think that there is any *right* answer to that question. Some scientists are really extremely successful staying in their offices or laboratories and focusing on nothing but what they do, and paying no attention to the philosophy of science, the history of science, the sociology of science, or any other field whatsoever. But, from my personal perspective … Number one: I enjoy it, reading and thinking about issues in philosophy of science or history of science and humanities more generally; and number two: I do think that it does affect, hopefully improve, the kinds of science that I do, but then I do the kinds of science where that's possible, where I'm thinking about foundational issues in cosmology, and statistical

physics, and quantum mechanics, and things like that. These are some of the issues where philosophers of science in particular have done some of the clearest work. Because physicists are in a sense a very practical and pragmatic people, and sometimes when they get the right answer, they don't want to think too hard about how they got there [because] if you get the right answer that's what you're there for. So, for example, I was just at a conference in Princeton, a very tiny workshop with 14 people, spending five days talking about nothing but the foundational questions of the early universe, the beginning of the universe, and part of our mission was to plan for a bigger conference to be held this summer. And one of the things we decided was we needed outside expertise, we needed either a philosopher or statistician or someone who thought about theory choice and probabilities and things like that. It was my suggestion, and people liked the idea, and so I think that personally, I get a lot of perspective as well as specific help from thinking about the bigger context, but I don't think that it is necessary that everybody think that way. I think that works for some people, but not for others.

Dolan: Wilson and Dennett go on to talk about the gap between the sciences and the humanities, what they call "the unbridgeable chasm" between their fields in their approach to understanding the human mind. Wilson says that there is "anxiety" in the humanities, that scholars feel that the funding and the prestige really are enjoyed more by those in the sciences. Because you had quoted *Arcadia* [twice in your book][3], it stood out to me this time in reading it that Bernard says to Valentine [here quotes], "Quarks, quasars – big bangs, black holes – who gives a shit? How did you people con us out of all that status? All that money?"

Carroll: That's a great line, yes!

Dolan: So, do you think there is such a chasm? Is it real? Is it perceived? Should we bridge it, and if so, how do we begin to do so?

Carroll: I think there is a chasm; I think it is real. It's not absolute. I don't think it's as simple as saying that scientists are high status and humanities people are low status, or anything like that. I think that the territory evolves through time, and questions that you might have thought were the domain of a certain discipline become the domain of another discipline as time goes on. Nevertheless, science has always had some sort of impact on foundational questions that matter to human life as well, what we now call quarks and the big bang. Did you know that Aristotle wrote on physics as well as metaphysics and ethics, and I don't think that those are just completely disconnected ideas in his mind? How you think the world works, and where you think the world comes from might matter to what you think is right or wrong, and the good life, and so forth. But what science has that the humanities *don't* have is this very tangible material effect on how we live our lives, you know, TVs and the internet and so forth and military applications and technological applications. And so, in terms of money, there will never be any contest. Science will always get a lot more money than the humanities. Even if the statuses were completely equal, I still think that the money distribution makes sense because science is expensive. We need equipment that the humanities don't need. On the other hand, I think that

when we're honest about it, my particular subfield of science, and certain other ones, are valuable for and only for the same reasons that the humanities are valuable. My kind of science, you know, where the universe came from, has no technological, military, industrial applications whatsoever and never will. We're interested because we want to know the answers to these questions. Wanting to know where did the universe come from, and what happened in the Big Bang, to me is the same kind of question as asking about the good life or all sorts of questions in the humanities. So, what I do is more expensive because we need to build a satellite that looks at the early universe, but I think the justification is ultimately the same, so in that case I think that the status *should* be equal.

Dolan: One of my colleagues pointed out that Hannah Arendt, in *The Human Condition*, claimed that one problem facing the contemporary West is that science has seemingly de-linked itself from the realm of social-political concerns and controls, writing, "The trouble concerns the fact that the 'truths' of the modern scientific worldview, though they can be demonstrated in mathematical formulas and proved technologically, will no longer lend themselves to normal expression in speech and thought." Yet, it seems to me that within the last decade, perhaps in part responding to the rise of fundamentalist beliefs or influences, scientists *have* become more aware of the importance of effectively communicating their ideas beyond the bounds of their own communities. Do you think there is such an awareness and corresponding attempt, and what do you see as the motivation?

Carroll: I find it very hard to be too definitive about historical changes because I don't really know what it was like to be, in the 1920s, just the sort of equivalent of what we would now call the *Scientific American* reader, *NOVA*-watcher kind of person, the kind of person who was not a scientist but liked science, follows it, reads books like mine. I don't know if there was such a class of person in the 1920s, maybe there was, I have no idea, or the 1820s. So I don't know about that, but I do know that within, so that I can say things with more confidence, my little subfield of physics, in the 1940s or '50s, physics ruled, and it's because we made the atom bomb, roughly speaking, and presidents would have physicists to talk to. It was good for physics; they had money, and they had power and prestige. It also, at least a little bit, caused some self-reflection: What are we doing? What was a very clear patriotic effort in 1942 fractured by the 1950s. You had Oppenheimer going up before Congress and being stripped of his [Top Secret security] clearance, and Edward Teller pushing as much as possible the biggest bomb you could imagine building. Whereas now, 50–60 years later, it's biology where the action is in terms of changing human life, in some ways, and physicists find themselves needing to respond to claims that the twentieth century was the century of physics, and the twenty-first century the century of biology. If you're a twenty-first century physicist, that's not what you want to hear. So I think that there is more of an attempt to justify what we do, and part of that is to talk to a general public. Again, I can't speak to history that much, but I think that personally, it is just important. If what I said before is true, and the justification for doing what I do is not to build a better TV set, but because it's a fundamentally human question, then doing the research I do and not telling

anybody the answer is completely beside the point, right? I just think it is absolutely part of our mandate as a discipline to explain to the most general audience we possibly can what it is we're thinking about and what kind of answers we are getting, and even to connect it to broader questions of human life, which is harder [to do], and is often done badly. Scientists are not necessarily the people to go to if you want to know how to live a good life, but I think that scientists should be part of the conversation with a certain amount of humility about those questions.

Dolan: PBS was doing something the other day; they have a series called "Pioneers of Television," and they were doing the one on science fiction, and *Star Trek* and *Twilight Zone*, and these kinds of leading TV shows that bought into the public imagination and put ideas out there that then inspired other people to go and perhaps pursue. Some of the actors from *Star Trek* talked about meeting NASA scientists who said, "I do what I do because of you." I don't know how many of them went that route, but for me, I see literature as being one of the ways, really before television, opened up this kind of communication [between science and the general audience], particularly science fiction then, obviously. Again, in *Science Is Culture*, Stephen Pinker, who's a psychologist, is complimenting science fiction writer Rebecca Goldstein as being at the forefront of bringing these scientific themes in fiction …

Carroll: You do know they're married?

Dolan: Yes.

Carroll: Okay. [*Laughs.*]

Dolan: [*Laughing.*] Nice that he's complimenting her, right? Well, again, these conversations that we have [between disciplines] …

Carroll: Good, yes.

Dolan: … He says that that collaboration is natural. You were saying, a lot of these ideas, these great questions that we have, are natural for both scientists and philosophers to worry about. I know in thumbing through the index at the back of your book, you've got a lot of literary references. What for you are the themes that resonate particularly across the two disciplines?

Carroll: Yeah, I think that's a fantastic question. Science fiction, number one, absolutely is a key driver of getting young people interested in science. A huge number of professional scientists grew up, you know, watching *Star Trek* or whatever.

Dolan: Yeah, so that wasn't overstated in that [PBS episode]?

Carroll: [*Emphatically.*] Not at all. I don't think [so]. So, let me digress a little bit. I will compliment my *own* wife, Jennifer Ouellette, who has served for a couple of years as the director of a new program for the National Academy of Sciences, called the Science/Entertainment

Exchange, whose job it was to connect scientists with people in Hollywood, to help recruit scientific representation in movies. It's been an amazing, fantastic success, and on both sides, like both sides are already …

Dolan: Are benefitting …

Carroll: Learning, that's right, are benefitting from it. And uh, I've lost the precise point I was going to make; there're too many good points to make here. But, it's just amazing how many movies and TV shows have some sort of scientific component to them, whether it's genetics, ethics, flying faster than the speed of light, you know, building new machines, new energy sources – *Inception* – psychology in the neuroscience, things like that. Almost everything does in some way. And the nice thing is that I think that science can help make those movies better, not just . . . Scientists are often just scolds, and they're like, "No, you can't do that, that's just bad." But when they relax a little bit and open themselves to the possibilities, they can provide ideas, because that's what scientists do, they come up with imaginative scenarios and so forth. And I don't necessarily think that job is to make the movie a sales pitch for science. I think that's actually a very, very counterproductive strategy. *Star Trek* isn't good science, right?

Dolan: [*Laughing*.] No!

Carroll: Not accurate in any possible way, but it was still inspirational to a certain generation. I think that – I believe, I don't have the data – that *The X Files* served the same purpose. *The X Files* certainly had no scientific credibility whatsoever, but it fires up that part of your imagination, and the Dana Scully character was inspirational for some people, and so forth. So I think that in the inspiring young people part of the story, it's perfectly clear what a wonderful place there is for science. There's also the question of [how] – now that we're all grown up and we're having this discussion about our lives, the discussion we have in the humanities, and in the sciences, and in fiction, and the movies and so forth – [of] how tightly coupled can that discussion *be*. Are there deep issues that scientists are able to speak to that can appear in fiction, movies, whatever? I believe the answer is yes. I actually don't know how much it really happens. I expect that we're still, from my experience – as part of Jennifer's program, I know that in Hollywood anyway, a lot of people are just afraid of scientists, because they've gotten the hectoring about how wrong they were about this episode, where the DNA evidence came back in a day and it normally takes weeks, right? And that's not helpful in any way to be hectored by that stuff. I think there's plenty of room for improvement in the open discussion between people on the science side of things and people on the arts and literature side of things. I think it is productive. I'm not sure that it's as anywhere near as active as it could be.

Dolan: And I, being a packrat, was fortunate enough to find this short story …

Carroll: Mm-hmm.

Dolan: … called "Lucid Dreaming" by …

Carroll: Oh no!

Dolan: … Sean Carroll from the fall of, I think, 1986.

Carroll: That's bad!

Dolan: Well, it's funny to me because I just, I happened to have these [issues of the undergraduate Honors magazine *Polis*] on hand, and to see that you had actually written …

Carroll: [*Laughs*.]

Dolan: … some science fiction, with Alan [the main character] here …

Carroll: Right.

Dolan: … looking at the Milky Way and falling into a dream that was perhaps not a dream but an alternate reality …

Caroll: [*Laughs*.]

Dolan: Do you actually then tinker [with writing]? I mean, you were saying that you have helped Jennifer with her project. Do you do creative writing still?

Carroll: The honest answer is no. I certainly had aspirations. I would love to be involved. I have close friends who are TV and movies writers, and we talk, so that might happen. I think that would be fantastic if that would happen. You know, I get to meet very, very big names in Hollywood, at the level of, sort of, Ridley Scott (*Gladiator*, *Black Hawk Down*, *Numb3rs*), Michael Mann (*The Jericho Mile*, *Public Enemies*), and sort of talk about ideas for things. So, yeah, I would love to do that, but you know, the question of "Are you a writer or not?" is "Well, what have you written?"

Dolan: Right, right.

Carroll: Well, I have not written anything like that [short story] so I not could possibly claim to be doing that.

Dolan: I was also reading [in a chapter of *Science Is Culture* called simply "Time"] that Alan Lightman was in a conversation with Richard Colton [about the relationship between time and art]. Alan Lightman wrote *Einstein's Dreams* (1992); I remember reading it maybe five years ago – it's hard for me to remember exactly when – and just being blown away with what he could do with the theoretical background and yet bring it into story form.

Carroll: Right.

Dolan: And so, he's talking to Richard Colton, who choreographed, then, that book. Now, I haven't seen the dance[4] that resulted, but the two of them are talking about the idea of this

connection of science and arts, and Lightman says that "the arts offer a respite or an escape from the sort of time-driven world that we live in," so I'm thinking of that too in asking you this creative question. And when he speaks of "time-driven," he's really talking about how rapidly we live our days, from one event to the next. We've got to go here, we've got to go there. The point made me wonder how *you* define time, and I know that you spend the entire book on time …

Carroll: Right!

Dolan: … and the first chapter really defining time, but if you could briefly, then, for *Expositions*, define time, and do you allow then, or could conceive of, experiential variations of time from theoretical time?

Carroll: I mean, one of the things I try to make clear in the first chapter is that one of the reasons we *think* time is confusing is because we use the same word to mean very different things, and many of the specific things we mean are actually pretty clear, it's not that mysterious. When we said – so the simplest thing that time is, is just a label on different moments in history of the universe. So that sounds very grandiose, but what it means is that I know what it meant to say we're meeting here at 12:45. That was not some mysterious thing that I need to figure out what that was supposed to be, but that's a kind of sterile notion of time, of what time is. It's useful, but the experience of time is a whole other thing, and I'm not an expert in it, and I know that there is expertise there, and amazing experiments have been done recently by psychologists and neuroscientists. Like, this one guy wanted to know, do we experience time differently when we are afraid? And as an experimental psychologist, that's a very difficult question to answer. You have to scare people, right? You have to scare people in a controlled way. Well, he figured out a way to throw them out of buildings. People would drop several stories onto a big, puffy trampoline thing, and while they were falling, they'd be answering little questions on their little, you know, handheld computer. And he wanted to know, are their reaction times changed in any way by the adrenaline that necessarily floods you when you jump out of buildings like that?

And there is some superficial connection in that our bodies, as I'll say in the talk [later] today, our bodies are full of clocks. Clocks are just things that do the same thing over and over again in a repetitive, predictable way. We have things in our bodies that do that. They're not very accurate, so they can be sped up or slowed down by our conditions, our local environment. So we tell time in that way through the clocks in our bodies, but we also accumulate things, and this is part of the mystery of the arrow of time, which is much less clear. Telling time is something we understand at the level of physics and we're getting there in psychology. Experiencing the flow of time, experiencing the aging process, or the development of time, the simple question of why do we remember the past and not the future, is not so simple, not very easy to [answer], either as an active neuroscientist, what happens in the brain when we do that, or as a theoretical physicist, what is it about record-keeping in bits and bytes that lets you say, this particular record is a reflection of something that happened in the past. That's a really deep and difficult question

to answer, it turns out. So, all I can say is a very vague thing, that yes, [there are] all sorts of connections here. [There are] also sorts of interesting questions that we're nowhere near solving yet. They're not independent questions. They're the questions that artists would have; they're closely related to the questions physicists would have.

Dolan: Lightman says, in thinking about time and talking about this time of relaxation – and obviously he reads for pleasure – he says that Virginia Woolf's *Mrs. Dalloway* is one of his favorite books because, he says, "There's this wonderful counterpoint between mechanical time and body time." So, I was just curious, when you read for pleasure, when you read fiction, do you have that mindset all the time [of] your discipline? Do you enjoy things that relate? Are you analyzing things from that background? Relatedly, what would you say are your favorite books?

Carroll: I think I do more now that I've written this book and I've had to sort of relate my physicist notions of time to other sorts of notions of time. And, I mean, *Mrs. Dalloway* is a very highbrow example, but there are plenty of lowbrow examples that are fascinating. You know, the TV show *Lost* does all of these things with time: flashbacks, and the flashforwards, the time travel …

Dolan: Sideways …

Carroll: Yeah, exactly, and … I got to meet them.

Dolan: Did you?

Carroll: I got to meet the creators of the show, and we talked about that a little bit. They're not scientists at all. They love the science, but it's a Wikipedia-level science, you know. They would just sort of come up with some ideas, like what scientists think about. It's not like they were being inspired by science. They were trying to tell interesting stories with interesting structures. That's why I decided to have a chapter in the book about time travel, because it raises both interesting physics points and interesting narrative points. Stories told backwards in time – Martin Amis's *Time's Arrow* is certainly the definitive statement of the story with time's arrow going backward, and it got very, very difficult to pull off. The fact that he did it for an entire book is an amazing accomplishment. There are stories that are told sort of episodically, so that every episode, the arrow of time goes forward, but the set of episodes is arranged backwards. There was a play … Jeremy Irons was in the movie version of it.[5] It was like that, the first scene you saw was the last scene that happened. And then of course, you have *Memento*.

Dolan: I was going to say, that jumped right into my thoughts.

Carroll: It's not a book, but that's probably my favorite playing-with-time piece of fiction, because there're two things going on. One is a series of scenes shot to you backwards; one is a series of scenes shot to you forwards that meet up at the end. I think it's brilliant; I think it's fantastic. The one thing that has never been done successfully is two arrows of time that point in

different directions. So, Martin Amis tells you the story of a world experienced from the future to the past, from the present to the past. But it's not in conversation with the ordinary people moving forward, and it's almost impossible to *imagine* that conversation; that's why it's so difficult. I mean, if I remember yesterday, and you remember tomorrow, what do we have to talk about? How even would it happen? That's one of my prospective screenplay ideas. If I could imagine a way to do that in a compelling fictional way, that would be a lot of fun. The lesson of all this, I think, is that our notion of how time works is ingrained so deeply in how we get through our everyday lives that there's this incredible space for narrative trickery that is not only formally interesting but can illuminate how we experience time because it's different. Time travel, moving things backwards, moving things sideways, telling the story backwards, simple tricks where you begin the story in the middle and you flashback and fill in some of the background. All of these things are interesting because they play with our notion that the past informs the present. The past happened, and you can't change it; we can change the future, it's up for grabs. But how we perceive things that happen in the present is highly dependent upon what we think happened in the past. I think that's what they're really taking advantage of.

Dolan: So what would you say your *favorite* work of fiction would be?

Carroll: Well, *Memento* would be my first.

Dolan: I know you [also] mentioned *Benjamin Button* a few times [in your book], but I think you were prompted by others on that.

Carroll: *Benjamin Button*, you know, both the story and the movie were interesting, but they didn't quite hit the intellectual home run that Martin Amis's book *Time's Arrow* or *Arcadia* or *Memento* [hit]. I'll take those three.

Dolan: Okay, [they're] going to the "desert island" with you. Colton, in response to Lightman, was noting that Einstein – not only because of his youth, but because of being "outside" of academia, not having to do conferences and such – at the time that he was doing his best work, or what Colton was finding as his best work, said that that helped Einstein be open to new possibilities. So I was curious, what's your view on the links between university science programs and needing to get funding – corporation, government [sponsorship], as you said before – needing the research, which is so expensive, to be funded?

Carroll: It's a tricky thing. I think that on the one hand, we're really lucky. I mean I can't complain. On a cosmic scale, compared to, for instance, *English* professors, physicists get a lot of money, right? And part of it is because physics is expensive and we need to build experiments and so forth, but we also get money to fund our graduate students or to travel in ways that humanities people don't. That's sort of just a tiny little perturbation on the larger funding we really do actually require. The flip side of that is that we spend an awful lot of time begging for money. Most of the money for people like me comes right from the government, either the Department of Energy or the National Science Foundation. So, every year there's a report: you

have to write up what you've done and you have to meet with the people, and every three years there's a big to-do about whether or not you're going to be funded at all. For me, it's not too bad, but for the principal investigator on the grant, it's a tremendous waste of time. It's because they want to do oversight; the money agencies don't want to give out money to people who aren't doing anything. But, if they really did just give a lot of money to people who did good things over the last five years, and cut their work by 90%, the results would be just as good. [*Laughs*.] And I think this is just a feature of bureaucracies; there's probably something in there about entropy and dissolution and something like that. Because we get a lot of money out of it, I don't think there's any real legitimate gripe.

Dolan: Do you have a view on how the result of twentieth century sciences, especially quantum mechanics, have – or actually have not – moved into the general culture? And the question really is, If the sciences are still thought of as objective – as compared to the humanities, which are supposedly subjective – does quantum mechanics undermine that dichotomy, because you can't take the experimenter out of the experiment?

Carroll: I think that quantum mechanics is not very well understood, and that's a statement that applies almost as well to physicists as to non-physicists. I think it is understandable. I don't think [there's] any insuperable barrier to make sense of it, but it's a perfect example of something that you can use and get the right answers without really knowing the deep meaning of it. That's why I think philosophers of science understand quantum mechanics better than most physicists. If that's true, then the chance of the person on the street understanding quantum mechanics is vanishingly small. There are a lot of untrue lessons that one could be tempted to think that one has learned from this casual introduction to the field. But, quantum mechanics does have absolutely earth-shatteringly profound ramifications for how we think the universe works. I think that quantum mechanics is the single most impressive intellectual feat in human history, the fact that we figured it out. Aristotle had ideas about physics, and the ancient Greeks did; Newton and Galileo changed those ideas a lot, and really brought them into focus. But, it was so powerful, that set-up that they gave us, that it was almost inconceivable that that set-up would ever be wrong: the idea that there's a clockwork universe that just ticks along and obeys laws and everything is deterministic if only you had all the information there was to have. It just fit so well, all the data, and it was just so clean and pretty, [that] it just seemed inevitable. And to realize that the world just doesn't work that way at a fundamental level … I really give incredible credit to my predecessors, because in the 1920s, there was some argument and some angst and so forth, that Einstein went to his grave not really buying into it, but as a *field*, they bought into quantum mechanics really quickly because that's what the data more or less demanded. That's when science is at its best, when they're confronted with something you don't want to believe, but someone says, "Look, I can understand this if you grant me this crazy idea." People will go, "Yeah, I guess the crazy idea must be right because that's what fits the data." We're still struggling with the consequences; we accepted it as true. We don't even know what it means. We don't have a consensus for what happens at the deepest level to explain quantum

mechanics. I *wish* that more people in the world understood quantum mechanics very well, including myself … There's a metaphorical role for ideas in science. People can be inspired by crazy ideas that they hear from relativity or quantum mechanics, biology or cosmology or whatever. But to take Darwinism as justification for social Darwinism, or to take quantum mechanics as saying, "Aha, you know, the Buddhists were always right all along," or to take a certain cosmological theory as evidence that "Oh yes, God created the universe then," or there's a different cosmological theory, "Oh yes, there's an infinite number of cycles," right? This is all cheesy. I don't think there's any justification for doing that. People who already have decided what they think is right and they're waiting for some respectable sounding thing [so] they can say, "Aha, you see, it was like that all along." So, I don't think that uncertainty or imprecision or anything like that helps. I mean, it might help inspire a good idea. I don't think it's actually sensible to use that as an argument in favor of your preexisting ideas about the general decline of society or the difficulty in predicting the financial markets. [*Laughs*.]

Dolan: My last question comes from Adam Bly's introduction to *Science Is Culture*. He says, "The trouble with commonly practiced organized religion is not God. It is that it offers truth without a way of questioning it. Worse, it punishes you for questioning it." And so he suggests that children be taught to embrace the scientific method. Not just taught it, but taught to embrace it …

Carroll: Right.

Dolan: … before they're taught about God. Meanwhile, Dennett says he's at work on a book about religion and science in which he hopes to study religion as a natural phenomenon with the *tools* of science. So, I'd ask, which approach means more to you in your work: bringing science to the masses to counteract that kind of dogmatic acceptance, or understanding the need some feel for things like religion to explain the world.

Carroll: Well, I would say, yeah, if that's the choice …

Dolan: You can give me a third choice, it's not always two!

Carroll: I mean, I think both of those are important. If we're going to prioritize them … I don't think Adam Bly's formulation is right. I think that it's a little naïve because we live in a world where some people have religious beliefs and some don't, and this idea of "what we will teach the children" is not a real-world belief.

Dolan: And can I say, having four children …

CARROLL: [*Laughs*.]

Dolan: … children are experimenters already.

Carroll: Every six year old is a great scientist, right? They're empiricists: they do things, they touch things, and see what happens to things.

Dolan: And taste a lot of things that they probably should not.

Carroll: And they push around and so forth. Along those lines I think that if I could pick something that I wish could be widely spread, it would be an appreciation of the humility that underlies science. I read a great blog post from a woman who actually was a major light in the New Age movement. You know, auras, and tarot cards, and the whole bit. You know, this is a sub-economy as well as an intellectual state to be in. Some people write books, and they give seminars, and she was a major fixture in that. She always felt, that you know, that some of that stuff is good, some of it's bad, some of it's right, some of it's wrong. We need to distinguish between the right and the wrong. We need to have a way of telling whether a certain thing is right or wrong. Ultimately, she has moved out of it entirely into the skeptical movement. The lynchpin for her was when she realized that she was always bombarded with this thought that the scientific establishment is kind of arrogant and they think they have it all figured out and they have all the answers and science is everything, whereas we are open to possibility in the New Age movement, which she eventually realizes that it's the New Agers who actually have an answer for everything. There's no phenomenon that they think they can't explain. Where scientists are quite confident in some things, but it's easy to ask them a question, [to] which they will say, "I don't know the answer to that." They're comfortable living in the uncertainty, that they haven't figured everything out yet, and also comfortable that they have figured some things out. I just encounter this among a lot of people. They can't seem to simultaneously accept that there are things we don't know and there are things we know, and we even have a pretty good idea of what the difference is. So when I say something is true, that doesn't mean I think I know everything, but I actually do know this little, particular thing well enough to get on with my life and not take that as an open question … Scientists, as a group of human beings, are not the most humble people in the world. That's undoubtedly true, but as a discipline, there's an inherent humility in the fact that the universe is bigger than we are, and we don't know all its secrets. We're trying to learn as much as we can, and everything we do is contention. We put forward hypotheses and we test them. It's not a deductive method overall. We make guesses. We sort out which ones work and which ones don't, and there're certain phenomena which we can't yet explain. I figure that sort of hypothesis-testing, guessing, and using empirical data to make choices methodology that science uses is the one thing I would like to be more widespread. And instead we teach this terrible Baconian scientific method in high schools, where you need to write down your hypothesis and test it; no scientist actually works that way. The *spirit* of science is what I would like to be more widespread.

Dolan: Thank you very much for your time.

Carroll: Sure, my pleasure.

Notes

1. Sean Carroll, *From Eternity to Here: The Quest for the Ultimate Theory of Time* (New York: Plume, 2010).
2. Adam Bly, ed., *Science is Culture: Conversations at the New Intersection of Science & Society* (New York: Harper Perennial, 2010).
3. On page 29, Carroll comments on Stoppard's discussion of "the arrow of time as a central organizing metaphor," quoting from scene one in which Thomasina comments on how one "cannot stir things apart." On pages 120–121, in explaining Laplace's Demon, he quotes Stoppard again as Valentine and Chloë discuss determinism.
4. Colton's dance adaptation was one of more than two dozen performance adaptations of the book since its publication.
5. *Betrayal*. Dir. David Hugh Jones. Horizon, 1983.