The Science Review:

Science, Society and the Merchants of Light

MR. ROGER BINGHAM: This edition of The Science Review is rather special. It comes to you from Arizona. We are at a conference, The Origins Initiative, put on by Arizona State University, largely responsible for that is on my left, Lawrence Krauss, we will get into that later. You have been watching possibly some of it on the web, and we will be carrying it on The Science Network later.

This is a discussion among some of the people who have been here. On my far left is Richard Dawkins, next to him A.C. Grayling, Lawrence Krauss, as I said. On my right, Steven Pinker, and Brian Greene. We are going to go through a few issues that deal basically with science and society, science and social policy, and I was going to suggest, as a beginning, that next year is the 350th anniversary of the Royal Society, it is a major event, an enterprise that has been going on now, essentially at the beginning of what would loosely be called the Scientific Revolution, and it is a manifestation, to some extent, of Francis Bacon's ideas. Bacon wrote this extraordinary utopian book called The New Atlantis, which, despite its flaws, had some wonderful ideas in it. One of which was that there were merchants of light on this island, the primary commodity that they were exchanging and seeking out was the light of understanding. So at some point next year, we will be doing a meeting called, in the Beyond Belief series, Beyond Belief: The Merchants of Light, and it will be in the form of essentially a shareholders report about the state of this enterprise of science over this period.

So I want to start by asking you, how are we doing? What are the upsides and the downsides from your own disciplines, what is your sense of science at this particular time, when we have a President in the United States who says he wants to restore science to its rightful place on the U.S. agenda, and a leader of the house here who also says that her agenda is four words: science, science, science, and science. So this is a great opportunity for scientists to speak out about what they are thinking at this point. So who would like to go first?

MR. LAWRENCE KRAUSS: I will. It is a great opportunity. It is a great challenge. One of

the reasons that it has become so important is we are recovering from a time when science was having extreme difficulties in terms of being the sound basis of public policy, eight years in this country where it was really being ignored or censored or distorted. At the same time, and this is perhaps more relevant to the group that we have here, there are great challenges, again in this country, but in other places in the world. Challenges to the notion of scientific rationality and I think more than any time in perhaps the last century, we are at this threshold of conflict that—it is hard to know where it is going to go worldwide. So I think the scientific endeavor is doing fine. We have, as a discipline, suffered in this country and elsewhere, because science was not being the basis of sound public policy, which it should be. It should inform public policy. That scientists—no one wants scientists to be decision makers so much as to be able to have the results of empirical study be used by those who are empowered by the public to make decisions on their behalf, and we have suffered severely, and so that is what makes this so exciting, it is a time of hope, but I think a great challenge, because we have suffered tremendously because of a lack of sound policy in the past.

MR. BINGHAM: Yeah, now it is no surprise is it, before we get another response, it is no surprise, I should obviously make the point that you guys obviously all believe in this to the extent that you are public faces of science, you are public intellectuals, you are communicators, Richard particularly on the selfish gene evolution story, but also on The God Delusion book and so on, Anthony Grayling, philosophy, communication of ideas about what is good, what is right, moral issues and so on. Steve, last book was The Stuff of Thought, so very much interested in how we think, and Brian, the cosmos, the big stage. Your role in this is obviously important, so let's start at this end and pick up from where Lawrence started there and see what your sense is from your place, on that. Unless Richard, you want to…

MR. RICHARD DAWKINS: I was just going to say, I thought we were talking about the last 350 years, not current policy in the United States.

MR. BINGHAM: Oh no, but you can—absolutely the last 350 years.

MR. DAWKINS: Okay.

MR. BINGHAM: Do you want to actually go in now?

MR. DAWKINS: Well, I thought we decided on two different things, one was the last 350 years, and then current policy. It sounds as though Lawrence jumped into part two rather than…

MR. KRAUSS: I thought he asked at the current time, but you want to start this all over again?

MR. BINGHAM: No, no, no, you are all such nimble thinkers, that we'll go between one and the other. I actually would make the case, I think I can at least try and make the case that there is something not dissimilar now to then. I mean, 1660 was a time of great turmoil. There was just the beginnings in science, Hook, Rand, Boyle, and so on, were just beginning to meet, there were no coffeehouses, if you will recall, in England, until 1650. Coffeehouses in London in 1652, and if you read Pepys and John Evelyn, you find that all these mechanics and the virtuosi, like Rand, Hook, Boyle, and so on, are meeting at these new places, and there is kind of a coffee internet, there is a cognitively enhanced driving engine going on, bringing all these people together, into a community, the kind of community of science that Bacon was advocating. I would suggest that after a lot of the disarray socially that has been going on recently, that the sort of sense of science now is not radically dissimilar. It is a great opportunity to do the same sort of thing. So that is the link I wanted to make.

MR. ANTHONY GRAYLING: It is quite a good point, because we have just come out of a period of turmoil, there is conflict in the world of a serious kind which the U.S. is deeply engaged in, and we have got this economic difficulty that we find now, just come out of a double presidency, a two terms president who has been very inimical to science, and Lawrence is right about that, and there are some parallels with 1660, the civil war period, the commonwealth period, the restoration of the monarchy and so on, so there are these superficial analogies at the very least. But one thing one has to remember is that the foundation of the Royal Society was not just the origin of something, or the beginning of something very important in the institutionalization of science as an important thing in society, but it was the end product of something, of 100 years of struggle between, on the one hand, the emerging empirical studies, and on the other, reactionary forces, in

particular the church, that was made very anxious by some of the things that the new sciences were saying, and the fact that an institution could be set up in 1660 was the mark of a success, that there had been a victory of an intellectual kind at the end of that century, that had started with Copernicus and all the great changes there. So it is an important point to remember that, that it is a mark of a stage in a process which has been a longer and a richer one.

MR. BINGHAM: I was focusing on the notion of how do you build a community which is engaged with, sympathetic to, supportive of, and doing good science.

MR. KRAUSS: I mean obviously, there is one huge difference between now and then, science has become such a community. What I think the people at this table try to do is explain to the public how the scientific community works so successfully internationally, together, to change the world. And that has happened and will continue to happen regardless of the public perception of it.

MR. BINGHAM: Yeah, Brian had a point.

MR. BRIAN GREENE: It's interesting, you began by asking, how have we done, and we have done really well. And you think back to Newton, he was trying to figure out the motion of everyday objects, from throwing a ball, to the motion of the moon, and he did a really good job, and he did such a good job, that it took us a long time before we were able to make the next dramatic steps, but we have. We have been able to understand how molecules work, how atoms work, subatomic particles, we have been able to go the other direction, figure out how neutron stars, black holes, entire galaxies, and the whole universe, we really have a fairly good understanding of our huge range of physical scales. That is a tremendous achievement, but it also sets up a challenge. We are now investigating realms that are so far from everyday experience that it really requires us to be a bridge from very unfamiliar territory, molecules, atoms, and particles, and the strange features of the quantum world and black holes and so on, we need to be the bridge so that the general public recognizes how important these studies are, and how exciting it is, the wonder of science, the inspiration that you can get from the ability of this thing inside our heads to go so far beyond and really grasp the universe in a very deep way. So it has been a great time, 350 years, but the success also sets up a great challenge.

MR. DAWKINS: I strongly agree with that. I think that the scientific enterprise during the last 350 years is without a doubt the crowning achievement of the human species. It is just beyond parallel, it has been progressive, standing on the shoulders of giants. In my own field of biology, since Darwin, we now understand why we are here, we understand what life is all about, we understand what it is for, we don't understand in every detail how it works, but we know what it is here for, and post-Darwin, we no longer have to resort to superstition when faced with the complexity of life, the elegance of life, the strong illusion of the design of life, which after all is a hugely persuasive delusion. Then after Darwin, staying within biology, molecular genetics, the achievement from 1953 onwards, has been a quite astounding achievement, the reduction of genetics to a branch of information technology, it has become a branch of computer science, the idea that every living creature carries within it a digital archive, a database of the way its ancestors lived. Darwin would have killed for such information, it would have been absolutely amazing to Darwin, what a tragedy that he is not here to share in it. I think that it is something we should be enormously proud of, as a species, but I agree with Brian that it is also an enormous challenge for the future as well.

MR. BINGHAM: Yeah, Steve?

MR. STEVEN PINKER: Of course the culminating step in this progression is that we are turning the tools of science upon ourselves, understanding how the human brain works, how human societies and culture emerge from interactions among the intelligent organisms such as us, and I would like to think that it is that final step of turning the microscope around and looking at us as humans that explains what is so special about science and why it is such a fragile, vulnerable enterprise, namely that there is much in the operation of the human brain that runs counter to the ideals of science, and enlightenment, more generally. Some of them are our cognitive limitations that Brian alluded to, it is very hard to wrap your mind around a black hole or relativity, or some of the findings from quantum physics. Some of them are because there are attitudes of mind that are hard to shake ourselves out of when it comes to familiar phenomena. It is hard to look at other people and not imagine that they are animated by a soul, it is hard to look at complex life and imagine that it could have arisen without a designer. But I think some of the impediments come more from our social emotions than our cognitive limitations. Namely,

the idea that you should believe in something because it is true, does not come naturally to people. In most times and places, the assertion of beliefs has been a sign of solidarity with ones culture, you say you believe things to show that you are a loyal member of a coalition. It is a matter of exerting authority, it is a matter of politeness and convention, and the kind of social norms that function within science, within democracies, within well-run intellectual forums like universities, that say you must have a reason for your beliefs, you may be called upon to provide them, you may legitimately be challenged without it being a form of disloyalty or insult, that a graduate student can challenge a Nobel prize winner, if she sees a flaw in his argument, and it is not a sign of disrespect to him as a person or to the community, that all discourse and all belief are subordinated to what is true, is a very unnatural social norm, and that I think is what science, but more generally, I think as enlightenment, secular humanism, well-functioning democracy, those are the values that animate all of those enterprises, of which science is a particularly successful part.

MR. KRAUSS: Yeah, but you know, I am not sure—that is true, except I think for the public, how we know it is true or not is a very different thing. Whether their willingness to accept that science can distinguish certainly at least what is false, which is more important, I think that is just not generally accepted. Obviously I agree with Brian and Richard that the last 350 years have been remarkable, but at the same time, if you look at people on the street, if you ask people why a book will fall faster than a piece of paper, most people will say, "The book is heavier," in spite of the fact that we have known for hundreds of years that that is not the case. If you ask most Americans, at least, whether they quote/unquote "believe in evolution" most of them will say they haven't, so there is this disconnect between this remarkable enterprise that has literally changed the world, and people's perceptions of it, so I think the biggest challenge for us is not just to convince them of the remarkable developments, for most people I think when they think of science, they think of technology. That science has produced better things that make their lives better, but the ideas and process is something we have done a very poor job I think of explaining to people about, and I think that is the big disconnect, that people need to understand how we make progress in science, and that is a real challenge.

MR. GRAYLING: One thing that comes immediately out of what you have just been saying is that science education, especially for the young, the grade school level, has got to be

thought about really carefully, because it is a very familiar thing that a lot of kids get put off of science, find it too difficult, they find the math too difficult. There have got to be ways of presenting this material to people that really attract them and bring them in, and get more people involved. It is not just a matter of producing more scientists, it is a matter of producing greater scientific literacy, because the crucial thing at the moment is you say that people are aware of the fact that technology brings benefits, it also brings serious disbenefits in the form of weapons and accidents that might happen and so on, and that makes people nervous, that is one of the reasons why some people can be hostile to science, too. And hostility is always a function of ignorance, largely. I mean, well-informed hostility is something to worry about, but generally speaking, it is ignorance. And so this business about improving scientific literacy in the community is absolutely key. And we know this, there are a heck of a lot of people out there who don't know anything about science. And we've got two problems: one is the people who don't know that they don't know anything, and who need to be educated, and worse still, the people who don't know anything, and they know they don't know anything, and they don't care. So that is another problem, too. In one or another way, and there are lots of enterprises now, Richard has been a professor of the public understanding of science, Brian runs this brilliant thing in New York every summer which educates people, finds ways of getting the message across there in unconventional, exciting, entertaining sort of ways. That is where the focus has to be now. It is absolutely crucial to our time, with this increasingly rapid explosion of insight, of mastery of aspects of nature, that more and more people should be good participants in the conversation about what science is, what it is for, what effects it can have on us, and that comes down to this product of a lifelong process of educating people to be more literate and to understand something of what is going on.

MR. GREENE: I have to say, I can't say that I agree with you—I agree with absolutely everything you say there, because I have encountered so many kids who, when I begin to tell them some of the interesting things or the things that I think are interesting about science, things about cosmology or astrophysics or particle theory, to see their eyes widen, and have them say, "That is science?" Because that is not what they have experienced science to be, because so often in the classroom, we quickly focus in on the details, trying to get kids to solve equations and balance reactions, and so forth, and the reason for that is clear, the details are important, they are also very easy to examine, right, so you can have

tests that are really based on the details, getting the right answer, and if we don't have a commensurate focus on the big, wonderful ideas of science, that get kids excited about it, they just don't care enough about the details to really want to engage with them.

MR. BINGHAM: Yeah, as you all know, Natalie Angier's wonderful book, The Canon, in which she has an interview with Peter Galison, the historian of science at Harvard, and Peter says there is this incredibly difficult task, you take these bright, energetic, energy information sucking objects—

MR. GREENE: [interposing] And beat science out of them or something, right.

MR. BINGHAM: And you manage to push this rock to the top of the hill there of making them completely disinterested. And Natalie says then what happens is that about the age of 12, people go and buy their kids a membership card to the Museum of Contemporary Art, and they leave the science behind, which is why the World Science Festival and all the things that you guys are involved in, sounds like it is—but it is not just the kids, is it? There has to be this entire spectrum.

MR. KRAUSS: And I am going to throw in a plug for why we are here. One of the reasons we have picked origins to focus on is specifically because we have found that origins is an area which both incites interest and controversy. You want to motivate people to get over the threshold to at least listen, and you want to bring together enough people that it will get people excited, and I have to say that one of the most exciting events that has happened in this meeting is we were in an inner city school in Phoenix, we had a thousand high school kids for two hours, and it was like a basketball event, with three of the Nobel Laureates here, and the kids, I just—I wouldn't have believed it. They didn't have to be there, they literally were not being forced to be there, and they were thrilled to be there. And so there is that inner interest and excitement, and we just have to think of ways to motivate, not only just the kids but the people who teach the kids, and the people who also write about science and the people who also show it on TV, that actually people are fascinated by this, if you give them a chance.

MR. BINGHAM: Yeah, Richard?

MR. DAWKINS: I think there are two problems with educating people about science. One

is that there is the presumption that you should sell science on being useful. Science is useful, but the important thing is that is not all it is. And usefulness is not the most exciting thing. A lot of people think it is, they sell the space program on the fact that nonstick frying pans were discovered. I mean, that is so demeaning to something as noble as the space program. An analogy which I like is that you can appreciate music without actually being able to play an instrument, and a lot of people have a love of music drummed out of them by five finger exercises on the piano, when they could be listening to Mozart. The equivalent to listening to Mozart is your thing about having the Nobel prize winners coming and telling about the wonders of the universe, and similarly, in school, you don't have to teach science by getting out a Bunsen burner and getting people to do the—melt things in crucibles and things, you can teach how wonderful it is, how elegant it is.

MR. KRAUSS: That is because we want also, as educators, we tend to want to create clones of ourselves, I think, and Brian brought it up well, we tend to think it is really important that these students have all the skills that we have, but most of them don't need them, they are not going to be physicists or biologists, what they need is an understanding of the process and the wonder.

MR. BINGHAM: Steve?

MR. PINKER: I agree with everything, except that we would be deluding ourselves to think that the only reason there is hostility to science is because there is ignorance to science, and in fact there are studies of people who endorse evolution, because they come from Blue states and they like Barack Obama, and they know that endorsing evolution is the correct thing to do, who actually have a rather faulty understanding of it, and I would not be surprised if the converse was true, that some of the people who are hostile to evolution probably understand at least the core of what makes it work. People also have attached moral and cultural significance to certain beliefs, and the people who are hostile to evolution are ones who think that it is incompatible with moral values, that if evolution were completely true, we would be like—if you teach kids they are animals, they will behave like animals, we would be raping, we would be carrying out the dictates of our selfish genes, value, purpose, meaning, would evaporate. So part of the story of science and what makes it so ennobling, is that that couldn't be farther from the truth, that there is nothing belittling, there is nothing about science that takes away meaning and purpose and

morality, and that we have been I think doing a poor job in letting the traditional religious and cultural right have the franchise on meaning and morality, there has to be a way of saying that the values that make science possible, such as self-examination, such as a respect for the truth, such as humility and awe and wonder, in the face of the natural world, are all ennobling and moreover, they lead to a sounder morality and ethics than ones based on dogma or cultural inertia.

MR. GRAYLING: Yes, I think it is a very, very important point, and I agree with Steven there. A lot of people think that science is reductive in the sense that you don't see the pearl, you only see the disease of the oyster, and somehow this takes all the color out of the world and all the meaning, and what you can easily do is to tell people that what the 18th century enlightenment was about was about the attempt to apply the canons of rationality and evidence based reasoning and empirical constraints, to the social sciences and the humanities and the business of government and thinking about the human good. I mean, it is a fascinating thing about that period in time, that people saw that there was a way of approaching things and thinking about things, discussing them, which would open up a new understanding, a new depth of understanding, across the whole world. So it wasn't just a matter of the natural sciences or natural philosophy as it was called then, but it was about that whole project.

And just to go back to something that Lawrence said right at the very beginning, about the scientific community, because it is connected to this idea of the ideal or not the ideal but the maximally meliorized sort of social setting, is that the astonishing thing about the scientific community is its internationalism, is the fact that it is a pure meritocracy, almost a pure meritocracy. The fact that there is a set of languages, spoken by physicists, by biologists, whatever it might be, which enables them to communicate and share ideas to challenge one another, to test one another, as a very healthy kind of competition sometimes, a little unhealthy and people nick other people's ideas and so on, but generally speaking, it is a very flourishing, a very vigorous community. And if only you could generalize that to other sorts of communities and perhaps to society at large, it would be great.

MR. DAWKINS: For example, honesty is an absolutely cardinal value of science. The whole scientific enterprise would totally collapse if we couldn't trust each other not to

fiddle our figures. Whereas the legal profession, for example, is essentially founded on the need to persuade not exactly against the facts, but at least trying to make the best case you can regardless of the facts. Science doesn't work—

MR. BINGHAM: [interposing] Now, you're not saying that scientists are inherently more honest, are you?

MR. DAWKINS: No, I am not saying that.

MR. KRAUSS: Science forces them to be, whether they are or not.

MR. DAWKINS: That is right. Whatever their personal inclinations, the whole scientific enterprise depends upon honesty in a way that the legal enterprise absolutely doesn't.

MR. GREENE: But it also has a self-correcting mechanism to enforce that.

MR. DAWKINS: Yes, peer review and repetition of experiments and so on.

MR. GREENE: Peer review and replicable results.

MR. KRAUSS: But it is incredibly susceptible, because we trust each other, when someone does make a fraud, there has been a lot of examples of how far it can go, because we presume honesty, but it makes it also difficult to counter. I know, for example, in the context of the debate against intelligent design, which I have been a big part of, there are—in fact, the Discovery Institute, which is a major proponent of intelligent design, they know very well that the end justifies the means, and they are willing to distort the truth for that, and many, many scientists have a difficult time responding to that, because it is very difficult for scientists to respond to people who are knowingly willing to lie in order to achieve a political end. It is very difficult.

MR. BINGHAM: But look, let's talk about this notion of truth, because that sounds like there is some final thing to be found, most scientists would subscribe to some extent to the philosopher Karl Popper's view of things, where you are constantly coming up with ideas and then you try and falsify them. And so he would do piecemeal social engineering and so on and so forth. I think there is an idea that the general public does have an idea that there is some final truth to be reached, and somehow find the enterprise wanting, when

they read in one newspaper that there is a new study out which conflicts completely with the study that came out three months ago, which caused them to change their entire medication, so on and so forth, so there is this conflict here between ideal—how do you explain that to people when you are out there?

MR. KRAUSS: Well, there is a large part—I think part of it is the need to sell—all of us have experienced—

MR. BINGHAM: To sell?

MR. KRAUSS: Yeah, to sell things. To sell papers, to sell anything. So that many times a new result is jumped on, first of all by the universities who promote it with press releases, when it may not yet be ready to be reported on, the journalists who then utilize it, and the fact that there is—and the need to always think that in order to sell it, Brian and I are probably more familiar with this, in physics, everyone, every new person has to be the next Einstein, and if they are not, it is not supposed to be interesting to the public, and so we tend to I think in our reporting of science, there is a great pressure to overplay things that are tentative, because science is tentative, and at the front edge, a lot of the stuff we are thinking is wrong, and that is what makes it interesting, but it is very hard to convey the fact that we are debating about exciting things, which are tentative and will evolve, but rather to be presented as great discoveries rather than great little steps.

MR. PINKER: I think there is a tendency in science journalism to publicize the latest single finding, ignoring the fact that has been shown often by statisticians that the majority of published findings are false.

MR. KRAUSS: Yeah, exactly.

MR. PINKER: Now that doesn't mean the scientific enterprise is worthless, because all unsupported conjectures are false, as opposed to only a large—a slight majority of scientific findings, and of course you accumulate scientific findings so that after there are a large number of studies and meta analyses and literature reviews are done, the overall picture of the truth can emerge. But focusing on a single study is as—can be as misleading as focusing on a single anecdote. And really there can't be—the problem with any kind of criticism of science for having promoted findings which we later discover to be false is that

it is only the standards of science that show that the earlier science was false, and in a sense, science as a method, as opposed to science as an institution, the particular people who happen to be running the scientific enterprise at any one time, but the standards of science, in a sense you can't argue against them, because the only way that you could show any of the limitations of the claims to limitations from science are with better science. It is like criticizing rationality, there is something inherently incoherent about it, because it is only by developing a more sophisticated rationality that you could criticize the rationality that is in effect at a given time.

MR. BINGHAM: I think Brian was frank the other day in a panel when he said that what you are actually trying to do, and I know this was loose, is to try to accumulate evidence to distinguish this just so story from that just so story, which acknowledges that science begins as we have always talked about, as storytelling. You have to tell some sort of a story to begin with, and then you test it against reality.

MR. GREENE: That is right, but the one thing that I would emphasize is if we were better at communicating the larger framework within which science happens, which is, it is almost unheard of for a new result to overthrow the past, simply wipe it out and we are on to something that completely erases everything that came before. Usually, almost always, it is incremental shifts in our understanding. We understand a domain a little bit better, we can extend our ideas a little bit further. And indeed, at the cutting edge, those extensions often will later be shown to be wrong, or need to be modified, but the core of the enterprise almost never is thrown away, is never wiped out, and that is the bit that gets lost, when we always think, "Oh, new result says this, new result says that," and we feel that everything is changing, no, no, the core is not changing, it is just at the edge things are changing.

MR. KRAUSS: I would get rid of the word 'almost'. The great thing about science and the biggest misunderstanding of science is that scientific revolutions do away with anything that went before. That which has satisfied the test of experiment is not false once you discover new things, and that is a huge public misunderstanding, but I want to jump on something you said that I think is really worrisome, and that is stories. The public has this perception that science is that of stories and religion is of stories and it is these stories versus these stories, but science is a lot more than stories. If it were just stories, it wouldn't be worth talking about. It is stories that make predictions and it is a view that makes

predictions about things that can be then tested, and that is the whole point, and I really do think that a lot of the public's perception or unwillingness to sort of accept things is the perception that it is just a set of stories and you can choose which ones you like best.

MR. BINGHAM: No, I already contexted that with Popper's discussion.

MR. KRAUSS: No, I know, I wasn't—obviously—

MR. BINGHAM: [interposing] It is fine for you to make the point more strongly.

MR. DAWKINS: I think there is a problem also with quoting out Popper all the time, because there is a real sense in which there is a double standard, whereby science is held to the sort of standards of Popper, you never actually prove anything, you only prove to disprove it. I mean, technically, that applies to everything, that applies to the fact that this table is sitting here and that it is sunny outside, these are just hypotheses that have never been falsified, but only science has to suffer this heckle of the Popperian standard. And the public misunderstands this. Evolution is only a theory. Well yes, but it is only a theory that we are sitting on chairs. In that sense, in the same sense that it is a fact that we are sitting on chairs, it is also a fact that evolution is true.

MR. GRAYLING: Because one wants to add to the idea of science as an accumulating, self-adjusting body of knowledge, which it is, and which a million times a day, every time you get in an airplane or use your mobile phone or something, its applications through technology is being constantly confirmed, it is getting a lot of supporting data there. But in addition to that, in describing what it is, one wants to say something about it as an attitude, that science is a way of doing things, a way of thinking and of finding out and of testing it. There is a very marked contrast between the scientific mindset, which is prepared not to know things, yet. Prepared not to understand things yet, prepared to be open minded, prepared to recognize that solving a problem may very well generate a number of new problems, and to be interested and excited by that, to be interested and excited by uncertainty and open-endedness. Whereas, there is another kind of mindset, which wants a neat story, with a beginning, middle and an end, wants closure, wants everything explained, and this is characteristic of the religious mindset, and it is very uncomfortable with open-endedness and uncertainty, not wanting to know. And there is a huge contrast

between the fact that you can tell a closed, neat story which has got a beginning, middle and end, and a meaning, in 10 minutes, and you can't do that with science, it takes a certain apprenticeship to be able to get in there and to be a net contributor to the scientific process. That is not the same thing as saying that it is hard to become scientifically literate, because this is the point we were talking about earlier, that we want to encourage people to be scientifically literate, but to understand that, this open-endedness, this uncertainty, the fact that not all the answers are in, that some answers create more questions, all that kind of thing, is an excuse which is used by the people who like the neat closure type story to say, "Well, you don't know the answers, and there is uncertainty, we don't know how it began, we don't know where it is going," and to use that as an excuse for stopping thinking about it.

MR. KRAUSS: To go back to what Brian said, I think that meshes really nicely to his initial statement, that the problem is somehow what we teach. That is a really difficult thing to teach, and it is a lot easier to teach a set of things you can test and moreover, I think in addition to what you said, the problem is, that the people who are doing the teaching are not necessarily comfortable with the science, and if you are not comfortable, if you haven't participated in the process and are not comfortable with it, it is very difficult to talk about it, and a great majority of the middle school science teachers in this country really have never taken—the statistics, have never taken science beyond high school, and I think there is a real—therefore we have a real problem, because we get people to teach these set of facts and not the process, which is probably the most useful thing that kids could come out of school with, and it is really a problem.

MR. BINGHAM: I agree with you, I agree with those points, but there is still—the reason I made them is that there is still, in my experience, anyway, this public perception of a need for certitude. The same thing with this recent stock market crisis. Decisions made under the conditions of uncertainty, the neuroscience of all of that, if the people understood more of the neuroeconomics of all of this sort of stuff, perhaps it wouldn't have gone in this direction. I have no idea.

But let me go back to a point that I think Brian made earlier, which is the—or maybe it was Richard, the fact that there is no overnight revolutions. What was it, 14 April, 1953, the Crick and Watson paper was published on the DNA, the structure of DNA. There were

virtually no citations of that paper, no increase in the number of citations, apart from the fact that it wasn't refereed, remember, because the enterprise of science at that point did not even have referees for journals, so it just got in because the editor thought it was a good paper.

MR. DAWKINS: Especially Nature. You know how the editor of Nature worked then?

MR. BINGHAM: With John Maddox was it?

MR. DAWKINS: No, before John Maddox. He took a briefcase full of appears to the Athenaeum Club in London, where all the members were sitting back in their armchairs after lunch, snoozing, handing out papers, and then he would come back at teatime and pick them all up again, them having been refereed.

MR. BINGHAM: Okay, so things have changed slightly.

MR. KRAUSS: I think.

MR. BINGHAM: There are two points in here. One point is that the DNA paper, the classic paper itself did not start being cited in large numbers until roughly 1990, when the human genome project got into gear, in other words when the technologicalization of it all started happening.

MR. KRAUSS: But that is not so surprising. We talked about it, I mean really important advances aren't obvious at the time, all the time. I mean, we had—at this meeting, Steve Weinberg here, who one the Nobel Prize for the standard model, and his paper wasn't cited at all, for years afterwards, and I think it happens in every one of our field. Darwin, you talked about that.

MR. DAWKINS: Darwin's paper was completely ignored in 1858.

MR. PINKER: Is part of it also that science doesn't work from canonical texts, and the actual paper is not that big a deal compared to the idea, that once an idea becomes so obviously true that it becomes second nature, you don't need to cite the original source? Because if I cite the—if I mention the inverse square law, I don't need to have a footnote attributing it to Newton.

MR. KRAUSS: Yeah, exactly. Once it is important, it is background.

MR. PINKER: And I think with Watson and Crick, I don't know how many people felt the need to cite that paper one it just became the indispensable infrastructure of biology.

MR. BINGHAM: I think the point was that it still took a while, as with the reading at the Linnean Society of the Darwin and Wallace papers, for it even to penetrate what was going on.

MR. GREENE: I think it can happen both ways. There is certainly—I am aware of papers that really changed people's thinking fairly significantly, in terms of what they were going to work on. That paper came out, and they just changed their research and focused upon it. Again, it didn't wipe out the score of the science that went before, it just had enough of a compelling story to tell, it had enough of a new direction, that people said, "This is something I really want to work on," they'd shift immediately, and yes, as you say, there are other examples where technology needs to catch up before you can really make use of it, but I think the bottom line is the core is stable.

MR. KRAUSS: Yeah, absolutely. But all of us, we all probably have to write research grants and proposals, and it always amazes me because you are supposed to be talking about what you are going to be doing four years down the road, and if science is any good, you don't know what you are going to be doing four years down the road.

MR. BINGHAM: Let me play devil's advocate for a minute and take that point beyond where it was going, the second point that came out of that was I have spoken to a number of scientists who would actually say, if they had to write a headline, "Science is broken," and what they meant by that is that there is too many people trying to get too many papers into too few journals, the refereeing process is very difficult, it is not people sitting at the Athenaeum and passing the thing around, and somehow there needs to be a different kind of refereeing system for each piece, for people to just their work, that maybe there shouldn't be anonymous referees, maybe people should have to sign their referee, do you have a sense of any of this? Because that is another part of the community, how the community is arranged.

MR. PINKER: I think that is a cogent point in that we scientists probably have not applied

scientific self-scrutiny to our own cultural norms as much as we should, it has been taken for granted that peer review is the only ritual that can sanctify a finding, even though we know from studies of peer review that it has a number of systematic flaws, the name, the reputation of the person writing the paper makes too big a difference, which you can always guess, even when it is blacked out, too much depends arbitrarily on the choice of referees, if you just pick two people, that is such a small sample, that the outcome is going to be determined by whether you have someone that is sympathetic or not, to the basic approach, and there are alternatives. I think we have inherited a practice that comes from the era in which paper was a limiting resource, that mailing out copies of a journal were so expensive that only a small number of organizations could do it. Now that we do have the internet as a form of disseminating information and space is basically limitless, we should look to other models of quality control and like PLOS, the Public Library of Science, which has some different techniques, such as people can post comments on published papers, and so if a bad paper gets published, it will live with the ignominy of all of the critical remarks.

MR. KRAUSS: Yeah, I have been in that position recently, in one of the positions I have in the American Physical Society, which publishes an un-peer reviewed journal, and there was a global warming skeptics paper that got into it and then it was interpreted immediately as a scientific finding. I am not sure, there is an editor friend of mine who would like to publish every paper he gets along with the referees beside it, and that is one possibility. It would make better referee's reports, I think that is for sure, but I think it is—peer review is like democracy. It has got a lot of problems, but I think right now it works on average, and I don't know if there is a better system, because the problem with the internet is there is no filter. At some level, if you want to—there is so much information out there and so little time to read, we already get too many papers that we can read, we have to, I think as a community, have some filter that allows us to select out—

MR. PINKER: [interposing] Let me make a radical suggestion that maybe we should evaluate the different methods empirically. As scientists, see which one—

MR. KRAUSS: [interposing] Yeah, that is not a bad idea.

MR. GREENE: But along those lines, Lawrence, do you actually read peer review articles?

MR. KRAUSS: Brian is exactly right. In our field, by the time it gets peer reviewed, it is old news.

MR. GREENE: Yeah, so we basically, everything goes on our online archive and we just choose what we want to read.

MR. KRAUSS: We decide what is garbage on our own as opposed to reading it in the journal and seeing it is garbage.

MR. GRAYLING: But there is a difficulty and that is that some people are competent to differentiate between stuff that is rubbish and stuff that isn't, and there are a lot of people out there who aren't really competent to make that, and this is why provided one is careful about this, that there is some utility in a bottleneck system, which serves, to some extent, as an expert filter for what comes through. You could have a situation where you let anybody publish what they like on the internet, in fact they can already, if you have written a paper and you want to publish it on your blog site or something, you can go ahead and do it, so there is no reason why absolutely anything that gets written shouldn't be out there, but what you do want is to have some sort of recognition that peers, that colleagues, are prepared to take this seriously and discuss it and so on. After all, peer reviewed publications in the traditional way, is any way only one step in the life of an idea or a paper and there are going to be lots of other things that test it too, when people try and replicate those results or something, they may well find out that, in fact, the stuff doesn't work and that is going to be a check on it, too. So I think there is something to be said for obliging things, if they are going to have a little bit of a stamp of acceptability on it from the profession, that there should be a bit of a bottleneck, providing that it doesn't result in a lot of good stuff and very innovative stuff just being excluded, as could well happen with something which is really genuinely original.

MR. KRAUSS: That is why we are archival, in a sense. We don't—not every piece of paper that we are going to keep for posterity, and we tend to think, peer review in journals in some sense have now become archival, it is more a record of those things which seem to represent progress in the field as opposed to the things which really drive progress right now, which are probably, at least in physics, before peer review.

MR. BINGHAM: There is an interesting point here, which one of the writers for Science, the magazine, John Cohen, made it at the meeting the other day, which he was saying that the way most undergraduates and maybe graduates as well, post-docs, get their information, is to go online to PubMed, put in their institutions subscription, download the PDF of a specific paper, and they are done. Well, half of the book, the journal like Nature or Science, the front half of the book is not papers, it is context. It is what is the science community doing and what is the world doing about science. It has got all the news stories in there, the context, the commentary, and so on. And very few of them actually physically touch these things anymore. Is that a loss? Context is…

MR. KRAUSS: Well, if it is correct context, although I think—I am not sure I agree, because at least most of us probably get a lot of our stuff electronically now anyway, and as far as Science and Nature is concerned, I tend to get their weekly news—I get on my email all the context and commentary that would have come in the front half of that by email.

MR. BINGHAM: You would be surprised, even if you were talking about an ordinary newspaper, how many people you will go to, when they are reading the online version, will suddenly, because they are staying at a hotel or something, get a newspaper and they will say, "I found such really interesting stories here that I never have seen before, because it was online." There is a…

MR. PINKER: There is an amazing service that will actually download and print stories on hard copy and deliver it to you in your mailbox, called magazines. It's a revolutionary idea.

MR. KRAUSS: But you know what, we are all of a pretty well similar generation, I think, and I am wondering, it will be an interesting empirical study. I am wondering if my daughter's generation or her children's generation, will in fact find it much more comfortable to read things online. For example, I bet all of us made this transition, when I first started to write scientific papers, at the beginning, it was very difficult for me to do things on computers. But now, I can't handwrite anything, and that transition has been made, and it could just be that we are just dinosaurs ourselves and we are relics of this paper generation and it is not easy for us to get information that way and that the next generation will find it much more comfortable to do that, I don't know.

MR. DAWKINS: I think Anthony's objection to the putting it on your blog, the need for a filter is met, if other people recommend it. I often get emails from people, "You must read this paper, it is terrific." And if that is from somebody I respect, then I will go and read it, and so you could sort of have a network of not formal refereeing but of informal recommendation and anybody can read. If Lawrence has a blog that I can read that he recommends this paper, I will do it.

MR. GREENE: We have an imperfect system in Physics where not everybody can post to the Physics archive. I forget what the requirements are, but you have to reach a certain threshold before you are allowed to freely post articles. Now, that is not always a good thing. I have gotten many phone calls from people, "Will you please be my sponsor, so I can post this paper?" And it maybe is great, I don't have time to read it, I get too many—but on the one hand you don't want to cut out the people because they don't reach the threshold and on the other hand, it does do what you are saying. It is not quite refereeing, but the people have a certain level of experience and already a track record.

MR. DAWKINS: The other thing is that publishing on paper has become so easy now, that I get vanity press books, essentially every day. I sort of look and say, "I don't recognize that publisher's name." Then you realize it is from the same small town as the author.

MR. KRAUSS: Exactly. I want to jump in. I don't know what it is like in biology, but I think we already operate under your principle. I bet Brian and I do not look at every paper that is on the archive every day, or even the abstracts of every paper, we tend to end up looking at those that are—the good papers tend to—word of mouth tends to filter, and our students tell us, or whatever, and there is just so much that we already rely on that filtering process before we choose stuff.

MR. GREENE: That is absolutely right.

MR. PINKER: We already have models from elsewhere in cyberspace. Imagine if the way that a search engine works is every time you have a website, two people get picked to peer review the website and then what comes up top on your internet search would be the one that is refereed by two people, as opposed to say Google page rankings, which is entirely implicit based on hundreds of thousands of choices of who links to whom, which is kind of

a collective vote as to which websites come up.

MR. KRAUSS: Have you talked to anybody, that is a great idea. You could become a billionaire, I think if you proposed that.

MR. PINKER: I think we don't know what the best model is going to be for scientific review. There has got to be some sort of quality control, whether the current system of two to three referees picked by a human being and having veto power over a paper is the best system, I tend to doubt.

MR. KRAUSS: But don't you think that is what is great about science, it doesn't depend on the human peer reviewing, what eventually succeeds is what works.

MR. PINKER: Yes.

MR. KRAUSS: People pick up—that is what is good about science, what works survives. The garbage doesn't anyway, and what works—people pick up on it because it works and it allows them to go further. So it is just the scientific process that moves beyond that sort of human frailty anyway.

MR. PINKER: Yeah, it is a self-healing process, which is why single fraudulent reports don't corrupt the entire enterprise.

MR. KRAUSS: For a while they can.

MR. PINKER: For a little while they can, but the enterprise works around them.

MR. GREENE: Are there any good examples of an absolutely excellent paper that was suppressed in the modern era and it took a while before it bubbled up?

MR. KRAUSS: Oh, sure. Yeah, there are the ones about—yeah, but I think more—

MR. GREENE: [interposing] In physics I am referring to.

MR. KRAUSS: In physics.

MR. DAWKINS: In biochemistry, my friend John Krebs has—

MR. GREENE: [interposing] The nice thing about physics is you can sit down with a piece

of paper and generally calculate it. Again, if it is an experimental, it is harder, but a theoretical, are there any wonderful theoretical papers—

MR. KRAUSS: [interposing] I think it is more being ignored rather than suppressed.

MR. GREENE: Right, okay.

MR. KRAUSS: I mean, just people didn't realize the importance, but I don't know. But I think Richard is right, there are suppressions and I think one of the main reasons may be because I tend to think maybe because of money, that biochemical things, there is a lot more money in medicine and pharmaceuticals that unfortunately adds a whole different set of pressures, that we don't really have in physics at this point.

MR. BINGHAM: There was a list that was going around, this is a slightly cheesy question, you will forgive me in advance, but there as a question in the Freakonomics column of the New York Times recently that said you get these top 10 lists of who is the best—name the top 10 science people you know, and we never get a who are the top 10 scientists list, right? Okay. So in fact if you go and take a look, it is mostly the people at this table, as it happens, but asking you the same sort of thing, over the past 350 years, not who is your—don't give me a list of Newton and Darwin, can you think of some unsung heroes that people really should go and figure out what they were doing?

MR. KRAUSS: I think that is the wrong question.

MR. BINGHAM: Alright, okay.

MR. KRAUSS: People are too fixated on people. And I mean, it is great. It is nice to have scientific role models, and I think it is good for kids to have scientific role models, but the people are—there may have been amazing people and its historical context it is wonderful, but they are irrelevant to the science.

MR. BINGHAM: Yeah, well let me tell you, the practice of science and science as a method is one thing, and I agree with you about that, but I find that practically, if you tell people Bill Hamilton's life story, and what he discovered, but put it in the context of who Bill Hamilton was, it somehow comes alive in a different kind of way.

MR. KRAUSS: Oh, sure. To get people interested, it is true.

MR. BINGHAM: Richard, do you see what I am getting at here?

MR. DAWKINS: Yeah, kind of.

MR. KRAUSS: There is a whole realm of journalism I call People Magazine sort of science reporting, which is always—

MR. BINGHAM: [interposing] That is not what I am talking about.

MR. KRAUSS: I know, and I agree with you, we need to make—we need to humanize the endeavor, people have to realize that scientists are human and that is why there is a lot of efforts in fact and I think both Brian and I are in this and maybe a bunch of others here, trying to get scientific themes in Hollywood and so scientists on, it is more integrated into the culture, so people realize that scientists are people and the scientific endeavor is culturally interesting, etc. I agree with you completely there, to humanize it, but—and so that is important.

MR. BINGHAM: And that is difficult in itself, you have a series like Lie to Me on Fox TV now, which is based on Paul Ekman's work, of course. The facial expressions and so on and so forth. So it is hard to convey some of the science in those sort of things. But I still liked my question.

MR. PINKER: According to one poll, people were asked to name famous scientists, and the one who came out on top was Bill Gates and the second one was Al Gore. So we have some work to do.

MR. BINGHAM: We have some work to do. Last question then. Over that period of the operation of this enterprise, the merchants of light, going forward, what is the most exciting thing in each of your fields that you are looking forward to?

MR. KRAUSS: Well, I will just…

MR. BINGHAM: That is another People Magazine question, but answer it. Answer it.

MR. KRAUSS: When someone asks me what is the next great thing, if I knew I would be

doing it, I think there are—

[crosstalk]

MR. BINGHAM: And Einstein said if it wasn't called research—yeah.

MR. KRAUSS: I bet Brian and I agree, that is what is great. You can add to this. But in cosmology, it is the nature of this weird energy that dominates the empty space. In particle physics, I think it is the domain that Brian has written about a lot, which is the way to try and unify the forces of nature and understand quantum mechanics and gravity and those are the frontiers, but where the next great discovery will be, it may be somewhere else. I don't know.

MR. GREENE: The only thing I would add to that is in my wildest dreams what I would hope to happen before I leave this earth or universe is maybe we will understand what are the basic constituents of space and time. There is a lot of evidence that space and time are derivative, emergent ideas, but we don't really know what the fundamental constituents of them would be. And we have got hints of it and maybe that is something we will make progress on.

MR. PINKER: I think for my field, the sciences of mind, the most exciting development is the melting of boundaries between psychology and

other sciences and the fields of endeavor, in fact. The birth of neuroeconomics, of behavioral economics, of evolutionary psychology, of the psychology of

aesthetics, of moral psychology applied to jurisprudence and moral philosophy, the elimination of these 19th century disciplinary boundaries that I think stood in the way of coherent understanding.

MR. KRAUSS: I'm going to jump in. That is another advertisement. That was the thing we were trying to achieve at this meeting and that is

the thing we are going to try and continue to achieve, but I should also say as well that Brian and I are biased, we are talking about particle physics, probably a related aspect of that, that is probably also extremely exciting, which is the disappearance of the boundaries

between physics and biology, which I think will be another huge threshold area.

MR. DAWKINS: Well, I think I would have to say understanding consciousness, which is more Steve's field than mine. So I won't say that, because it is not my field. I think I would say perhaps a complete computer simulation of an origin of artificial life and subsequent evolution in an artificial world with its own physics and its own ecology, its own ecosystem, a second life, that actually evolves rather than being designed by humans.

MR. GRAYLING: The most exciting thing in my field, is science. Because I am not a scientist, I am a philosopher and a spectator, and an amateur of science. And it is thrilling, I mean, beyond description really, to see what is happening across all these fields, cosmology, and fundamental particle physics and biology and biomedical sciences. The progress that is being made now is really extraordinary, and because I have an interest in philosophy and philosophy of mind as well, what is happening in the neuroscience and its effect on understanding psychology and on consciousness, but what all this does, in a way, is to show that Lawrence's point is absolutely right, that the sciences are bleeding into one another, that the boundaries are coming down, that what is in effect happening is that we are having a sort of a new second wind of the enlightenment. I talked earlier about the way that ideas and methods in the natural sciences have been applied more broadly, social sciences and humanities and the enlightenment that altered our conceptions of society and human nature and human flourishing, and with this breach in the walls of the different disciplines, because there has been too much over-specialism, we all know that, since the 19th century, since the German attitude to how you conduct research really became the dominant paradigm. And now that all these walls are being breached and we are seeing tremendous amount of cross fertilization, and as a result huge new insights, to be a spectator of this process is to be enthralled by it.

MR. BINGHAM: Well, thank you gentlemen. Richard, A.C. Grayling, Lawrence, Steve Pinker, Brian Greene. I will see you back here in 2360.

MR. GREENE: I hope so.

MR. BINGHAM: For the 700th anniversary of the Royal Society. Great. Thanks a lot.

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