BILL MOYERS' WORLD OF IDEAS

Murray Gell-Man

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Murray Gell-Mann

BILL MOYERS: *[voice-over]* To walk around with Murray Gell-Mann is to see the world through the keen eyes of the scientist.

MURRAY GELL-MANN: That's a change, I'll say, since—

MOYERS: What's the one with the— up there, on its wings?

GELL-MANN: It must be another— the red-winged blackbird.

MOYERS: Epaulet.

GELL-MANN: Yes, it has a red and yellow epaulet.

MOYERS: *[voice-over]* Murray Gell-Mann began birdwatching as a boy growing up in New York City. So when he returned to New York recently for our conversation, we ventured out into one of his old birding spots, the Ramble in Central Park.

GELL-MANN: Oh, what's that over there? Whoops.

MOYERS: *[voice-over]* Gell-Mann, by temperament, approaches elementary particle physics from the point of view of the naturalist.

GELL-MANN: Another one. Another yellow-rumped warbler.

MOYERS: *[voice-over]* We owe to him the discovery in 1952 of the quantity in theoretical physics called strangeness. Later, he proposed quarks and colored bluons as the fundamental building blocks of atomic nuclei. In 1969, he received the Nobel Prize for this work on the theory of elementary particles.

But Gell-Man's interests have transported him far beyond his teaching and research at the California Institute of Technology in Pasadena. In the early 1960s, he consulted for the government on anti-ballistic missile systems and arms control. He's been both a member of the President's Science Advisory Committee and the Council on Foreign Relations. In the 1980s, he could often be found tramping through tropical rainforests. He's an active environmentalist who has helped to develop strategies for coping with deforestation, loss of biological diversity, global warming and pollution.

A few years ago, he co-founded the Santa Fe Institute, a think-tank for scholars and scientists interested in understanding the complexity of the universe. That is not as far as it seems from the flight of the red-winged blackbird.

[interviewing] When did you realize that science was your calling?

GELL-MANN: Well, it depends what you mean by science. I learned such a lot from my older brother, Ben, about many different things, about nature and about history and many kinds of what you would call science, but we didn't distinguish so much. And I have never really distinguished so much among the different subjects.

The unity of human culture is what really impresses me, with science being an important part of that culture.

MOYERS: But you're flying in the face of the prevailing tendency of our time, which is into increasing specialization in the university.

GELL-MANN: Well, that's important, too. It's necessary that people study particular fields deeply, simply because our knowledge has become so detailed about things that it's necessary to pursue specialized study. But that shouldn't be to the exclusion of the concern with unity in human culture. I see them both as very important. At the Santa Fe Institute, we try to do that. This is our principal mission, or the principal mission.

MOYERS: To do what?

GELL-MANN: To study issues that transcend so many of these specialized subjects, while utilizing the skills that people who are familiar, responsibly familiar with the facts of a lot of different specialties, to look for principles, laws, that cover many of them at once. In particular, the study of complex adaptive systems.

MOYERS: Complex adaptive systems?

GELL-MANN: Yeah. Systems that can evolve or learn or adapt, and they would include— such systems would include biological evolution as a whole, the evolution of biological organisms on the Earth, the evolution of ecological systems on the Earth. The telical evolution that preceded the first life. That's called prebiotic chemical evolution, which one can try to imitate to some extent in the laboratory. And then, many things that arose as a result of biological evolution, for example, individual learning and thinking. Human cultural evolution, including such things as the evolution of language, the global economy as involving complex systems. All of these have a great many things in common, because learning, adaptation, and evolution are all very similar phenomena.

MOYERS: Were you a specialist when you discovered the quark?

GELL-MANN: Oh, yes, very much so.

MOYERS: Because you were looking for the building blocks.

GELL-MANN: That's right.

MOYERS: Scientists had told us, well, that it was molecules and crystals. And then they told us that it was atoms and ions. And then told us it was nuclei with electrons around them. And then they said the nuclei were made of neutrons and protons. And then you came along, won the Nobel Prize for discovering that no, it's not just neutrons and protons, it the quark.

GELL-MANN: Quarks, "are" that's right, fundamental constituents of neutrons and protons. And actually, the Swedish committee which very kindly awarded me the prize, didn't mention the quarks in the award. I guess they were worried that those wouldn't turn out to be right.

MOYERS: What did they say?

GELL-MANN: They mentioned all the earlier work that I had done, which the notion of quarks summarized and synthesized very nicely. But they didn't go so far as actually to recognize the quark in the award.

MOYERS: Did you name the quark?

GELL-MANN: Oh, yes.

MOYERS: Does a scientist get that privilege, if you discover something new in the universe, you can name it?

GELL-MANN: I guess that's right.

MOYERS: Why quark?

GELL-MANN: Well, I didn't want some pompous name, some—

which I could easily have invented, some pompous name derived from a Greek root or something like that. But these things usually turn out not to be very appropriate later on, as you learn more and more, the name derived very carefully from some appropriate root turns out to have been derived from something inappropriate, because you understand more about the phenomenon later in your life, that what you called it wasn't the best thing after all. With a meaningless name like quark, this could never happen. I had the sound first. I didn't know how I would spell it. And then, paging through Joyce's *Finnegan's Wake*—

MOYERS: James Joyce?

GELL-MANN: —yeah, I came on the line, "Three quarks for Mr. Marks." And undoubtedly he pronounced it quark, because it rhymes with Mark and several— park and bark and several other things like that. But I wanted the sound "ork," and so I invented this elaborate rationale, saying that there are multiple determinations of the various words in that book. A quark, for one thing, is listed in the dictionary as the cry of a gull. And in this particular passage, the four commentators in *Finnegan's Wake* are incarnated as gulls following the ship on which Tristram and Isolde are together.

MOYERS: But how did you know the sound? You just made it up?

GELL-MANN: Oh, it seemed like the right sound.

MOYERS: It was the sound you were reaching for, no one knows what a quark sounds like, do they?

GELL-MANN: That's right. It seems a natural name for the fundamental constituent of nuclear particles.

MOYERS: I'll take your word for it. *[laughing]* Whether it was natural or not, it's now the name.

GELL-MANN: *[laughing]* That's right.

MOYERS: And your new book is going to be called, *The Quark and the Jaguar*?

GELL-MANN: I thought of calling it that, yes, and I may do so. A friend of mine, a wonderful Chinese-American poet who lives in Santa Fe and is married to a Hopi weaver, his name is Arthur Siu, wrote a poem, which I have here in his book, *River River*. Let's see, I'll read a line or two from it. He starts out: "A Galapagos turtle has nothing to do with the world of the neutrino." Then later on he says, "No!" He changes the tone to the opposite. And then he says, "The world of the quark has everything to do with the jaguar circling the night."

And I think that's— it's a very good line.

MOYERS: You believe that, don't you?

GELL-MANN: Yes, I do.

MOYERS: You believe that the fundamental particle of the universe has a great— has to do with everything—

GELL-MANN: Exactly.

MOYERS: —including a jaguar's movement at night.

GELL-MANN: And the relation between the two is just what fascinates me. The relation between the fundamental, simple laws that underlie the operation of the universe and the enormous complexity of the actual universe as it's observed. The relation between those two

is what fascinates me nowadays and what I think about most of the time now. So I thought of calling it, *The Quark and the Jaguar*, and it expresses so well so my various ideas.

MOYERS: Do I understand you to say that if you— if we find the fundamental constituent of the universe,

GELL-MANN: No, the fundamental law of the universe—

MOYERS: Law —and if we found the initial condition of the universe—

GELL-MANN: Yes.

MOYERS: —we would be able to explain all human behavior?

GELL-MANN: That's just the point. We would not.

MOYERS: We would not.

GELL-MANN: For very fundamental reasons. The— we in fundamental physics believe that there is a simple law of the elementary particles, the fundamental building blocks of the universe and their interactions. Indeed, that may have already been written down by my colleague John Schwartz and his friends in the form of superstream theory. It's the firsts candidate, viable candidate there has ever been for a unified quantum field theory of all of the elementary particles. Similarly, my friend Jim Hartell, a former student of mine 20-something years ago, professor at the University of California at Santa Barbara and now collaborator in work that we're doing in trying to understand the meaning of quantum mechanics, Jim and Steve Hawking, who has made himself notorious with his book—

MOYERS: Best-seller.

GELL-MANN: —*History of Time*, Jim and Steve proposed some years ago a candidate for the initial condition of the universe at the beginning of its expansion. Now, those two principles, whether they've been correctly written down in the form of superstream theory and the Hartell-Hawking condition, doesn't matter so much. But those two principles, when they are written down correctly, will be the fundamental principles of the universe, and in fact, they may be related to each other. Jim and Steve have a proposal which amounts to saying that the same formula that gives the fundamental equation for the elementary particles and the forces, will also give the initial condition of the universe. So the two laws may actually be just one.

Now, given that law, your question is the most natural question.

MOYERS: Would we know about all behavior?

GELL-MANN: Would we, then, know how everything works? And the answer is no. And there are, actually, complicated reasons for that. But the simplest reason is that the world is quantum mechanical.

MOYERS: Meaning?

GELL-MANN: Meaning that the fundamental law does not tell you exactly the history of the universe, but only gives probabilities for a gigantic number of alternative histories of the universe. And the particular details of the history that we experience we can learn only by looking around us.

MOYERS: In laymen's terms—

GELL-MANN: Yeah.

MOYERS: —aren't you talking about what happened 10 to 15 billion years ago?

GELL-MANN: In the initial condition of the universe?

MOYERS: Or something like that.

GELL-MANN: Yes, yes. Of course.

MOYERS: And all one can do to address that is with— with a beautiful theory, as Einstein would have said. Somebody once said that Einstein gave up on ugly theories, he only wanted beautiful theories.

GELL-MANN: Yes, and it's a very deep question, perhaps too deep for us to get into here.

MOYERS: Certainly for me.

GELL-MANN: But the very deep question as to why our sense of beauty and elegance should be such a useful tool in discriminating a good theory from a bad one. It's a fact that it is, and the reason why is because many scientists have scratched their heads over the years. I have some thoughts on the subject, but I don't know if I can go into it here.

MOYERS: But can you put into laymen's terms what a beautiful theory is, as opposed to an ugly theory? Just roughly. Crudely.

GELL-MANN: Well, roughly speaking, it's that it can be written down very simply in terms of what appear to be fundamental mathematical quantities. Now, why we are familiar with those mathematical quantities and why we consider them to be fundamental, that's, of course, the mystery. For example, Einstein wrote down his theory of gravitation, which he liked to call general relativity. He wrote down that theory utilizing very fundamental quantities referring to the curvature of space and time. And in terms of those, it's very beautiful.

My father was an amateur of math, physics and astronomy. He wasn't very well-versed in them, but he used to try to read books on those subjects and try to understand what was going on. And he would look at Einstein's equation for general relativity or the theory of gravitation in empty space, for example, which reads, roughly speaking, R sub Mu Nu equals zero. And he would say, "Gosh, that's a simple equation. The only thing is, what is R sub Mu Nu?"

MOYERS: Your father and I are— share a lot in common.

GELL-MANN: And of course, he tried to understand what R sub Mu Nu stood for. But it stands for something very simple and fundamental about the curvature of space time. My personal view of why simple, beautiful theories work in fundamental physics is that simple and beautiful means that we have the mathematics available already. We already have heard of R Mu Nu in some other context, and can therefore write down R Mu Nu equals zero. Now, why have we heard of it in another context? Well, how would we have heard of it? We would have heard of it through an earlier scientific theory, an earlier attempt to understand nature at a different level, a level of larger distances, lower energy that we encountered at an earlier time in history. In fact, Isaac Newton made a comment, I can't remember the exact words, but he made a comment of that kind at one point, that the laws of nature were somehow self-similar, that they had a tendency to resemble themselves.

MOYERS: Something of congruity in there.

GELL-MANN: Yeah. And I think that someday we'll understand that more deeply.

MOYERS: And what will it mean to us if we find it, when we find it?

GELL-MANN: Well, that's— what interests me is what is the rest of the story.

MOYERS: Yes.

GELL-MANN: And the fact is, as I said, that knowing that fundamental formula by no means predicts everything about the universe, because we live in a universe with an enormous amount of uncertainty. Quantum mechanical law such as these laws are can only give probabilities for alternative— different alternative histories of the universe. And all the things that are not predicted are nevertheless very important for determining the outcome. So that the particular events of the history of the universe are co-determined by the fundamental law and a whole series of intrinsically unpredictable accidents.

MOYERS: Accident. There are a lot of—

GELL-MANN: Intrinsically unpredictable accidents.

MOYERS: What do you mean intrinsically? I mean, I know there are accidents, but you mean they're built into the nature of things?

GELL-MANN: Into the nature of the uncertainties of quantum mechanics. You cannot ever predict those. They're just random. They're just accident. For example, the existence of our galaxy, the development of our particular star, the sun, similarly depend on accidents, fluctuations that are intrinsically unpredictable. The emergence of the particular planets of our solar system, likewise. The details of the development of life on the Earth, likewise. The evolution of particular forms of life, likewise, depend on utterly unpredictable accidents.

MOYERS: So what's the practical consequence of the rest of the story? When you know that—

GELL-MANN: Aha. The practical consequence is that there is simplicity and complexity in the universe. The picture that we have, at least. Simple underlying laws, but very complex results. And among these complex systems in the universe are systems like us, that can process information.

MOYERS: Human beings.

GELL-MANN: Complex adaptive systems. It's not just human beings, no. There is life all over the universe, no doubt.

MOYERS: Sure. Yes.

GELL-MANN: There are planets of other systems with life and there may be complex adaptive systems that don't closely resemble life, but also are processing information in ways that we can't understand. And it's part of the work of the Santa Fe Institute, is to try to understand what these general laws could be that govern such complex adaptive systems throughout the universe.

MOYERS: You've just helped me to understand, first, what you're doing down in Santa Fe, at the institute, and also a question that's bothered me for some time. Lewis Thomas wrote recently that if he could ask the world of medical science to settle one thing for him, it would be to tell him what happens in the mind of a honeybee. He'd like to know, he said, whether a honeybee's mind is a machine, or does the honeybee know it is thinking about what it is doing?

And I thought, what would be the one thing I'd like to have settled for myself? And it is this. Why is it that I can't change my ways? And you're just suggesting, there are a lot of reasons why we human beings— why I as an individual and we as a species don't easily change our habits?

GELL-MANN: The same kind of thing comes up in the study, which also interests me, of creative ideas and how we get our creative ideas. It's the same kind of thing. We are constrained in our choice of schemata. It's as if we had what in nonlinear mathematics are called basins of attraction, as if our thoughts keep running back to particular points of attraction.

MOYERS: Yeah.

GELL-MANN: And it's very hard to get them to go over a barrier into another basin where the thoughts would tend to run to some other end.

MOYERS: Well, how do you do that?

GELL-MANN: You can—

MOYERS: You studied creative thinking.

GELL-MANN: Well, the way it usually happens, as you know, was summarized a long, long time ago. I discovered it myself in my own work and in that of colleagues and in talking with artists and all sorts of other creative people, found that we had almost identical experiences. And then I discovered that all of this was written down a hundred years ago by the physiologist and physicist Helmholtz, great Prussian scientist of a hundred years ago.

MOYERS: German— Prussian.

GELL-MANN: It's actually very well-known. And those stages are saturation— you fill yourself full of the contradiction between the problem you need to work on and the existing idea that's somehow not good enough, or the existing method that is somehow not good enough to deal with the problem. After you've confronted this contradiction between what's available and what's needed, for a long time, apparently further conscious thought is no good anymore. And at that point, some sort of mental process out of awareness seems to take over, I guess what the shrinks would call the pre-conscious. It starts to cook this material, and that Helmholtz called, using an English translation, incubation.

MOYERS: Saturation, incubation.

GELL-MANN: And then, one day, while cooking or shaving or cycling, by a slip of the tongue or even while sleeping and dreaming, according to certain people, an idea suddenly comes. That's illumination. And maybe the idea is right. Frank Arrea added the final fourth stage, which is verification. See if it's a good idea.

MOYERS: Yeah. Did it ever happen to you, a slip of the tongue?

GELL-MANN: Oh, yes, oh, very much so. Yes. Yes. I discovered the notion in physics called strangeness by a slip of the tongue. I was giving a lecture in Princeton on why a certain idea that I had tried and that somebody else had tried and it didn't work, and while describing that wrong idea and trying to say why it didn't work, instead of saying five halves, two and a half, I said one.

MOYERS: Mistake.

GELL-MANN: Mistake.

MOYERS: Slip of the tongue.

GELL-MANN: And I realized that if the quantity was one instead of two and a half, it would work.

MOYERS: And you realized that while you were standing there in the class?

GELL-MANN: Yes, oh yes.

MOYERS: After the mistake.

GELL-MANN: It wasn't a class, it was a seminar—

MOYERS: A seminar.

GELL-MANN: —at the Institute for Advanced Studies, in 1952.

MOYERS: Do you have an unsettled account such as Lewis Thomas's wish to be reconciled? He wanted to know the mind of the honeybee. Is there something in your mind you'd like to have science yet to settle for you?

GELL-MANN: Oh, yes, well, many things. What is the threshold of complexity? How complex does something have to be in order to be able to think or to adapt or observe the world and record what it sees in highly compressed form, with highly predictive power? What is the threshold of complexity that's needed for that? And, of course, there's another question which scientists are mostly scared to discuss, which is what is the nature of self-awareness?

MOYERS: Why is that?

GELL-MANN: Do we dare utter the C-word, consciousness? What is the nature of consciousness? What kind of threshold of complexity is there for consciousness? What does consciousness mean? Well, you're not thought to be very scientific if you use words like that. Even the word mind, the M-word, is one that can a scientist in trouble.

MOYERS: Why?

GELL-MANN: It doesn't sound very scientific to talk about.

MOYERS: Why?

GELL-MANN: I don't know, it just isn't. Mind, of course, is nothing but the phenomenological aspect of what otherwise you would talk about in terms of brain and endocrine secretions and so on and so forth. Anyway, many scientists— at Cal Tech, for example, one gets into terrible trouble if one mentions the M-word.

MOYERS: The mind word. What about the—

GELL-MANN: If one mentions the C-word, one is in real trouble.

MOYERS: —consciousness. Because? Because?

GELL-MANN: It's thought to be unscientific to talk about things like that.

MOYERS: But you cannot empirically prove the presence of consciousness?

GELL-MANN: It's an interesting question, anyway.

MOYERS: Well, it is—

GELL-MANN: We certainly have the notion that there is such a thing. Why not try to understand more precisely what we mean by it, what it corresponds to scientifically and what is the threshold of complexity necessary to reach it, whatever it is? Whatever it is, it's