Photo by Joe Umbro, October 1999

AHMED ZEWAIL
(1946 - 2016)

INTERVIEWED BY
HEIDI ASPATURIAN

June – November 2015

ARCHIVES
CALIFORNIA INSTITUTE OF TECHNOLOGY
Pasadena, California

Subject area

Chemistry, femtochemistry, physics

Abstract

Interview in seven sessions (June-November 2015) with Ahmed Zewail, Linus Pauling Professor of Chemistry and professor of physics, and 1999 Nobel laureate in chemistry. Zewail talks at length about growing up on the banks of the Nile in Desouk, Egypt, describing family and cultural influences, and the interplay of education, politics, and faith during his youth and adolescence. He recalls his early "passion" for knowledge and fascination with science, and the moderate, "intellectually rich" Islam of his day. He talks about his studies at the University of Alexandria (BSc '67, MSc '69), the stimulating intellectual and socially tolerant environment there, his designation as a "special" (outstanding) student majoring in chemistry, and his determination to pursue a doctorate in the United States. He recalls his adjustment to life in America, both at the University of Pennsylvania, where he earned his PhD in 1974 with R. Hochstrasser, and as a postdoc at UC Berkeley, where molecular dynamics research with C. Harris set the stage for his future forays into laser-based femtoscience. He recalls turning down numerous academic jobs, including one proffered by S. Hussein in Iraq, to

accept a faculty position at Caltech in 1976. He traces the decade of work that led in 1987 to the first direct observations of the making and breaking of chemical bonds, including collaborative work with R. Bernstein and the crucial role of Caltech institutional support. He recalls traveling to Saudi Arabia and Israel to receive the King Faisal and Wolf Prizes respectively and the circumstances surrounding the announcement of the Nobel Prize in 1999 and its aftermath. Zewail talks about the Nobel's impact on his personal and professional life, including his involvement in public policy, global educational initiatives, and commitment to advancing science education in Egypt, and discusses his post-Nobel 4D electron microscopy research and the establishment of Caltech's Physical Biology Center for Ultrafast Science and Technology. He recalls discussions with then-Egyptian president H. Mubarak that ultimately led to the founding of Zewail City and touches briefly on his involvement in the 2011 Egyptian Spring. He offers his thoughts on personalities who influenced his life and career, including the iconic Egyptian singer Umm Kulthum and numerous members of the Caltech community. The oral history concludes with a retrospective on his 40 years at Caltech.

Occasional references in this oral history to a memoir or autobiography refer to *Voyage through Time: Walks of Life to the Nobel Prize*, by Ahmed Zewail, American University in Cairo Press, 2002.

Administrative information

Access

The interview is unrestricted.

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CALIFORNIA INSTITUTE OF TECHNOLOGY ARCHIVES

ORAL HISTORY PROJECT

INTERVIEW WITH AHMED ZEWAIL

BY HEIDI ASPATURIAN

PASADENA, CALIFORNIA

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Ahmed Zewail, October 1999

Photographer, Joseph Umbro

NOTE TO READERS

These interviews with Professor Ahmed Zewail were conducted in seven sessions between June and November 2015. The original plan called for ten, grouped into three stages: his formative years, from his youth and upbringing in Egypt through his first decade in America; the years of scientific development and discovery at Caltech and his engagement with the Caltech community; and in the aftermath of the Nobel Prize, his growing commitment to science diplomacy and world affairs, focusing on his role as the first science envoy to the Middle East, his involvement with the Egyptian Spring, and his vision for Zewail City, an Egyptian institute of science and technology modeled on Caltech. The first two aspects of his life are fully represented in the oral history. It is the final third, to which we had hoped to devote three sessions in the second half of 2016, that he did not live to complete.

When Ahmed agreed to sit down with me for these interviews—"for history," as he expressed it—one of the reasons he gave was that the year 2016 would coincide with the 40th anniversary of his arrival at Caltech, an event that he considered pivotal in his career and in many respects his life. It seems fitting that the publication of this oral history in 2017 will mark the 30th anniversary of his landmark breakthrough in femtochemistry—a tribute to the scientist and his achievements and to the institution that he firmly believed made those achievements possible.

Heidi Aspaturian
June 2017

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Stimulating intellectual environment at Berkeley. C. Harris as inspiring scientist and mentor. Zewail commences work on concept of coherence: Collaborates with Harris on MRI studies of molecular dynamics and considers how to extend this research to laser-based studies. Mulls return to University of Alexandria faculty but is convinced by

Harris to apply for jobs at U.S. universities, e.g. Harvard, Princeton, Caltech. Declines job offer from Iraq after "red carpet" visit to Bagdad and warm reception from S. Hussein; comments on state of Iraqi R&D at time of visit.

Visits Caltech, is suitably impressed, and forgets how to spell "Feynman" during faculty talk. Meetings with chemistry faculty A. Kuppermann, H. Gray, V. McKoy, P. Dervan, E. B. Wilson, and J. Baldeschwieler lead to job offer. Initial impressions of Caltech as "small, focused, classy," with strong sense of community among faculty and staff. Perceives dearth of chemical physicists as attraction rather than deterrent. Recalls supportive Caltech culture, "family style of interaction," and absence of bureaucracy at time of hiring (1976).

Begins developing plan for laser system to observe molecular transition states in real-time; credits Caltech environment and research group for early successes. Productive collaboration with students K. Jones and T. Orlowski on mapping out coherence in molecular and material systems. Successfully demonstrates proof of concept with experimental work in nanosecond regime on pentacene and anthracene molecules and moves on to femtosecond laser studies. Granted tenure in 1978 and receives first intimations of decision from owner of Pasadena hamburger haunt. Reflects on personal scientific approach, characterized by having the insight to identify and probe "simple" questions that yield deep answers.

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Recalls inherent difficulties of explaining significance of molecular coherence even to fellow scientists. Submits ambitious proposal to NSF to pursue femtosecond laser research. Observes coherence phenomena in molecular beam experiment at Caltech in 1985. Encounters skepticism from chemistry colleagues at Caltech and elsewhere (G. Porter, D. Herschbach) regarding validity of femtosecond studies; remains confident in "back of the envelope" calculations.

Interactions in 1980s with J. Polanyi and N. Bloembergen. Recollections of R. Bernstein as outstanding scientific collaborator, mentor and friend. Origin of name "femtochemistry." Receives Air Force funding in 1986 to establish femtosecond laser lab at Caltech. Supportive involvement of M. Goldberger, F. Anson, and T. Tombrello. Caltech as uniquely supportive incubator for cutting-edge science. Working with M. Rosker and M. Dantus, observes molecular bond-breaking in real-time; insists on numerous control experiments to rule out artifacts or errors; publishes landmark 1987

paper, "Real-Time Femtosecond Probing of 'Transition States' in Chemical Reactions," in *Journal of Chemical Physics.*

1989 election to NAS. Crucial role of T. Tombrello in directing gifted students to Zewail laboratory; subsequent work with M. Lin. Chemistry community's reaction to successful femtosecond observations includes gossip and speculation about Nobel Prize. Observations of bond breakage and formation produce exciting new science; Berkeley's 1991 study of rhodopsin an early indication of applications to biology. Personal pride in making major scientific discovery. Maintaining confidence in face of skepticism. Early critics' failure to appreciate key insight that uncertainty principle can be harnessed to capture rather than capsize molecular coherence subsequently summarized in 2001 article "The Fog That Was Not."

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Awarded King Faisal Prize in 1989 and meets future wife, Dema Faham, at awards ceremony in Saudi Arabia. Comments on differences between Saudi and Egyptian culture. Awarded Wolf Prize in 1993: recalls decision to accept prize in Israel and fleeting exchange with Israeli cab driver. Israel's "amazing" success in creating its scientific infrastructure. Comments on Ben Franklin as personal hero, pride in receiving Benjamin Franklin Medal in 1998, and elated reaction in Egypt. Public speeches in Egypt about science and scientific progress attract huge audiences and lead to some tension with then-President Mubarak.

Prestigious international awards prompt growing speculation concerning Nobel Prize. Zewail develops habit of leaving town during Nobel week each year to avoid possible "condolences" from well-meaning well-wishers, but is in Pasadena to receive the call from Stockholm in October 1999. Exuberant reaction at Caltech and in Egypt. Comments that circumstances of Nobel-winning work could only happen at Caltech, and reflects on good fortune in timing. Recalls outpouring of enthusiasm in Egypt and his children's reaction to award. Reflects on Nobel's personal and professional significance. Acceptance speech acknowledges Egypt's intellectual heritage.

Receives Grand Collar of the Nile from Mubarak; broaches idea of establishing Caltech-like institute of higher learning in Egypt (now Zewail City). Comments on Mubarak and his record as Egypt's president. Evolution of thinking on Zewail City; discussions about it with Mubarak; hopes for revitalizing the culture for science and education in Egypt.

Jennings, S. Koonin, and E. Stolper. Receives warm welcome in Egypt after calling upon Mubarak to step down as president in 2011; Chameau's offer to hire a security detail.

High quality of chemistry and chemical engineering division. Circumstances of selection as 2011 Caltech commencement speaker; well-received speech, "Revolutions in Science and Society" emphasizes "unique qualities of Caltech," future prospects for science, and how true revolutions in science are made. Recalls Nobel-day speech in Athenaeum attributing much of scientific success to Caltech's exceptional environment and expresses hope that unique character of Institute will endure.

CALIFORNIA INSTITUTE OF TECHNOLOGY ARCHIVES

ORAL HISTORY PROJECT

Interview with Ahmed Zewail **by Heidi Aspaturian**

Pasadena, California

Session 1	**June 17, 2015**
Session 2	**June 23, 2015**
Session 3	**June 27, 2015**
Session 4	**July 1, 2015**
Session 5	**October 6, 2015**
Session 6	**October 20, 2015**
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SESSION 1

June 17, 2015

ASPATURIAN: This is June 17th, 2015, and this is the first oral history interview session with Professor Ahmed Zewail. I'd like to start by asking about your family, your family background, and what you know about your roots. So let's talk a bit about where the Zewails and your mother's family come from.

ZEWAIL: Right. Well, starting with my father [Hassan Ahmed Zewail], it's a very interesting part of my life. There are so many Zewails in a city called Damanhur—

ASPATURIAN: Where you were born.

ZEWAIL: Where I was born. In fact, if you go anywhere in the city and you say "Zewail," there is somebody there with that name. The Zewails got interested in the cotton industry and cotton manufacturing, and many of them are doctors and in other professions, but to be honest, I don't know them because I left Egypt quite young. I grew up not far from

Damanhur, in Desouk, then I was in Alexandria for my four years of college, and from there I came straight to the United States. So I didn't know a lot of the family. In fact, after I got the Nobel Prize, someone would say, "I'm a relative of his," but I didn't know him. But I know for a fact that my father and many of the Zewails in Damanhur had to move from Alexandria down into the Nile delta to Desouk, and that's because of the bombing that was taking place during the war.

ASPATURIAN: During Operation Torch [the Allied invasion of Nazi-occupied North Africa in 1943]?

ZEWAIL: Right. So this bombing was so serious to them that they decided to go down to Desouk, which is where my father met my mother [Rawhia Rabi'e Dar] and where I grew up. My mother is from the delta; she's truly a person with roots in this region. But, strangely enough, when my kids decided to do one of these genetic analyses for me two or three years ago as a Father's Day gift—

ASPATURIAN: This is so funny. I was thinking earlier about whether I should ask you if you had ever had a genetic analysis done.

ZEWAIL: [Laughter] What they found is that my father's genes are concentrated around Upper Egypt [refers to the strip of land on both sides of the Nile Valley extending geographically toward southern Egypt], which is where the big civilization—the pharaohs, Karnak all of that—happened. His genes were really highly concentrated there. So I come from this origin, and then for some reason—we don't know why—my father or his father migrated to Alexandria and from there into the delta. On the other hand, the genes for my mother, which are taken from the mitochondria, come from all over the region northeast of Egypt. In other words, it could be Turkey, it could be Syria, it could be the northern part of Egypt. So that's what I am made of. The pharaohs' genes at the south apparently, and then some of what you might call even the European part. So that's the roots.

ASPATURIAN: It's fascinating that you know this. Ten years ago we couldn't even have this conversation.

ZEWAIL: That's right. I'm the only son, and I have three sisters. My father actually was a man that I admired in my life because, as I have said elsewhere, he took life in a simple way. He found nothing complicated about life. He always can smile. He always can find a way to make people feel good. People were attracted to his company. On the other hand, my mother was a very serious person. Everything had to be thought of, such as what are we going to do with Ahmed, how will he live when he goes to college, and so forth. But my father didn't think that way; his attitude was, let's live.

ASPATURIAN: Your mother was the strategic thinker.

ZEWAIL: Yes. My father always said, "Life is too short, let's just enjoy it." But to be honest, I left my home at a very young age. After I finished high school, I went to university right away in Alexandria. When I finished high school at seventeen and left home, I never returned back. After I finished college, I got a master's degree from the University of Alexandria and took off to come to the United States.

ASPATURIAN: One of the things I noticed in your memoir was how your parents met. Did your father use a matchmaker to meet your mother? Is that how it worked?

ZEWAIL: In those days, you could never talk to the lady directly.

ASPATURIAN: The one in whom you are interested?

ZEWAIL: Right. So the tradition was—there's a word for it; it's like "I'm seeking the hand of" or something like that. You go to her father, and if the father is deceased, you go to the mother. My father had a business besides his government work, which was the import-export of bicycles. In the case of my mother, they tell me—of course, I wasn't there—that he had his shop at the corner of the street, and that when my mother was

coming out of her house, he would peek at her, and so on, and then he went to her family and proposed.

ASPATURIAN: I see, having only seen her.

ZEWAIL: Having only seen her, and you're not supposed to talk to her at all. By the way, it's very interesting that even with my generation in the university—and this was not the Stone Ages—we had a tremendous, I will use the word "respect," for our female colleagues. I recall that if I were to go and talk to my female colleague at the university, my eyes will tend to be at a lower angle because I'm not really supposed to be looking directly at her and making her uncomfortable. If I wanted to marry her, again, there was a method—I had to go introduce myself to her family. Then bring in my family and all of this. That's even in the 1960s.

ASPATURIAN: So this tradition persisted for quite a while. What level of education did both your parents have?

ZEWAIL: My mother didn't really have an education because all her life was simply to take care of the family.

ASPATURIAN: Did she read and write?

ZEWAIL: Barely, barely.

ASPATURIAN: Although I notice that you say in *Voyage Through Time* that she took care of the finances. She must have had a head for figures.

ZEWAIL: She did very well in that. If it was numbers, there was no problem with that. I remember that very well. My father had an education—up to high school, I think—but he didn't go to college. In those days, education was self-taught in many ways. By the way, he also knew some English.

ASPATURIAN: How early in his life did he acquire a government job, and was this still under King Farouk?

ZEWAIL: That's a good, really interesting question. You know, it would have to be before the Nasser revolution.

ASPATURIAN: Did he serve in the Egyptian military at any time?

ZEWAIL: That I don't know. I didn't. I was the only son. There is a rule with that.

ASPATURIAN: There's an exemption for only sons?

ZEWAIL: Exemption, right.

ASPATURIAN: You were seven when Colonel [Gamal Abdul] Nasser [president of Egypt, 1956–1970] and his fellow officers overthrew Farouk, a watershed moment in the history of modern Egypt. What do you remember about that period?

ZEWAIL: You know, I started primary school at the age of about—in Egypt, it's either five or six, depending on the cycle. I must have been in primary school for about two years or so when it happened. I'll tell you a funny story—I may have told it in my book—before I tell you about the Nasser period. Near where I lived, there was a guy who makes falafel, and I would go and take a sandwich from his stand. And he made beautiful falafel—you can smell it up and down the whole street—and I go to him, I take a sandwich, I don't pay, and then at the end of the month, they charge my sandwiches to my father. There's no bank account, nothing of the sort. There was this kind of trust. But, going back to your question, what I do remember is that Nasser symbolized hope, and so as a young person at that age, what I knew from my surroundings and the people around me was that there was a new regime now that will take over Egypt, kick out the British from the country—

ASPATURIAN: End colonialism?

ZEWAIL: End colonialism. That this is a regime that will have the inequality problems solved because under Farouk, there is a *pasha* and there is a *beg* and all of these other titles, which means that if you are a *pasha*, you own, oh, hundreds of acres—I've forgotten how many now—and you are a lord, a big guy. And if you are a *beg,* you own this and that. So it is really a stratified society. The middle class doesn't really exist in the sense of the American middle class. There are the very rich and connected to what we call the palace, and there are those who are really suffering. So when the Nasser revolution came, the mood around me—it doesn't mean that I comprehended it, but the mood around me is hopeful. First of all, Nasser's the first man to rule Egypt who you can say is from us.

ASPATURIAN: "He's one of us"?

ZEWAIL: Yes. And that meant a lot. It meant so much in Egypt. Secondly Nasser was talking about big projects and saying that Egypt must regain its glory from the past. And that resonates—there are a lot of Egyptians today who still feel that way. And third was this issue of inequality. We call it here social justice. As you know, it's very important to have a middle class and not to feel that you are very poor compared to the very rich. So these were the three things basically surrounding me at the time. That prompted me to write Nasser a letter.

ASPATURIAN: You were a bit older I think?

ZEWAIL: Maybe eight.

ASPATURIAN: Did you do that all on your own? Or did you go to your parents and say, "I want to write Nasser a letter"?

ZEWAIL: No, I did it on my own. You know throughout my life, probably even now, I just like to use myself as a sounding board. I'm not one of these people who are loud and talk about it, so I'm quite sure that I did it on my own.

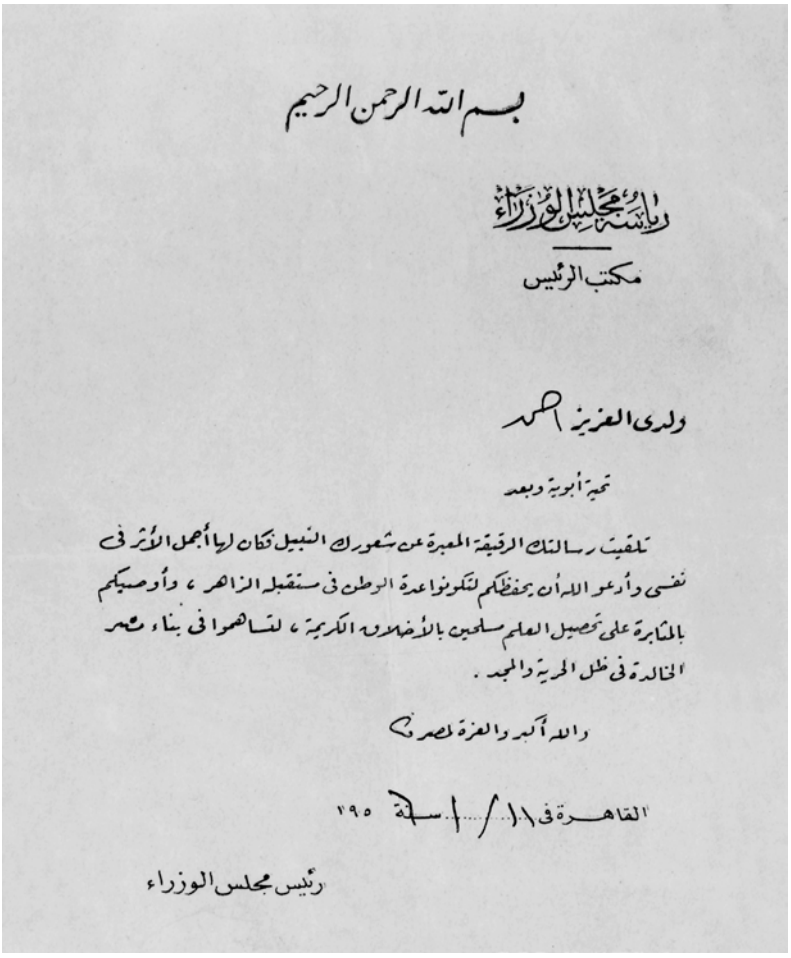
ASPATURIAN: You were a very independent-minded child.

ZEWAIL: Yes, that's the word. Even in the setting at home, there was a small room for me, and there is a desk and a couch and that's it, and I'm organizing it with a closet and things like that. I liked it to be clean, organized. My mother knew that. And then when I go into that space, I'm independent.

ASPATURIAN: It was your territory?

ZEWAIL: It's my territory. So I must have written the letter to Nasser from there. I think there's a copy of his answer in the book. It's almost prophetic, what he said.

NASSER LETTER TO THE YOUNG AHMED ZEWAIL



بسم الله الرحمن الرحيم

رئاسة مجلس الوزراء

مكتب الرئيس

ولدى العزيز أحمد

تحية أبوية وبعد

تلقيت رسالتك الرقيقة المعبرة عن شعورك النبيل فكان لها أجمل الأثر في نفسي وأدعو الله أن يحفظكم لتكونوا عدة الوطن في مستقبله الزاهر، وأوصيكم بالمثابرة على تحصيل العلم ساعين بالأخلاق الكريمة، لتساهموا في بناء مصر الخالدة في ظل الحرية والمجد.

والله أكبر والعزة لمصر

القاهرة في ١١/١/١٩٦٠

رئيس مجلس الوزراء

TRANSLATION OF LETTER TO ENGLISH

My son Ahmed,

I wish you the very best. I received your letter . . . . which expresses your thoughtful sentiments, and this letter has had a great effect on me. I pray to God to protect you to remain essential to Egypt's bright future. I ask you to continue with patience and passion in harvesting al–'ilm [knowledge, science]*, armed with good behavior and good thought so you can participate in the future of building the great Egypt.*

ASPATURIAN: Yes. Do you remember—I don't think there's a copy of your letter in the book—what you actually wrote to him?

ZEWAIL: Oh, that's interesting, right. Basically I said that you are one of us, and in Egypt that's very important, and that we are so happy that you are leading the country. Then I said, "I pray that you will succeed in your position as the president of Egypt." These are the three messages that I remember.

ASPATURIAN: It's of great interest to me that one of your earliest childhood inclinations was political, even though you went on to a career as a scientist.

ZEWAIL: [Laughter]

ASPATURIAN: Well, look at what has happened since you won the Nobel Prize; you've circled back in a way. Isn't that interesting?

ZEWAIL: I never thought of it this way, what you say. Right.

ASPATURIAN: How many kids your age would have thought to write to the president? And basically you were laying out sort of an agenda for him: "These are my expectations for you."

ZEWAIL: Exactly, exactly. Actually, I never thought of it this way, but there is no doubt that I wrote that letter with an idea in my mind for Nasser—as a kid.

ASPATURIAN: Do you have any early memories as a young child that stand out in your mind?

ZEWAIL: You mean events, instances?

ASPATURIAN: Yes.

ZEWAIL: I'm trying to think. I think some of the most significant things had to do with my thirst for knowledge, and, Heidi, even today, I really, honestly don't know where it came from. In other words, my father was relaxed about these things; my mother cannot absorb what I am trying to do—she's good in finance, but, you know—and I'm hungry for knowledge. Everybody tells me I was like this, but it's strange that even as a child, I seemed to know what I wanted to do. I knew what I wanted to do, what I wanted to be; on my door I wrote "Doctor Ahmed."

ASPATURIAN: How old were you when you did that?

ZEWAIL: Ten, maybe.

ASPATURIAN: It's around the same time that you wrote to Nasser.

ZEWAIL: Right. For example—a little analysis of my personality at that time. I was a boy who explained mechanics to my fellow students, and that lives with me still today. People say I'm a good teacher, a good public speaker. And it's the same thing! I did this also in college; after class hours, I would give public lectures. It's like this kind of thing has lived with me. Knowledge, knowledge—and I loved it. In other words, these are dry things for a kid at the age of, let's say, ten, so why would I be passionate about this? Why and how this came about I don't know.

ASPATURIAN: You talk a great deal in your memoir about reading. What did you read as a child?

ZEWAIL: As a kid, what we studied was not like what the American kids do. For example, in college my kids will take classics and things like, which sadly they're going to get rid of now.

ASPATURIAN: Liberal arts. A lot of the humanities are suffering.

ZEWAIL: Humanities are suffering, yes.

ASPATURIAN: That's how I was educated, yes, with this broad-based liberal arts curriculum.

ZEWAIL: The humanities hand to you so many opportunities for creative thinking, for thoughtful ways of looking at the world at large. Your writing, which is superb—this is not going to come from somebody at Caltech who just studies science and technology. You need this kind of preparation. Anyway, during my childhood, we didn't do it this way. In school, I would be focusing on, let's say, science and the other areas that we're supposed to cover, but in the summer, I did a lot of independent reading. In the Arab world, Egypt, Lebanon, and Iraq were really the three countries that produced most of the literature.

ASPATURIAN: The intellectual centers.

ZEWAIL: Yes, the intellectual centers. And actually Egypt was the center of the Arab world, but the saying was that the Lebanese would print the books and maybe the Iraqis will read them. [Laughter] So during the summers, I would read novels. But, you know, I wasn't that much interested in fiction. I always thought of fiction as "Okay, here is somebody who is imagining things, but I want to read about the real thing." One exception I remember was *The Good Earth* [by Pearl S. Buck]. It was a beautiful book. This is a novel about China and the Chinese people and the life there. So I was from this

young age always interested in other cultures and other people, but factually. In other words, not fiction. Of course in Egyptian literature, [Naguib] Mahfouz [1988 Nobel laureate in literature], for example, produced a tremendous amount of novels, and we had other people like him. So the summer really was the time for reading, and after you finish one book, you start another one.

ASPATURIAN: Did you read popular history as a kid?

ZEWAIL: Yes. But I have to tell you that the history I read was not taught in the right way in Egypt. And I loved history and since coming to this country I have a library now at home of it. History in Egypt was focused on lots of memorization. You're supposed to know the names of the cities and what they do, and the names of the personalities themselves, which sometimes in the Arab world are quite long. That didn't resonate with me. But here, I very much enjoyed reading about history, whether it's Europe or Asia; I actually learned more about the Middle East after I came here.

ASPATURIAN: Because you had access to more writing about it?

ZEWAIL: More writing. It's writing that is very attractive.

ASPATURIAN: It's interpretive and intellectual.

ZEWAIL: Exactly.

ASPATURIAN: Did you read much in translation? Did classics from the West that you might be interested in get translated into Arabic?

ZEWAIL: During my time in Egypt, it was not classics to read but to see in the movies. *Gone with the Wind*, that was a classic you went to the movies for. Humphrey Bogart.

ASPATURIAN: *Casablanca*?

ZEWAIL: Yes, *Casablanca*; These movies were always in Egypt, in theaters.

ASPATURIAN: Subtitles or dubbed?

ZEWAIL: Subtitles, subtitles. Dubbing was not there yet. I'll tell you a story to make you laugh. When I became a professor, I gave a lecture in Tokyo, and when I went to my hotel, I turned on the TV for a movie—and here comes John Wayne speaking in Japanese, and that didn't make sense!

ASPATURIAN: Very incongruous.

ZEWAIL: [Laughter]

ASPATURIAN: Did your family take newspapers, listen to the radio, have an interest in current events?

ZEWAIL: Oh, yes. In fact, we had a dinner tradition about this. This was not like in the U.S.; the major meal, which we called dinner, was at two o'clock. Breakfast was early; then came dinner; and then at eight in the evening or so, you took something light.

ASPATURIAN: I see. It's actually a better way to do it.

ZEWAIL: Right. So at two o'clock, when we're all seated at dinner, we turn on the radio and then we listen to the BBC. The BBC was important in our house.

ASPATURIAN: The BBC in Arabic?

ZEWAIL: In Arabic. Exactly, exactly.

ASPATURIAN: So that's how you got global news?

ZEWAIL: Global news. And even when the Egyptian news came about on radio and TV, we said we still wanted to know what the BBC will say.

ASPATURIAN: So your family grew up with a great deal of admiration for Nasser and what his regime was attempting to do, but at the same time you were interested in a broader perspective?

ZEWAIL: Right. And I think there's a misconception actually in the media here about Egyptian attitudes. Egypt, through thousands of years of history, has interacted with and made connections with other nations, either through commerce or culture.

ASPATURIAN: It's been a huge player in the Mediterranean.

ZEWAIL: Exactly. And so I think there's a misconception in the media about how Egypt, the Egyptians, dislike the Americans. It doesn't work that way.

ASPATURIAN: Things are more complicated?

ZEWAIL: More complicated. You listen to BBC, you put on T-shirts from America, you have McDonald's in downtown Cairo, but you don't like what the American government is doing. [Laughter] So it is not that simple. In fact, most of what we enjoyed at that age was really coming from the West. Holland, for example. I remember that in school they used to give us cheese, a piece of bread, and an apple and milk, that kind of thing. Well, all of this was coming from Holland, and so Holland was known for this. The U.S.—there's a lot that was going on—but, of course, what shook up the relationship with the United States was the High Dam, as you know.

ASPATURIAN: Yes. The Aswan Dam. [In 1956, the United States, which had committed itself to support construction of Egypt's Aswan Dam, withdrew its funding out of disapproval for what it perceived to be Nasser's anti-Western, pro-Soviet policies. *–Ed.*]

ZEWAIL: Right.

ASPATURIAN: In addition to reading, did you have special hobbies? Were you active in sports, did you go bike riding with your father? Did you play chess?

ZEWAIL: Besides reading I very much enjoyed sports, not on the level that I was naturally one of the best guys, but I played basketball, soccer, and what we called volleyball. So I was involved in that, and I enjoyed it very much. Also in high school, we used to write plays or they gave us a play to perform, and the schools asked our parents and everybody in the community to come and see. But as kids in those days we didn't have money to have stage curtains and things like this.

ASPATURIAN: I remember this from your book. It's a wonderful story. A group of students formed an animated human curtain.

ZEWAIL: [Laughter] Animated human, exactly, and we jumped up from our haunches to open the production, and then down into a crouch to close it. I remember that very well. The other hobby that I enjoyed very much—and that relates to the Nasser days—was photography, where we learned how to magnify a picture. So if you give me a small picture of Heidi, I divide it into pixels and then I try to recreate it on a big canvas by drawing—copying—each pixel there, and then at the end we have a big portrait of someone.

ASPATURIAN: I bet you found this interesting.

ZEWAIL: That was extremely interesting. I did magnifications of Nasser many times because we were proud of him and so on.

So there was photography, and there were summer sports. Bicycling also, because my dad taught me that. Reading, as I said, was always very important. What else? The thing that's ironic is that I never got intrigued by swimming in the Nile. This is good and bad. It's bad because I did not learn how to swim and enjoy a historic river like this. The good aspect of it was that at the time there was a disease called bilharzia [Schistosomiasis]. Bilharzia is a parasite that invades your intestine. It actually killed a number of famous people in Egypt who contracted it because they were swimming in the Nile. There is no such disease now. They eradicated it completely. But—my good luck—I didn't do that.

I also wanted you to know that I was really—Heidi, the general picture that comes

out of this is that I didn't adventure in things that are not good. I have never tasted or smoked a drug, not when I was a boy in Egypt, not today. For some interesting reason, I always felt that such things make you lose control of your mind, and that to me was a very serious issue. Very serious. So I've never done that.

ASPATURIAN: You liked what your mind was doing just fine without it.

ZEWAIL: Exactly. So I really didn't adventure like "real" boys do, certainly not like the ones I hear about in this country. In our country, America, it's amazing what you hear about. I didn't have any of that. I was happy with myself and enjoying my life. I didn't want to disturb it. In physics we say you take it too far in the non-equilibrium regime. I didn't want to be in non-equilibrium.

ASPATURIAN: When did you first realize that you were interested in math and science?

ZEWAIL: I would say—well, we have primary, secondary, and high school.

ASPATURIAN: Secondary would be our equivalent of middle school?

ZEWAIL: Middle school. And I think it happened in the middle school. But according to my mother, there were signs in the primary school that it is clear to me that that's the way I'm going. She always said, "From day one, you knew what you want to do." I think that's probably true.

ASPATURIAN: Do you recall what first touched off your interest in science?

ZEWAIL: Yes, oh yes. It was really how to solve the mechanics of objects that are coming down the slopes or being pushed up on the equivalent of the pyramid or something like that. That intrigued me so much.

ASPATURIAN: The fact that these natural behaviors could actually be described?

ZEWAIL: Exactly. And that you have to think of the forces that affected this. There's gravity. There is an external force, and it's a natural thing; it's a natural phenomenon that we try to dissect and to understand how it works.

ASPATURIAN: Suddenly we have the power to explain something in the world.

ZEWAIL: Exactly. Boy, I remember it was so exciting. And then I explain it to the kids around me. I think that was the first thing.

ASPATURIAN: Were you the standout student in your classes at this young age in these subjects?

ZEWAIL: I was in math, mechanics, and chemistry, things like that. But I wasn't in areas where memorization was required. For example, the Arabic language. I never really scored high in it. I mean they give us the formal language, but it's memorization, and I couldn't commit to the amount of work required to remember everything.

ASPATURIAN: On the mechanical side, your father, who ran a bicycle shop, must have been very good with his hands.

ZEWAIL: He was. He was. Of course, he also had people working in the shop. He was always a handy person. He did that actually in the home too when something like the radio needed to be fixed.

ASPATURIAN: So that aptitude was there. Did your mother keep the finances for his business as well?

ZEWAIL: My mother was the central bank of the house. In those days, any penny my father earned, he would bring back home for my mother. As a matter of fact, I recall that after he gives everything to her, she gives him the allowance. [Laughter]

ASPATURIAN: She was the financial manager. One of the things you mention in *Voyage Through Time* is that while you enjoyed school a great deal, you did not like the rote memorization and you did not like corporal punishment. Corporal punishment was a feature of schools in America too, at that time. And you said there was an incident where you were slapped by a teacher?

ZEWAIL: Yes. I didn't like it because—

ASPATURIAN: Well, of course you didn't.

ZEWAIL: But also I didn't think it would be effective. I recall that when my teacher did this, my father came to the principal and was very unhappy, and the principal apologized. So really nothing came out of it. As I have learned in life, the best way to really get somebody, including your own children, to do something is to get them to understand what this whole thing is about and what you are trying to achieve. This other kind of behavior is not good.

ASPATURIAN: One of the people who seems to have been quite an influence in your youth and throughout your life in Egypt is your uncle, your mother's brother. I'd like to have you talk about him.

ZEWAIL: His name was Uncle Rizq**.**

ASPATURIAN: Was he your mother's younger or older brother?

ZEWAIL: Younger brother. First of all, there was a coincidence there that both of us, I think, had the same type of personality despite the age difference. For instance, he reads the newspaper every day. When I sat down with him to analyze things and talk about what's going on, he always felt comfortable about explaining it to me. I, similarly, liked very much to discuss the issues with him. He really was a major force in my life. I recall for example that both of us loved [the iconic Egyptian popular singer] Umm Kulthum in terms of listening to her songs. [*See also Session Four*] And so he would arrange that he

and I would go alone to Cairo and attend her concerts. After the concert, there was a café in her name, and we would go the café, and we would have food and enjoy life. Maybe because his children were not here yet, he saw in me that I knew what I wanted, and he was always behind this in terms of my education, in terms of my getting my degree from Alexandria University. So he was always supportive of my decisions vis-à-vis education. And very generous.

ASPATURIAN: I believe you write that he was a very successful businessman.

ZEWAIL: He was a very successful businessman. And with me he was very, very generous. I remember that during my last year in college, when I wanted to know what my academic ranking at the university was, both of us went to the university wall where all these results were posted, and afterward we had a wonderful meal. But then, you know, he would make sure that he would gift me a beautiful suit and this and that. He was very appreciative of intellectual achievements.

ASPATURIAN: It sounds like in some sense he was a role model for you?

ZEWAIL: He was in many ways. The only thing I didn't have from him—and I didn't care too much—is a business aspect. You should know from the very beginning of this recording here that my brain is not wired for business. Even if my father was good in something business-related, or my uncle was very good—

ASPATURIAN: It sounds like your mother would have been, too.

ZEWAIL: My mother too. I just don't have it. There are some people—I tell this to my children—who have it, I don't. I don't. I don't see opportunities where I say, "Let's invest here!"

ASPATURIAN: Your brain was wired for science. That's certainly what it sounds like.

ZEWAIL: I think that's so. But interestingly enough, when it came to things like the Egyptian Revolution [the 2011 spring uprising and national protests that resulted in the ouster of Egyptian president Hosni Mubarak. *–Ed*.] or trying to impact the politics of the country or so, my brain can do it and can function. It's just that business stuff where I have no interest.

ASPATURIAN: The Nasser revolution was a very secular one, I believe, to an extent that isn't generally appreciated in the West. And you also describe the mosque of your youth as a kind of intellectual center. How did all of that work? You had a government that is trying to put across a quite secular and modernizing agenda and a religious tradition that dates back more than a thousand years.

ZEWAIL: Very interesting question, yes. I have always thought, even today, and I have written about this—that religion and secular life do not have to be in collision. Actually, I feel that people don't understand that, and this is sad. It's the same as those who are anti-science because of the fact that they think it's in collision with religion. It is not. I can prove it by a variety of ways. But I think the Islam of Egypt in that period—

ASPATURIAN: We're talking the 1950s and '60s.

ZEWAIL: Yes. In that period, it was incredibly moderate. It was all geared toward educating the children. I know for a fact that there were people who sold a piece of land in order to educate their children in major universities. The feeling at the time was that education is a real enrichment you can have in your society.

ASPATURIAN: Do you think this was also to some extent by Nasser's example—the sense that we can all move ahead as he did regardless of where we come from?

ZEWAIL: I think it's a different thing because religion in Egypt at the time was not like it is now—trying to sort of be in conflict with the leaders of the government. Islam at that time—independent of Nasser now, but I'll come to Nasser in a moment—was moderate, seeking the value of education, and intellectually rich. So I recall, for example,

Egyptians going on Thursday to the theater and movies and things like that. On Friday, which is the equivalent of Sunday for Christians, they would go the mosque and pray. So there was no conflict for the average Egyptian between his faith and his life. He can enjoy his life. I'll tell you that this actually is a major part of the problem that's happening right now in a country like Egypt. I lived in a society where I can go to the mosque at Ramadan—which is actually starting in a day or two this year—and study in a group of five or six. And the *imam* of the mosque, the man who's leading the prayer in the mosque, would come to us and bless what we're doing, whether it's in algebra or chemistry—and it's a beautiful feeling, I remember. It's incredible. It's in the middle of the mosque, and you have this beautiful space and the serenity, and you have water and also rosewater. So the intellectual atmosphere was there. We didn't have anybody come to us and say, "If you do not join this and this and this, you're going to go to hell." There was none of the kind of thing that's going on the country now. Now when Nasser came, he himself was part of this tradition. You see?

ASPATURIAN: I see.

ZEWAIL: So he knows that this is the way the country is going. His only problem at the time was the Muslim Brotherhood. He had a problem because they wanted to topple this and that—the usual thing. So he put them in jail. The story goes on. But the society as a whole was incredible. I'll give you a story. It might shock you about what was going on. In college, I was part of a special group.

ASPATURIAN: This would have been around 1962, '63?

ZEWAIL: Let's see—I graduated in '67, so it has to be '63 when I started. So in the second year they took me into a special group made up of seven people. But the entering class with me was about 500 people. Roughly 50 percent were women, and 50 percent were men. What is shocking is that none of them, out of the half of the class, had hijab [the head scarf worn today by many Muslim women].

ASPATURIAN: I remember the pictures in your book, all these young women with their beautiful dark hair.

ZEWAIL: Exactly. Exactly. Now today when I give a lecture, let's say, at Cairo University, there are maybe a thousand people in the auditorium. I would say 90 percent of the women are wearing it.

ASPATURIAN: It's happening in this country, too. We thought the debates over evolution basically ended in the 1920s with the Scopes trial. It seems to be a worldwide trend.

ZEWAIL: You're exactly right. It's a worldwide trend. I can't believe that in the United States, we're still debating the issue of evolution—that Kansas, for example, doesn't want to teach this in a country where science and technology has been the reason for progress. I think Islam at the time—

ASPATURIAN: It was accommodating?

ZEWAIL: *Very*. I wrote a piece for the *New York Times* describing to readers what Islam was when I was a child. I saw none of what I'm seeing today. Sheikhs and other people appearing on the TV and saying you must do this and that, and if you don't do that, God will wreak vengeance. I mean that's not the way things were.

ASPATURIAN: The way you describe the mosque with the rosewater and so forth, it sounds like you saw it as a temple of learning. Would that be—

ZEWAIL: Temple of learning, and people also go to pray. So when they call for the prayer, at noon or other times of day, we're all praying but then we go back and study.

ASPATURIAN: Did you ever explain some of your mechanics lessons and other things to the *imam* as well?

ZEWAIL: No. But he would come, put his hand on us, and say, "This is great, boys and girls." Boys—we didn't have girls there.

ASPATURIAN: So you are in high school, thinking of applying to the university. Am I jumping ahead too fast?

ZEWAIL: I think you do it your way.

ASPATURIAN: Well, you've written your own memoir too, so I know you have some thoughts about this.

ZEWAIL: No, I think it's fine. And if there's anything, we'll go back.

ASPATURIAN: I actually do want to jump back first to a couple of things you relate in your memoir. One was that as a kid you nearly burned down your bedroom with your chemistry set?

ZEWAIL: Yes. [Laughter] This is the only experiment that I did when I was around that age.

ASPATURIAN: You were about twelve?

ZEWAIL: I would say about that. I was intrigued by what they told us in the class.

ASPATURIAN: Who got you the chemistry set? Your uncle by any chance?

ZEWAIL: Actually, it was not a chemistry set. I constructed it; it was very simple. This was after they taught us in school about combustion. One of the things that the textbook said was that if you light this wood, you will see a strong lighted gas coming out and that's because, they told us—we didn't understand, really—this puts the atoms and molecules in the excited state and when they emit energy, you see light. I was so intrigued; I wanted to see the gas that comes out from combustion. So I went home to try

it myself. All I needed was a test tube and a 90-degree tube. So you have a test tube with a cork, and in the cork I put another tube, just bent by 90 degrees. My mother had a burner that she used for making Arabic coffee, and the tradition there is that you make it when your friends come over and you are all sitting together around the table. The burner has a small flame that she can just light and then put the coffee pot on it. I took that burner and put it under the test tube, and I put some wood in the test tube, and the wood started to burn, and I saw the gas through the tube.

ASPATURIAN: Just as it had been explained.

ZEWAIL: Just as it had been explained, I saw the gas coming out and lit the match. When my mother saw me doing all of this, at first she was very happy with me. [Laughter] When I give lectures now, I show her picture and how she's happy, and then all of a sudden she is unhappy because when I applied the match, indeed I saw the gas lighting up! That to me was really like a revelation. Very exciting to see. But my mother was afraid that my "experiment" was going to burn down the house.

ASPATURIAN: The other thing you mention is that you knew how to drive a car—theoretically. I guess you were a little older.

ZEWAIL: [Laughter] I think I must have been at the time in high school. I would say fifteen, sixteen.

ASPATURIAN: This was the family car?

ZEWAIL: Was it the family car? Actually I would have to say it was my uncle's car, and he had it parked. We have lots of branches of the Nile that go through many cities, and he had his car parked close to the local branch of the Nile in the city where he lived. There's a waterway there. I knew theoretically what to do. I put my left foot on the clutch, and I turn this on. To make a long story short, I tried to apply the theory to the experiment. Well, the car was headed down into the waterway! This is the only time that

my father gave me a lesson. I think he lost his senses. He was just imaging that his only son—

ASPATURIAN: Will perish in this silly escapade.

ZEWAIL: This stupid thing I did. So I got some beating from him. The only time in my life.

ASPATURIAN: What did your uncle say?

ZEWAIL: He was cool about the whole thing. He tried to take me from my father and calm down the whole process. But that's the only time that I did get this unpleasant punishment.

ASPATURIAN: How close was your home in Desouk to the Nile? Were you literally on the banks? What was that like, growing up next to this iconic body of water?

ZEWAIL: You know, Heidi, there's something about us humans, and it is that we do not appreciate what we have until something important happens. You can apply this rule that I'm telling you about everywhere. You can apply it to children. They don't appreciate you and me until they are grown up. Yesterday for example—I have a grown-up kid, and he came to me and he said, "Dad, I just went to Northern California, beautiful area, and I had a debate with people, and I just realized that there is no conflict between religion and science." Then he looked at me and he said, "But, you know, you told me this tens of times. It didn't sink in," until now after the debate. This same applies to a boy like me with the pyramids, with the Nile next to me, with all of this. You don't appreciate it, you don't think of it when it's there with you. I didn't visit Upper Egypt until I was at the university. It's like when you're living with it, you don't get a feeling as to why this is important.

ASPATURIAN: It's like breathing. You take it for granted.

ZEWAIL: Exactly. Exactly. And really I did not appreciate the importance of all of that until I came here.

ASPATURIAN: One thing that struck me about the boyhood photographs you have in your memoir is that you always look very serious.

ZEWAIL: [Laughter]

ASPATURIAN: Family members might be smiling. You're with other kids; some are smiling, some are not. You always look like something is on your mind. I wondered about that. You don't look sad; you don't look unhappy. You look serious.

ZEWAIL: I think you're absolutely right. First of all, culturally, in terms of taking photos in Egypt at that time, you're supposed to look serious. They asked us to be serious. So culturally I think that was something that we all did. But I think in my case you're right—there was always something that I'm thinking about. Even today, that's the same thing.

ASPATURIAN: Given what you've been saying, I wonder if in some of those pictures you were thinking about the mechanics of how the camera was working.

ZEWAIL: [Laughter] That's the kind of thing that will come to my mind. Exactly.

ASPATURIAN: So let's return to you as a serious young man, applying to university. How did the application process work in those days?

ZEWAIL: There was something that still exists in Egypt called *Maktab al-Tansiq*. *Maktab* means the bureau. *Tansiq* means to organize—in this case, to organize university admissions. We are all under the mercy of this *Maktab al-Tansiq*, meaning that all of our exam grades go into this bureau, and they decide: "Heidi got 90 percent of this; she will go into engineering. Ahmed got this and that and will go into medicine," and so on. This is really not a good system because, obviously, Heidi might have nothing that interests

her in engineering, and she might want to study humanities. Her brain is wired this way, and it would be much better for the country. But unfortunately the problem then and now is that the numbers are large. So right now, about half a million students are applying to all the Egyptian universities, and in my time it was probably 10,000 or something like that. So after you go through all this, you get a piece of paper that says you are going to be admitted to the faculty of something. In my case—I still have the letter somewhere—I was told that I'm going into the faculty of science.

ASPATURIAN: This must not have come as a surprise.

ZEWAIL: No. But I was so thrilled. So thrilled.

ASPATURIAN: Did the paperwork that you received stipulate that you would go to Alexandria rather than Cairo?

ZEWAIL: Oh yes.

ASPATURIAN: How did they make that determination? Was it geographical?

ZEWAIL: Either geographical or, I think, more depending on your grades. In other words, it could be that somebody two points ahead of me would go to Cairo, and I would go to Alexandria.

ASPATURIAN: You must have been all of sixteen, maybe? Because I imagine you applied while still in high school?

ZEWAIL: Exactly. I recall, because I loved knowledge and all of that, that after I was admitted to the University of Alexandria, my Uncle Rizq and I went to visit the faculty of science complex, which was built on a beautiful hill.

ASPATURIAN: Your uncle accompanied you on this first visit rather than your father?

ZEWAIL: Yes, because we did many of those things together. My father was the kind who, when you tell him, "I am going to Cairo with my uncle," says, "Oh, great!" You know, that kind of thing. But my uncle was very much interested in seeing the faculty of science. We went there, and it's on a hill, and the buildings—there were, I think, six—are very old and charming. Just like Caltech. They were built when the Brits were there. And so you have a beautiful building standing on its own, large and huge, and that would be chemistry; and then you have physics and then biology. I still remember it this way. Of course the library was somewhere and the machine shops and all of that. So when we went, he and I, up on this hill, I had tears.

ASPATURIAN: You were that moved.

ZEWAIL: I was so thrilled that this is the house—the house of knowledge, as I called it at my age. It was clear that my destiny was to be at the faculty of science for four years, and I was thrilled to enter the first year. It was tough because then there was, "You are going to the university, that's right; but how are you going to live?"

ASPATURIAN: You have to work all that out as well.

ZEWAIL: You have to work all of that.

ASPATURIAN: You mention in *Voyage Through Time* that your father suggested you consider one of Egypt's applied institutes of learning as well, but that you and your mother did not want to do that.

ZEWAIL: That's right. Alexandria was a distance from where we were living. But the government at the time had established institutes of higher education at various places in Egypt, and one of them was very close by. In fact, I could easily go and come back home every day. Typical for my father, he tells me, "You could go to one of these, and you will be what we call an agricultural engineer. You will do whatever you like, and the country is full of opportunities in agriculture." But I knew that science is what I want to

do, and my mother and my uncle supported this. So there was the decision that I was to go to Alexandria.

ASPATURIAN: Did your father have a problem with that, or was he just trying to suggest a different option?

ZEWAIL: No. It was just typical of him, being easy-going and saying, "Why don't we do it this way?" But I had decided that science is really the thing. You know, even today, if I have solved a problem and then go home, my wife [Dema Faham Zewail] will say, "I know you've been solving a problem because you behave like a boy."

ASPATURIAN: Very perceptive.

ZEWAIL: You're excited; there is nothing in your mind except this.

ASPATURIAN: Is it correct to say you were captivated by science? You did not see it as a *career* path, as a way of achieving prestige—

ZEWAIL: No, no, no, no, no. It is what I wanted. Exactly.

ASPATURIAN: It's like your feelings, as you describe them in your book, about this singer [*Umm Kulthum, see Session Four*].

ZEWAIL: Exactly. In other words, from a very early age, there was no question that this was what I wanted to do. When I see my children now, going on the Web and finding the average salary for certain professions, I tell them that they are much more sophisticated than we were because my ambition had nothing to do with this.

ASPATURIAN: You had a calling, as we would say.

ZEWAIL: Right.

ASPATURIAN: It's actually a religious term.

ZEWAIL: Right. I was captivated. *Passionate* is the word I usually use. I was so passionate about it, and what was really important to me was that I do very well in the classes and get the best grades. And there was no—I mean we are all human and we look forward to a better life, but the better life that I was thinking about is not like what I'm seeing young people think about today. The better life means a comfortable life. In other words, I knew that if I graduated from the faculty of science, I could have a job and a home and that's it. I didn't think the money would be this or that, or "If I did this I could start a company."

ASPATURIAN: You were thinking about the life of the mind. Were there scientists whom you admired and knew about, growing up, who helped shape your thinking at all?

ZEWAIL: You know, especially after the Nobel, a lot of people ask me about who was your hero. I'll tell you about the hero later. [*See Session Five*] But, really, then there was no one special.

ASPATURIAN: Einstein? He was sort of an emblem for that generation.

ZEWAIL: Yes. But for me, it was just the love of what I'm doing, in my own small way. If it had been Einstein, I would be looking forward to being another Einstein, but that never came to my mind. That's the other thing I was going to tell you, as a side note. This business of the Nobel Prize, it didn't come to my mind, nor did I know any details about it or what it meant. The prizes may have been announced in the newspapers, but I had no idea that this is a very important distinction and that I should be working to get one. None of that whatsoever. When I hear nowadays that somebody has committed fraud in biology or while trying to make a molecular nano-switch or some such thing, and the explanation is that he wanted to get the Nobel Prize, I cannot comprehend this. For me it was the sheer love of whatever we can discover in a small way.

ASPATURIAN: I think you mentioned that when you started at the university, there were no more broad curriculum classes. You went into the faculty of science, and that's all you studied. How did you choose your subjects?

ZEWAIL: Yes, within the faculty of science students chose subjects, and I chose chemistry, physics, math, and geology. Somebody else might take chemistry, physics, botany, and something else.

ASPATURIAN: You stayed away from most subjects that required a lot of memorization. No biology, no botany.

ZEWAIL: Exactly. For example, with biology, when I looked at the Latin names and all, I decided not to get into that. Today I'm doing work on biology, but it's very different. Math was essential for me because I loved math you see. I was—to brag a little bit—I was a student in the first [freshman] year, and my professor, Dr. Shehata [Gouda]—and I still remember this as if it's yesterday—called on me out of the entire class of five hundred or so and asked me to do calculus on the board.

ASPATURIAN: This was your first encounter with calculus—at the university?

ZEWAIL: That's right, and in the first university year. Right up to today when I do math I don't like the speedy way of doing it because you can easily make a mistake, and when that happens in mathematics, it's different from chemistry or physics. So I write the integral, I put the brackets within brackets, and all of that; and Dr. Shehata would look at me and say, "What Ahmed is doing is exactly what you should be doing." That gave me a lot of pride, and I went to the blackboard probably not less than five or ten times where he's calling on me to show the rest of the class how to solve problems.

ASPATURIAN: Were you that far and away ahead of the rest of the class?

ZEWAIL: Yes, usually, I put in a lot of effort to be reading ahead. I even did it in the summer sometimes. So I was doing this, and math was just going along well. In geology, I liked it, although I felt it's a lot of memorization of rocks. But I still liked the idea that I would take a microscope and look at rocks and crystals under it and apply the art of analyzing crystals and distinguishing between them, and asking "Is this quartz or is it something else?"

ASPATURIAN: Do you think that's where your interest in the microworld originated, looking at these geological specimens and studying their structure?

ZEWAIL: That's an interesting question. Well, I think this will be the effect of using the tool. In other words, I developed an appreciation that we have a tool like a microscope that allows us to magnify and see the invisible. That's definitely something that stuck with me.

ASPATURIAN: It resonated with you early on?

ZEWAIL: Resonated with me, right. But it was chemistry that really stood out, because of two things. One, we were taking inorganic chemistry from a teacher who was young and had just came back from Germany. He loved the interaction with the students, and I liked his way of presenting the problems.

ASPATURIAN: He'd gotten a PhD there?

ZEWAIL: Right.

ASPATURIAN: East Germany?

ZEWAIL: No, West Germany.

ASPATURIAN: Ah, unusual for an Egyptian in that era.

ZEWAIL: Yes. He actually had done infrared studies of many chemical compounds. His approach was more analytical than in organic chemistry, which I did not appreciate as much.

ASPATURIAN: What was the name of this teacher who was so inspirational?

ZEWAIL: Doctor Issa. Rafat Issa. He really inspired me and many other people into realizing that chemistry is exciting and interesting. We used to crowd around him after

he would finish his lecture. So there was some feeling that chemistry is not "just cooking," as we would say. Physics, and this is ironic because as you know I'm a professor of physics and I love physics, but—it was the teacher. The teacher I felt was too informal and not serious.

ASPATURIAN: Not rigorous enough.

ZEWAIL: Not rigorous enough to attract me. So I was not too happy. But luckily, I got high marks in all of my classes the first year. Now, at the end of the first year, you had to drop one class; I dropped geology. At the end of the second, I dropped math. The faculty was very upset that I would leave. But in the second year, if you get "excellent" or "distinction" in all three classes, you are now to specialize in one field only while everybody else will go and specialize in two. They graduate with two degrees—for example chemistry and physics or chemistry and biology. But in my case, I could specialize in a single field. I chose chemistry, and that's how I got to be among the seven students that were selected to be "specials"—to specialize in this way. In the third year, I got distinction again. In the fourth year, I was first among the whole class. The progress was going in that direction. And even though I was a "special" in chemistry, there were areas within chemistry that I didn't like as much because, again, they went too much into memorization. For example, organic chemistry. I would not do it as a researcher, although when I took the class, I loved it. Why? The teacher himself was fantastic. The seven of us would go to his office, where he would be giving you the concepts, the principles of how to synthesize a very large molecule, for example from A to Z. Strategy, thinking—that attracts me. But telling me to remember that benzene plus alcohol gives this, this, and that—I turn off.

ASPATURIAN: You liked the intellectual challenge? The problem-solving aspect?

ZEWAIL: That's it. Problem-solving aspect, and that you have a clear strategy. That's one of the things that has stayed with me all my life. The clarity is very, very important.

ASPATURIAN: What would you say the overall caliber of teaching was like at Alexandria?

ZEWAIL: In those days, it was excellent. These were professors with training from England or Germany or the United States. They were all committed to teaching at the highest level. Also the number of students was small. Even five hundred—that is not a big number. The auditorium that accommodated this five hundred was in very good shape, excellent. So these were very good teachers. In fact, I owe a lot of my success to these people.

ASPATURIAN: You mention in your autobiography that the level of instrumentation was not always that advanced, but that one of the things you were able to do was some spectroscopy. And you said that interested you right from the start. Why?

ZEWAIL: Because first of all, what is spectroscopy? Spectroscopy is where you have something that is essentially a fingerprint of Heidi, but you haven't seen Heidi. When you scan, for example, a molecule at certain wavelengths, you really haven't seen the molecule, but this imaging gives you an idea about this molecule and then you have to use your brain, you see—

ASPATURIAN: Yes, I understand. You do a lot of interpolation.

ZEWAIL: Interpolation and extrapolation. The intellectual challenge. And that's what I did for my master's degree in Alexandria. I finished it in eight months because I could understand these kinds of things and move on them. I had a wonderful thesis supervisor, Dr. Samir El-Ezaby, who had just came back with a PhD from Utah, and with a big car, an Impala. We used to get into this car and go to restaurants and things like that. But I owe to him learning how to really do spectroscopy.

ASPATURIAN: How much exposure did you have to Western science through your studies at Alexandria? Were there lots of journals? Most of these must have been in German or in English. How did that work for you?

ZEWAIL: We were actually exposed because the people that we worked with came from the West. For example, I wrote several papers with Dr. El-Ezaby, and these were

published in the West. He knew which journal was which. So, scientifically, we had a lot of interaction.

ASPATURIAN: Did you have visitors coming through from Europe and the United States, or were relationships strained at that point because of the Cold War?

ZEWAIL: Yeah, I know what you mean. I can't recall really that we had—but on the other hand, Dr. Issa, for example, was married to a German, and she came and lived in Alexandria. I think on the personal level, there wasn't much of a problem, but it's the governments.

ASPATURIAN: Nasser's neutrality stance caused a lot of trouble with NATO.

ZEWAIL: Yes.

ASPATURIAN: Where did you live when you were studying? You lived in Alexandria?

ZEWAIL: Right. I lived in a place called Sporting Street.

ASPATURIAN: Sporting Street. A British name.

ZEWAIL: 211 Sporting Street. It was a villa. My first two years I lived with my uncle in Damanhur and took the train.

ASPATURIAN: This was your mother's brother?

ZEWAIL: Yes, but a different brother. I used to commute back and forth, and it was only about an hour or so, I think. So we used to go in the morning and come back at the end of the day for about two years.

ASPATURIAN: How often did you visit your hometown while you were a student?

ZEWAIL: Only for the big celebration events—for example, Ramadan. For Ramadan and Eid [Eid al-Fitr, a celebration that marks the end of the month of Ramadan] and these kinds of things, we tried to get together as a family.

ASPATURIAN: So like any kid being away from home.

ZEWAIL: Yes. It's like Thanksgiving.

ASPATURIAN: During your four years at Alexandria, did you have time for recreational activities at all? I mean it sounds like you were a very conscientious student.

ZEWAIL: While I was a student, the university used to sponsor student trips, like the one my group of seven did to Luxor and Aswan.

ASPATURIAN: This was the first time you'd been there?

ZEWAIL: Yes. It's amazing actually. You know, this is Upper Egypt. Now I know a lot more about it. But also during all these four years, we ourselves, the students, arranged a trip to El Alamein, which was very close to us—about half an hour from Alexandria—to see the remnants of the Second World War battles [the 1942 Battle of El-Alamein, Egypt, ended the Nazi occupation of North Africa. *–Ed.*]. Or to go to play soccer somewhere. That was something else we did. But—if I go there on Friday, that's enough for me. I need to be serious and get my work done.

ASPATURIAN: Had you ever traveled outside the country before you left for America?

ZEWAIL: No, no. In fact, it was my first air flight.

ASPATURIAN: At what point did you start thinking about studying abroad for the PhD?

ZEWAIL: When I was doing the master's degree.

ASPATURIAN: So this was during your fifth year?

ZEWAIL: In other words, I already graduated with a bachelor's degree in 1967, and that was during the [Six-Day] war. And then I stayed in the country, where I did the master's degree for eight months. But I only left the country in '69 because of the huge bureaucracy regarding going overseas.

ASPATURIAN: It took that long?

ZEWAIL: Yes. In order to leave. But during that time, I wrote to about five or six universities.

ASPATURIAN: What made you decide, first, to study aboard, and second to focus on the United States? It would have been easy, for example, to go to the Soviet Union.

ZEWAIL: That's an excellent question. Again, I knew what I wanted. Not to keep repeating this, but I knew that science in the East is not on the level of science in the West.

ASPATURIAN: How did you know this? Talking to people?

ZEWAIL: Just also reading the literature, and also feeling the power. The power of the nation, you know. At that time the Egyptian government was underwriting what were called "missions," which sent people in my position abroad to obtain the PhD and then come back to teach and do research. Essentially, all of them went either to the Soviet Union or East Germany or Hungary—Budapest. Everybody that I knew was either coming back from Budapest or East Berlin or Moscow State University. Somehow I wanted to be in the West.

ASPATURIAN: Did the example of these professors who had come back from West Germany and America influence you?

ZEWAIL: That's part of it. I saw in them quite a level of free spirit that I liked. [*See also Session Two*] Also they were really quite knowledgeable. They always talk about life in

the United States. But I knew that for me the issue was not the PhD. I knew that for me the issue is to gain the best education and knowledge, and I knew that would happen in the United States. So if I waited for the Egyptian government to send me abroad, it would be to somewhere in the Eastern bloc. I decided to go my own way and apply for the Western post.

ASPATURIAN: The Egyptian government didn't put any obstacles in your way particularly?

ZEWAIL: No. The obstacles were in the issue of, how do you leave the country after eight months; you're supposed to wait for two years after receiving your degree—that kind of thing. But they were not against me going to the United States. I asked one of my professors about where to apply, and he said there was a great man at Florida State University in Tallahassee by the name of Michael Kasha, and that there is another, younger guy at University of Pennsylvania by the name of Robin Hochstrasser, who was doing very important work in spectroscopy.

ASPATURIAN: Which was an interest of yours.

ZEWAIL: Which was of interest to me. And there is a person at Caltech by the name of [G.] Wilse Robinson, and he's also doing state-of-the-art research in spectroscopy.

ASPATURIAN: You'd had a professor who came back from Utah. Did you apply there?

ZEWAIL: Right. I asked about Utah, but I didn't apply there, because this other professor told me a lot about Caltech and Penn. So I wrote to Professor Hochstrasser. I wrote to Professor Wilse Robinson. I wrote to Professor Kasha. I told them that I am interested in studying with them, that I have graduated with distinction, first class honors, and that I'm seeking a fellowship, a scholarship. Because the fact that I didn't go through the Egyptian government meant that I had to get financial support on my own; I needed somebody to pay the tuition.

I still have the letter that I received back from Caltech. Of course, later I gave a hard time about it to Wilse Robinson. [Laughter]

ASPATURIAN: What did he say?

ZEWAIL: Something like "in the event that you are admitted to Caltech, I will be pleased to meet with you." To us Egyptians, that is a very distant response. It was not warm and saying, "Your application looks great, and I will forward it to admissions." You know what I mean? So when I talked to him about it, years later, Wilse said, "I didn't write it. I just gave to the secretary and she—" [Laughter]

ASPATURIAN: The secretary was responsible. Okay, sure. Whatever.

ZEWAIL: The one who understood the mentality of the system over there in Egypt was Robin Hochstrasser, and I owe it to him that I came to America. Because he immediately wrote me a letter. He said, "Yes, I'm interested in your application, and I have forwarded all of the materials to the admission committee; we will be getting back to you."

ASPATURIAN: It sounds like a much more sophisticated response from Penn actually. Caltech was still kind of provincial, here in Pasadena.

ZEWAIL: Penn probably knew how to deal with this.

ASPATURIAN: That's right, a northeastern university.

ZEWAIL: I wrote to him, and I was so excited. Then he sent me a letter. All of this I have. He said, "I'm pleased to let you know that the graduate admissions committee has approved you, etc., etc., and that we will pay tuition; your stipend is $300 per month." Oh, my gosh, this is fantastic! So I take this letter to the chairman of the chemistry department and tell him that I want to leave now because this is a fantastic opportunity. They're paying tuition. They're paying my stipend.

ASPATURIAN: They really want you.

ZEWAIL: They really want me! And the chairman said, "It doesn't work that way." I said, "I finished my master's degree. So what else do you want?" He said, "Well, you finished your master's, but you're supposed to be here two years. A master's degree takes two years."

ASPATURIAN: This came as news to you?

ZEWAIL: I was just shocked at the way the bureaucracy regarded this. It turned out there was something called the "unknown" letter, meaning that Dr. Hochstrasser was supposed to write the letter of admission not to me, but as a general inquiry to the department of chemistry, and then the department would ask all of the instructors—let's say there were thirty in the department—if they were interested in this fellowship or scholarship at Penn. So silly and so ridiculous.

ASPATURIAN: Instructor was the level that you reached having completed—

ZEWAIL: Having completed the degree with first class honors, now you are hired to teach in the department because your grades were very high. So it is unbelievable. I wrote back to Dr. Hochstrasser explaining this, and he really saved me because if he hadn't done this, I wouldn't be in the USA. He wrote the required letter.

ASPATURIAN: Did he write to you or to the chairman of the department?

ZEWAIL: He always wrote to me to give it to the chairman. But at the end of the letter, he wrote that the final selection is up to the University of Pennsylvania. In other words, "Do whatever you want to do, but in the end, we're going to say 'Ahmed Zewail.'" I don't think the chairman understood that line at the end. But my job was to see if any of these other instructors were interested. Can you believe it—I went to each one of them and said, "This is the situation," and will they sign that they are not interested in that scholarship. They know deep in their hearts that I am the one who received it.

ASPATURIAN: Do you suppose that the department chairman had no choice when he initially said to you: "We can't do it this way"? He was hamstrung by the bureaucracy?

ZEWAIL: Just the bureaucracy. Because the way they think about these things is in those terms. You know, during my first week in the United States, one of the most exciting things to me was to see the difference in the way bureaucratic matters were handled. For example, my Alexandria diploma was covered with university and government stamps because I had to get all these approvals for the leave. But when I came here and I was registering at the University of Pennsylvania, I'm standing in the line. The woman handling the registration asked for $25, something like that, so I paid her whatever the amount was. But then, I didn't move. I have a line behind me. I said to her, "Stamp, where is the stamp?" You see? She said to me, "We don't have stamps here." So it was the first encounter.

ASPATURIAN: The first inkling you had of how different things were going to be.

ZEWAIL: How different things are.

ASPATURIAN: So, back at Alexandria none of your classmates expressed an official interest in this position.

ZEWAIL: No. And they all signed. So the selection was me at the end. Then I had to go to Cairo and get permission from the minister of higher education.

ASPATURIAN: You talk about this in your book. It's very interesting; at one point, you run into a mail deliverer who escorts you upstairs?

ZEWAIL: Right. According to Egyptian regulations, the chairman of the department, the dean of the faculty of sciences, the president of Alexandria University, and the minister of higher education, they all have to sign off. I got the chairman of the department, and the dean follows the chairman so, no problem. Now I need the president of Alexandria University. So I'm going to see him, wearing a suit and tie, very formal. I run into the

guy who's the postman and told him I would like to meet Mister President, and he looked at me and he said, "Is it that easy to meet the president?" I'm not an aggressive person by nature, but I wanted to get my signatures, and I said to him, "Well, I now have two signatures, and I need the president's to go to study in America; so please help me." I think I must have touched something in him. So he said, "Okay, carry the mail, and I'll take you there." So I carried the mail. We went up to, I think, the third or fourth floor, and I went in to see Mr. President, and he looked at my paperwork. I'm standing there, sweating from nerves and from being the mail carrier. And he said, "I'll sign it, but you're not coming back."

ASPATURIAN: What did you think when you heard that? Do you recall?

ZEWAIL: I didn't take it seriously really. But it was prophetic. The university president was out of town, so this was actually the acting president, and he later became my friend because he wanted to build up science at Alexandria, and by then I was doing very well here at Caltech and other places. He was just a charming, fantastic man, Dr. 'Abd al-Rahman El-Sadr, a medical doctor. He is no longer alive, but I still have a relationship with his family. But he was right. I did not come back. I think what he saw was my student-with-distinction designation, first-class honors, and master's degree in eight months and realized.

ASPATURIAN: "This man will stay in America." Yes, probably.

ZEWAIL: So he signed it, and then after that I had one more signature. But the education minister is not in Alexandria; he's in Cairo. So I had to go there on the train almost every week until I got his signature, because you show up one week and then his aide says, "He's not here."

ASPATURIAN: You couldn't call and make an appointment?

ZEWAIL: No. No way. You try again next week. He says he's too busy. So it must have been the fourth or the fifth visit before I was able to have him sign.

ASPATURIAN: It's interesting to listen to this. Clearly Egypt had a lot of bureaucracy, but if you had a great deal of determination and ingenuity, none of these people seemed to have been ill-intentioned.

ZEWAIL: That's it. Exactly. Nobody is trying to hurt you. And, in fact, in Egypt at that time they valued education so much it was beyond belief. Do you know that when I got my degree with distinction, Egypt had a practice of reporting in the national newspaper that you are one of the leading students in your field and publishing your photo. When my photo was published, people in our town would go to my father and congratulate him because they had read about it in the newspaper. "Oh, Ahmed is doing great, congratulations!" So education really was an important thing in Egyptian society. The problem was with the bureaucracy. Now when I go to Egypt, I talk to the Egyptian media about bureaucracy; and of course, when we established Zewail City, the one thing that I have been after for fifteen years is to have a rule, a law, that would allow us to be separate from all of this bureaucracy. Otherwise you could never achieve what we want to achieve.

ASPATURIAN: What was your family's reaction? You were going far, far away.

ZEWAIL: Well, actually, in this case, yes, my mother cried.

ASPATURIAN: I'm sure.

ZEWAIL: Cried and cried and cried.

ASPATURIAN: It must have been very bittersweet for her. You'd achieved everything she'd ever hoped for, but now you were leaving.

ZEWAIL: Right, exactly. Now, I don't know if this is true, but she always said that throughout my life I never gave her any problem.

ASPATURIAN: Maybe. It wasn't her car you almost drove into the Nile.

ZEWAIL: [Laughter] No. I think the reason for this is because I was always focusing on my own interests and therefore I never really created problems for her, with either the family or people in the town. As such, she always felt that "Ahmed, the one who was always close to me and never got into any of the mischief that children do, is leaving. And I don't know when he will come back. I don't know *if* he will come back." And so she was always crying. And of course when she came to the airport, I just couldn't handle it because it was so sad.

ASPATURIAN: How about your father and your uncle?

ZEWAIL: The same. The same, actually.

ASPATURIAN: They must have been enormously proud of you.

ZEWAIL: Yes. And I think the reason for the whole family to be in that situation was a feeling that most probably I would not be returning. They knew I was what we call in Egypt an "exceptional student," and they knew how well the United States absorbs such people. I'm sure that if my mother had thought that it's only four years and after that Ahmed is coming back, she would not have reacted the way she did. In other words, she had more perception than I did.

ASPATURIAN: Well, you were very young. At that age, we're very focused on the moment. We don't think ahead a lot. Even when we think we're doing it, we're really not.

ZEWAIL: [Laughter] Exactly.

ASPATURIAN: Speaking of the United States, as a student in Egypt who was very interested in science and the future, do you recall how you felt when President Kennedy announced the U.S. space initiative in 1961 to go to the moon?

ZEWAIL: Of course. Oh, my goodness. I recall it vividly.

ASPATURIAN: "We choose to go to the moon."

ZEWAIL: And we choose to go "not because it's easy."

ASPATURIAN: "But because it is hard."

ZEWAIL: It's hard. That second statement, I appreciated a lot more after years in the United States, but the first one was like music, really like music. You have to remember that when I came here in the late 1960s, in this country, the resources and the interest in fundamental science was huge. It's not what you're seeing these days. The transistor was in the 1950s, the laser in the 1960s. These were scientific revolutions in America, and then Kennedy said, "We're going to the moon." Kennedy, I guess, had electrified everybody. I lived it myself. I lived it in the sense that, as a graduate student in the United States, I saw that in science and technology the sky is the limit. People were getting grants for fundamental science. There weren't restrictions in any way. It was an amazing atmosphere.

ASPATURIAN: You landed on the shores of a golden era in American science.

ZEWAIL: You know, I always say, I'm a lucky man because in Egypt, I got the best of educations. Why? Because when the Nasser revolution occurred in 1952, I was six years old. The post-revolution era benefitted greatly from the distinct and excellent education system that had been established before the revolution. So I was fortunate to be at the interface between the revolution and the Farouk era, which provided very elite, high-quality education but only for some. When the revolution came, it opened that opportunity for all, and I benefited from this. Now if I were to go to college today in Egypt, I wouldn't get what I got fifty years ago, because Cairo University now enrolls 250,000 people.

ASPATURIAN: It's a city.

ZEWAIL: Exactly. You cannot offer quality education this way. So I was lucky there. And then lucky again when I came to the United States, because in the 1960s, as I say, the sky was the limit. It was an incredible time, actually, when I was hired at Caltech. We'll get to that.

ASPATURIAN: So much of life is timing.

ZEWAIL: Exactly. It's being in the right time at the right place.

ASPATURIAN: As Woody Allen says, just showing up—ninety percent of life is just showing up. On that note, let's end this session. [Actual quote: "Eighty percent of life is showing up." *–Ed.*]

ZEWAIL: Okay. [Laughter] With Woody Allen. That's good.

ASPATURIAN: With Woody Allen. Why not?

Some of the material in this session was originally recorded during Session Two.

AHMED ZEWAIL

SESSION 2

June 23, 2015

ASPATURIAN: Just before I turned on the recorder today, you were making a couple of observations about the religion of your youth, if you'd like to recapitulate.

ZEWAIL: Yes. We spoke last time about the mosque and the role of the mosque in our lives in Egypt at the time I was growing up, and the fact that the *imam* would come and bless what we were doing as a mentor or a teacher. I just want to point out that this world of conflict between, for example, religion and science, I don't recall at all. It obviously became much more of an issue after 9/11 [September 11, 2001, Al Qaeda attacks in the United States] especially. But really at the time I came to the U.S, this idea of conflict between science and religion and between civilizations and things like that—there was nothing like this.

ASPATURIAN: It was pretty alien to your experience.

ZEWAIL: Either I was insulating myself from the society, or I just didn't hear it.

ASPATURIAN: It may also be the suburbs of Alexandria, where I assume the environment was rather tolerant?

ZEWAIL: But, you know, I made friends at Alexandria University from all over the country. There was always—you know the first word in the *Quran*?

ASPATURIAN: "Read."

ZEWAIL: "Read." And so people really valued knowledge, and I think that goes with having the ancient civilization. The Jewish people have a similar thing. You know—knowledge, knowledge. You have to learn; you have to learn. You have to go to school.

You have to achieve. At Alexandria University I was with so many people from everywhere—from the delta, from the south, from the north.

ASPATURIAN: This type of thinking about science and religion being in conflict never surfaced?

ZEWAIL: It just never—in fact, if anything, it was the idea that religion was pushing us to achieve at the highest level. That is what I knew at the time.

ASPATURIAN: I recall when we talked about this a few years ago, you said that the word *jihad* had a completely different meaning in your environment and in your youth. It meant "to strive."

ZEWAIL: I recall, in fact, one of the articles I wrote about this issue after a lecture I gave in Paris at UNESCO, in which I said that the word *jihad* is derived from *ijtihad*, which means "to achieve your best." There is a connotation of "jihad" in the sense that if you are oppressed or if you are in a war, for instance, then you have to do your best.

ASPATURIAN: Yes. But that was not the dominant interpretation?

ZEWAIL: No, no, no. In fact, it was a word that was used in the society everywhere. "Ahmed, *ijtihad*—go to Alexandria University."

ASPATURIAN: "Go up."

ZEWAIL: "Go up" and try to achieve.

ASPATURIAN: To raise the question I asked before we turned this on, we hear so much now about the division between Sunni and Shiite Islam. I believe Egypt is mostly Sunni, but it sounds like this division was not part of your understanding either.

ZEWAIL: I'll tell you something: The biggest mosque in influence—not necessarily in size, but in influence—in Cairo and probably in the whole country is called Al-Hussein Mosque. There is an area of Cairo where they always take tourists—it's called the Al-Hussein district. They show you the old alleys and so forth, and [Naguib] Mahfouz wrote many of his novels about these alleys and the love stories that take place in this district. It is a very attractive area to tourists. This mosque, Al Hussein, is named for Mohammed's grandson Hussein, and the schism that took place early in Islam [seventh century CE] dates back to Hussein's father, 'Ali. So Hussein is a Shia if you consider the way this happened. But when I am growing up, the sectarianism is not there. To this day, when a person like me goes into this district, I don't think of Sunni and Shiite. I remember growing up that there would be religious holidays such as *Ashura*, and my mother would make and serve some special dessert. When would I ask, "What's the occasion?" it would be something to do with the Shia. So, remember, the Shia were in Egypt for a long time, and that's when Al-Hussein Mosque and the like were built. There are so many monuments in Cairo that date from the Shiite era. So we didn't—we didn't even ask the question who is Shia, who is Sunni during my time in Egypt. So, what does this mean? That means that when politics are involved, then you start to ask these questions in order to divide the population at large. Sure, I know that there are political issues between Iran, which is Shiite, and the Sunni Arabs that people are not happy with, but I don't think it is as fundamental as people want to make it.

ASPATURIAN: It's certainly a very heavy tool of propaganda right now—emphasizing these divisions. Speaking of Egyptians with very ancient antecedents, did you have Coptic friends?

ZEWAIL: Oh, tons. [Laughter] Let me give you a story also about this. As I mentioned to you last time, at the University of Alexandria, I was in a group of seven students—the "specials." The real competition in that group was to be the top student because if you are Number 1 in special, you are the top student of your entire class year. Okay. The competition was between myself and a Coptic student by the name of Adel Naguib, and it was my good luck to be the first.

ASPATURIAN: He was also from Alexandria area?

ZEWAIL: From Alexandria. And years later, maybe five years ago, the University of Alexandria decided to give me various honors, including an auditorium in my name. So I went to Alexandria, and, of course, they lined up the faculty. Adel was now on the faculty. We hugged each other, and then he stood up and told a story that I had forgotten about. He said, "I want everybody here"—a thousand people were in the auditorium—"to know that when Ahmed went to America, I was here doing experiments for my PhD in Alexandria University." And he told the story of how he needed some tubes of a special type in order to take spectra and so forth. And so he wrote to me because I was in America, where these tubes are available. I bought these tubes with my own money, put them in a box, and mailed them to Adel in Alexandria. Not thinking that he's a Copt, not thinking that he had been a former competitor. It's just—to me he's an Egyptian and a good guy, and we had had fun together. About ten percent of Egypt's population is Copt. And so you might be living in an apartment building where you got to know tenants who were Copts. We celebrated their feast days—Christmas and things like that—and they would visit us for Eid and Ramadan. I'm not trying to make it ideal—

ASPATURIAN: I can easily believe—

ZEWAIL: —Really, but we lived in peace. One of my best friends today is Sir Magdi Yacoub. He's a top heart surgeon in the United Kingdom, and he's a Copt. You talk about the Shia and the Sunni. Many of the Iraqi people I meet are Sunni married to Shia. It wasn't like this now where everything is sectarian until recently.

ASPATURIAN: At the University of Alexandria, was the educational system modeled on the French or British—

ZEWAIL: More on the British. For example, that "special" thing is British, because you are trying to select the lead students. Even graduating with first class honors, second class honors, and so forth.

ASPATURIAN: When you made the decision to apply to Penn and thought of it as one of your top choices, you mentioned [*Session One*] that you had this young professor who had been there, and that of course he encouraged you. I wondered, did he also bring back American attitudes?

ZEWAIL: Oh, yes, Dr. Yehya El-Tantawy. There were actually three such professors at Alexandria at that time. They all brought us a picture of the American culture. So, for example, we are used to the British system, where the professor comes in, suit and tie and very formal to give the lecture. There is this formality. These three will come, with a tie but in a short-sleeved shirt and with a very free style. They move around as they talk. We learned as university students that this actually is the American style; it's informal. You don't have to have the jacket and so forth. Also they brought the American-style curriculum into the classroom, which was quite important to us. I remember that all three were much more into, shall we say, the advanced world of discoveries. There was a distinct style.

ASPATURIAN: Did they encourage more participation in the classroom also?

ZEWAIL: Yes. And they addressed us by our first names. They will come into the classroom, and say, "Ahmed, what do you think of this or that?" It's a different way—one that we have not seen before.

ASPATURIAN: I see, I see.

ZEWAIL: That's why I personally was attracted to apply to schools in the United States.

ASPATURIAN: I can imagine. Also it occurs to me that with Egypt having had difficulties with the United States during the [John Foster] Dulles [U.S. Secretary of State in the Eisenhower administration] era and the Six Day War, you perhaps had an opinion of the United States that might have been a little ambivalent?

ZEWAIL: Very interesting point. How did I feel about it? It was very strange because it was as if in my mind I made a distinction between politics and science. It's like what I do right now in the world. On one hand, the United States for me in '67 was the nation that was supplying arms and materiel to Israel. The Suez Canal incident actually was favorable because—

ASPATURIAN: Oh, that's right, the U.S. told the British and the French after they invaded that they had to get out.

ZEWAIL: They had to leave. And the Israelis also.

ASPATURIAN: That's right.

ZEWAIL: I think it was the '67 [Arab–Israeli] War and the building of the Aswan Dam. [*See also Session One*] I think withdrawing from the Aswan Dam was one of the biggest mistakes that the United States could have made because they had already invested a lot of money in it. The withdrawal was unnecessary, and the way it was done was humiliating to the Egyptians. So there was a lot of national pride at stake and being shown at the time. But I made a distinction. In 1967, for example, the year I graduated from Alexandria University, we students all went out into the street because the Israeli planes were all over Cairo, and there was a call to shut off all the lights [i.e., implement a citywide blackout at night so that potential targets were less visible –*Ed.*], and we went out to help. But on the other hand, when I was applying for PhD study, it was America that I wanted to go to. So there was a dichotomy there. But in my mind I separated the two somehow. On one side is politics and war is involved, and on the other—"I'm going to go to the United States and gain some science and education and come back to Egypt."

ASPATURIAN: Was there also a sense of "I'm going to go to America and find out *for myself* what thing are like?"

ZEWAIL: No, I didn't really feel that way. I was coming to American with a well-defined mission, namely that I would like to get one of the best PhD degrees possible and learn a

lot more about what's going on scientifically and then come back to Alexandria, because as the top student I had my guaranteed faculty position at the university.

ASPATURIAN: You also got married before you left for the United States.

ZEWAIL: Two days before, I think. [Laughter] One or two days.

ASPATURIAN: Your wife was also a student at the university?

ZEWAIL: Mervat was my student, in fact, because I was what they call a demonstrator at the University of Alexandria.

ASPATURIAN: Also a British term, I believe.

ZEWAIL: Yes. I think so. It's like I'm an instructor helping the professor. So she was in my class, and, you know, I proposed to her—and to her family. I remember going to Cairo the night before and getting married officially and then flying to the U.S.

ASPATURIAN: You accomplished a lot in the space of a week. One of the things that struck me about your arrival in Philadelphia was that you said you couldn't believe how humid it was. I grew up in Pennsylvania, so I identified with that immediately.

ZEWAIL: [Laughter] Boy, it was humid. I think I came in August.

ASPATURIAN: No air conditioning in those days; I remember.

ZEWAIL: But I'll tell you something I still remember that you might laugh at. Before I arrived, of course, the University of Pennsylvania had sent me beautiful brochures. Ancient buildings, statues of Benjamin Franklin, beautiful campus, everything. So I arrive. The two most striking things at the time about America were, first, how easy it was to enter the United States. I was just in a state of shock that the person at customs or immigration has a smile and stamps my paperwork and my wife's in a relatively short

time, and then we enter. You have no idea how this had an effect on me. I told you last time the story of the bureaucracy I had to go through to leave Egypt and all the stamps I needed. So that was the first thing. Unbelievable. Then the university was kind enough to send a car with some people to pick me up.

ASPATURIAN: At the airport? Very nice.

ZEWAIL: At the airport. This was sent by an organization at Penn that also helped with housing and settled you in.

ASPATURIAN: They gave you an orientation?

ZEWAIL: Right. And advance money and things like that. Now keep in mind that my wife and I left Egypt with something like only twenty dollars each, because during this Nasser revolution era there was no hard currency, and you were not allowed to take any hard currency with you. So my first impression was of getting through customs and all of that. But then as we drove in the car out of the airport, I saw two things: First, the humidity was enormous; I couldn't even breathe; and there was no air conditioning in the car. And the second thing was that as we drove on the Schuylkill Expressway we saw a junkyard for cars—and this was not the Philadelphia they told me about. [Laughter] So it was really shocking seeing this until we got to the campus itself. You just couldn't find a nicer and more helpful reception than we had at this point from the American people who were at the desk, trying to accommodate my wife and me and give us an advance of one month's salary so we could move on. Because we didn't have anything, you know. Life was tough, actually. I tell this to my kids all the time. But there were certain things with the Americans—they smile, they are extremely helpful. When I started school at Penn, I would go into, say, a store, and the lady behind the counter would say, "Oh, you have a beautiful accent." I couldn't speak English, so I don't know what kind of accent she's talking about. [Laughter] This really was characteristic of the American people, welcoming the foreigner. That's what I remember.

ASPATURIAN: How did you feel Penn compared to what you had experienced in Alexandria?

ZEWAIL: It was a very different situation, very different. Penn or most American universities now as I know them are real universities, in the sense of offering a broad-based education. I think you Americans don't appreciate this, but to those of us who come from the outside and see this, it's amazing. I see it with my children—the liberal arts education that you get here in the United States was not there in Egypt. In Egypt, as I said last time, when we went into science, that meant science; there was not much else. The science was done excellently, but there weren't the liberal arts courses that connect us to many other activities. Today, I see how my son can go and take a course in Middle Eastern history—or typing. I couldn't type when I came here, and I was amazed that all my American friends could type. Thanks to the computer, I was forced to learn. So, no, it's a different education here in America. Actually it's interesting now; our universities here are trying to get away from liberal arts.

ASPATURIAN: A terrible mistake in my opinion.

ZEWAIL: Isn't it? Among Americans now there is a strong feeling of "Let's focus on STEM, science, technology, engineering, and mathematics, and we don't need these liberal arts."

ASPATURIAN: Ideally, you want both.

ZEWAIL: Yes. The undergraduate life in this country is incredibly rich; really kids are treated very well. When I see undergraduates here at Caltech coming and taking classes from people with Nobel Prizes—in the rest of world, you don't have that. For me, at the graduate level, it was also different. At Penn the facilities were enormous in terms of instruments and the state-of-the-art quality of the libraries and laboratories. At Alexandria, we were trying to put out our best effort with whatever instruments we had, like the ones I described to you. But here, as I said before—the sky is the limit. That was a huge difference.

ASPATURIAN: What efforts did Penn make to help international students like you adjust?

ZEWAIL: Fantastic. There was the International House at Penn. There was a special office for international students to help with things like improving your language skills.

ASPATURIAN: How good was your English when you arrived?

ZEWAIL: [Laughter] I could write and read it.

ASPATURIAN: I imagine so.

ZEWAIL: But spoken English was terrible. I think I mentioned to you some time ago that I used to even confuse "desert" and "dessert." So several times I ordered "deserts." And the great thing about the Americans is that they say, "Oh, oh, you mean desserts." In other words, there was not a look like you would get some places. No, no, no, my English was really weak and poor. But I picked it up quickly.

One of the things I did when I came—and I tell my students now that they should do this too—is that even though I had Egyptian friends and I dropped by the International House occasionally to see what was happening and to associate with people coming from Europe and Africa or wherever, my eye was on the culture that I was in. I did not isolate myself or just remain in a circle of Egyptians, so that after four or five years pass and I say goodbye, it's as if I didn't learn anything about America. I see it with students from some cultures now, that they do that here. They come, they are insulated. No, what I did was to make American friends right away. We would go for pizza; I would get to learn what the culture is about, get into discussions of current events. I recall, for example, the Nixon impeachment hearings, all of that—

ASPATURIAN: 1973–1974.

ZEWAIL: Right. You wouldn't believe this of somebody like me, but I would finish all of the experiments that I'm supposed to do in the laboratory and then I'd come home by two

or three in the afternoon and stay until five or six to listen to the Watergate hearings. I just wanted to know, what is the psyche of this whole thing? So I got into the culture.

ASPATURIAN: Were you the only Egyptian or one of the few Egyptians in the international group, as far as you know?

ZEWAIL: As far as I know, there were maybe half a dozen. One of them actually is very famous; he became the governor of the central bank of Egypt.

ASPATURIAN: Was he at the Wharton School?

ZEWAIL: He was at the Wharton School, and then I think he went to one of the big banks in New York—maybe Citicorp—and stayed here for some time, but then the Egyptian government asked him to come back and become the governor. And he's a very good friend of mine.

ASPATURIAN: I see. You met as students?

ZEWAIL: We met as students. He claimed that I was better than him, but I claim that he was better than me.

ASPATURIAN: Better at making money perhaps.

ZEWAIL: [Laughter] He was much better at making money. There is no doubt about it. There was a pharmacist and also an engineer, and he went back to Egypt and became a full professor at Cairo University. So there were about half a dozen of us.

ASPATURIAN: It sounds like some very, very bright kids, the cream of the crop, came to the American schools. In general, what did the Americans you encountered know about Egypt and the Egyptians? I ask this because when I was growing up—and I was a fairly well-informed teenager—my knowledge of Egypt probably consisted of the Sphinx,

Cleopatra, the Nile River, Nasser, the library at Alexandria, and the Arab-Israeli conflict. That was basically my framework.

ZEWAIL: I couldn't say it better than you.

ASPATURIAN: Yes? That's pretty much it?

ZEWAIL: That's exactly it. But I have to say, there wasn't an image for the Americans about modern Egypt. It's more toward the ancient stuff. They are very much intrigued by the pyramids, the Sphinx.

ASPATURIAN: The ancient civilization aspect?

ZEWAIL: If you are also more educated, then you will think of the Alexandria library and its influence, that's the kind of thing. Unfortunately, the Arab-Israeli conflict was bringing in more questions about modern Egypt. But you summarize it very well.

ASPATURIAN: Did you feel yourself to be kind of an ambassador for your nation in this context?

ZEWAIL: You know I took a direction when I came to Penn. It was 1969, so the war in the Middle East was finished, and I decided that the best way for me to succeed in this country was to focus on achieving at the highest level in science. I didn't want to get into the business of representing a particular point of view. I had opinions, and I could, for example, speak with friends at dinner about these various topics, but there were other people, especially in the Arab student associations, where they have every week a speaker and things could get really heated. I felt, probably already in the first months, that it's all speeches and all talks and there's nothing constructive coming out of it. It's all emotional, you see. I just don't do that, and I tried to avoid it. I thought that my real mission here, as far as being a good Egyptian, was to achieve at the highest possible level that I can. Doing that was a good enough way to be an ambassador, for example.

ASPATURIAN: I think when we talked a couple of years ago, maybe more years than that now, you mentioned that you had two or three host families at Penn. They did Thanksgiving and things like this?

ZEWAIL: Yes. There were two host families. You know, forty years later, four-zero, I still recall how kind and decent they were. The local families would go to the university and look at the names of the foreign students who had just arrived and decide that they would like to host an Egyptian student or a French student, and so forth. So, we had two of them at different times. One was a Jewish family, and when we met them, I felt from the warmth of their reception and the kindness that it's a culture similar to Egypt in many ways. The other one was more striking to me because of the following: The family was living in the suburbs of Philadelphia; I think the Lancaster area. Obviously well-to-do.

ASPATURIAN: The Main Line, I think it's called.

ZEWAIL: Beautiful home, beautiful family—husband, wife, and daughter. The daughter was probably four years old, and I remember that she had a kind of bow—

ASPATURIAN: Bow barrette?

ZEWAIL: Bow barrette. The reason the memory is so striking is that they always liked to meet us on Sunday after going to church, and the girl was always dressed up beautifully. They were our first host family, and at that time we didn't have a car. They would drive in from the church, pick us up and we would go to their home, where we would have cake or tea, the four of us and the little girl. Their interest was in ancient Egypt. We used to have a lot of nice discussions about this. In some of it, I felt like they knew more than I did about the civilization. I appreciated it very much that after going to their own church, they would come to pick us up and afterward, the husband would take us back home. We did this almost every week or every other week. So there were lots of discussions, and I also got to learn a lot more about well-to-do Americans.

ASPATURIAN: Did Robin Hochstrasser, the professor who recruited you into his group, have a reputation for encouraging international students to come to work with him?

ZEWAIL: Yes. Our group, Robin's group, was truly international. There were Indians, Taiwanese, an Egyptian. Also, you know I picked up some words from him, like he always enjoyed the phrase "jolly good." He had a special way of interacting with his group; he was demanding, extremely demanding. He used to have his group meetings on Saturday mornings, and so you know, when Americans are going to parties on Friday, I'm working in the lab. So it was very tough, but Robin—Dr. Hochstrasser—said that we have to do that. But I learned a lot from him. Really, I owe him quite a bit.

ASPATURIAN: How soon did you begin writing papers and so forth in English after your arrival? It must have been almost immediate.

ZEWAIL: It was almost immediate. I remember the first paper was a communication of some research work that he asked me to draft. And so [laughter] Robin was an interesting man. I wrote a draft, but of course I didn't know how to write it at a high level, and he did me a favor. I'll tell you about it. I shared an office with a Dutch post-doc, Douwe Wiersma—we became good friends—and in front of my desk there was a coffeemaker. I used to make coffee for Douwe and myself, and I would also ask Dr. Hochstrasser because he was just next door if he would like a cup. "Oh, jolly good." So I make a third cup and give it to him. When this paper was done he said, "Why don't you make a cup of coffee and let's come to my office and look at it." Great. So I made that and we sat down together, and he looked at it and looked at it. Then he took it and threw it in the garbage can. And he said, "Let me tell you; when you write a paper, a short paper like this, you have to be thinking of this and this and this." Now, maybe, I had the ability beforehand, but certainly he was the catalyst to bring this out in me because today what I hear is that so many of my colleagues in chemistry enjoy my writing.

ASPATURIAN: The clarity, the style?

ZEWAIL: The clarity, the thing in my mind is very clear.

ASPATURIAN: The quality of the thought.

ZEWAIL: The quality—that's a good term that you have. So it's interesting. Maybe he catalyzes this. He brought it out. I think that during my PhD I wrote about twelve papers. I was productive during this time.

ASPATURIAN: With so many international students representing different nations, different faiths, different political systems, how did you cohere as a group? Was there conflict or was there more a sense that everyone was joined together by common research goals? A bit of both? How did that work for you?

ZEWAIL: I would say that we were more coherently—

ASPATURIAN: To use a word that crops up a lot in your life—

ZEWAIL: Right. [Laughter] Coherently interactive, interested in different cultures. I remember a number of parties we would go to where it would be Indian food or Asian food. And then, remember, Philadelphia is very famous for the hoagie.

ASPATURIAN: And the cheesesteak.

ZEWAIL: Right, exactly, and many of us would go out together for these—boy, I wouldn't be able to eat them now because I would gain two pounds instantly.

ASPATURIAN: So you all pretty much got along?

ZEWAIL: Yes. It wasn't all perfect because there was one person there that I felt that—what's the word? It's not racism because I have never felt in my forty years in America that something was being held against me and that I should have a chip on my shoulder—never. In all the committees, all the positions I took here at Caltech, I never felt as if they were dealing with me this or that way because I'm an Egyptian. Quite the contrary. I was doing well. Certainly at Caltech I never felt—"discrimination" is the word. But that

one person at Penn who was extremely conservative, from the Philadelphia suburbs—I don't want to say that he was racist; what I want to say is that he looked at me as an Egyptian.

ASPATURIAN: Was this a professor?

ZEWAIL: A graduate student, a couple of years ahead of me. When I came to the group with Hochstrasser, he felt I would never be able to make a real contribution in a PhD thesis because Egypt was a developing country. He always told me about the F-16 and how the F-16 devastated the Egyptian Air Force [in the Six Day War]. Several times he said to me, "You should really do a thesis, that's okay, and then go back to your country."

ASPATURIAN: How about when you came in at the top of your quantum mechanics class?

ZEWAIL: He didn't appreciate it. It's interesting and maybe ironic, that many, many years later, in San Francisco—he went to work for a company there—I was given a big award and who do I see in the front row? It was John. Then after I received the award, I came down and shook hands with him, and I felt that he was not feeling good about all the past attitude and the remarks that he made.

ASPATURIAN: People evolve, you know.

ZEWAIL: Exactly. Exactly.

ASPATURIAN: Thank goodness, because if they didn't—

ZEWAIL: We would be in trouble. People evolve. He probably appreciated a lot more that I could do it because now he saw that when they were giving me this award, I was speaking English fluently and presenting a big picture and that I'm a professor at Caltech. So he's changed.

ASPATURIAN: So there was this one slightly discordant note. Was he Jewish—did this stem from the Arab-Israeli conflict?

ZEWAIL: No, no. I mean he was pro-Israeli, but I think more importantly he was an extremely conservative fellow. And let me tell you something: I have written many, many papers and op-eds and opinion pieces saying the biggest problem of the world today—people talk about money and food, and I agree with all of that—

ASPATURIAN: —If you don't have it, it's a big problem.

ZEWAIL: Right. But the biggest problem is ignorance. And if we can help the world by the price of an F-16, to gain some knowledge and understand better what goes on, nothing will be equivalent to this in terms of arms, in terms of anything else you can think of. I think in the case of John it was a bit of ignorance. In other words, he's knowledgeable about science and has a PhD and everything that implies, but he's a bit uninformed about other cultures.

ASPATURIAN: His mind was closed to certain things. So we were going to talk about the science. I struck by the description in your memoir of how Professor Hochstrasser proposed a project to you, and you came back a week or two later and said, "I'd really rather do something else." I thought this must have reflected a lot of self-confidence on your part. Was this before or after he threw your paper in the trash?

ZEWAIL: No, before. This was just a couple of weeks after I arrived. My English is still really poor and the question is, what am I going to do for the PhD? And so he was very much interested at that time in studying the electric- and magnetic-field effect on molecules. I recall that he came to me and said, "I think I've got a good proposal for your PhD. What if you were to take a biological molecule like a protein, and then we examine the electric-field effect on it, and in solution?" In solution, this protein would be tumbling all over the place, and he wants to apply an electric field to it and see how this will affect what we call the dipole moment of the molecule. So I said to him politely, "I would like to think about it," and he said, "Sure." So I went and looked into it and

thought about it carefully and realized—and this is interesting because this perspective has lived with me until today—that when the problem is so complex and you're trying to get one result out, you would have to make so many approximations and deductions that at the end, it's not satisfying to somebody like me. Even in the work that we did for the Nobel, you know, I just wanted to be decisive, to sort of nail down certain aspects so we can understand these thoroughly and go on, you see.

ASPATURIAN: Yes.

ZEWAIL: And so I went to see him again, and I said, "Dr. Hochstrasser, it's too complicated for me." He looked at me, shocked. Why shocked? Because he saw, "He's right!" Because here is a guy coming from Egypt, who hadn't yet taken courses in statistical mechanics and quantum mechanics and modern techniques, so he doesn't know all of this. I was just basically relying on insight or intuition when I said I would rather study this small molecule that is rigid in a crystal.

ASPATURIAN: You wanted to tease out real answers?

ZEWAIL: Real answers. And that's what actually I did; I started the research in that direction.

ASPATURIAN: You also mentioned that you had to get used to a whole new approach and environment of working with instrumentation.

ZEWAIL: Right, because in Egypt even as a demonstrator, you buy the instrument, you bring it to the laboratory, and there is a method of how to use the instrument and you use that method to take the data and you work with that data later. But here, I saw that we are devising new techniques.

ASPATURIAN: In effect, on the fly?

ZEWAIL: On the fly! Exactly. New techniques on the fly. So you think of the problem; there's a question being raised; you devise a new way of instrumentally examining the problem. That was a completely different way of looking at it. And a story here is that I was doing the first experiment on this small system that I just described.

ASPATURIAN: What was the molecule?

ZEWAIL: It was the nitrites—a nitrogen-oxygen-oxygen bond—and then benzene, also a very small molecule. I was always enthusiastic about things, and I started one experiment after dinner, at seven o'clock. I was applying a magnetic field where you have to cool the coils with liquid helium, which is at 4.2 kelvins. So I had come back to the lab, and when it was time I started to do the transfer of helium and then to tap the current. All of a sudden, at two in the morning I see that the field is lost and the liquid helium is bubbling out! I'm frightened because the amount of current I had applied is huge, and so—what do I do, what do I do? [Laughter] Remember, I am just starting out in the lab. So, I ran to my desk and found the telephone number of Hochstrasser's home. I called him at two in the morning: "Dr. Hochstrasser, I'm really terribly sorry but—" He didn't know what to do, but he called somebody in the group who knew about this, and that person contacted me and we took it from there. So the instrumentation was quite sophisticated.

ASPATURIAN: What was the title of your PhD thesis, roughly?

ZEWAIL: I think I might have it, Heidi, if you'd like to see it?

ASPATURIAN: Sure.

ZEWAIL: I can get it. [momentary pause] "Optical and Magnetic Resonance Spectra of Triplet Excitons and Localized States in Molecular Crystals."

ASPATURIAN: It sounds to me like you were using spectroscopy to study changing states in these particular crystals?

ZEWAIL: Right, right, and in particular these states in solids, actually. Right. That's what I was doing.

ASPATURIAN: And one of your insights was—and this was the reason you didn't want to start the first project—that an inorganic molecule would be a lot easier to manage?

ZEWAIL: Smaller. The key was the size. It's in here [looking at thesis] in the table of contents. So you see, I did benzene, benzophenone; also 1,4-dibromonaphthalene. These were all really well-defined solids. They don't have the complexity of a biological protein.

ASPATURIAN: If I can make a very rough analogy, it's a little like Seymour Benzer [Boswell Professor of Neuroscience, 1993 Crafoord laureate in biosciences; d. 2007], whose oral history I also did [http://oralhistories.library.caltech.edu/27/], opting to study the genetic basis of behavior beginning with the fruit fly rather than, say, the mouse or the human being.

ZEWAIL: It's exactly the same thing. In the work we did here at Caltech, everybody in the world was going to study the human body, but I told my group, let's get to the fruit fly first. And then beautiful things came out of it.

ASPATURIAN: That will be very interesting to talk about [*Session Four*]. You were at Penn when the Yom Kippur War occurred. Is that right? 1973.

ZEWAIL: Yes, I was.

ASPATURIAN: Do you recall that causing any interest or conversation? Did it affect you, or were you mostly focused on your science?

ZEWAIL: Mostly on science but there was a pride there because the 1967 war was really humiliating. I mean the entire Egyptian Air Force was knocked out in the first hour or so by Israel. In '73 however the Egyptian Armed Forces crossed the Suez Canal and

actually took over the Bar Lev Line [a chain of Israeli fortifications] and reached the eastern part of the canal. So as an Egyptian who had witnessed '67 and was on the streets of Alexandria at the time, when you see something like that, that definitely had an effect on me.

ASPATURIAN: I noticed that when you applied to be a postdoc you applied to several schools on the West Coast and overseas, but nothing in the northeast. Did you just want a change? I thought—Harvard, Columbia, MIT? You didn't want to go to any of those places?

ZEWAIL: Interesting. The only criteria at the time for a postdoc was, What I was interested in? Harvard and Columbia really didn't have that. Because, you see, I was doing this optical and magnetic spectroscopy, and I can't recall that these universities had that. But I was so excited about [University of California] Berkeley and working with this young professor, Charles Harris, whom I finally did decide to go with. And then I also considered the top-notch two institutions in Europe, the University of Stuttgart in Germany and the University of Leiden in Holland.

ASPATURIAN: I imagine your advisor had some input, too, in saying you should look at these places.

ZEWAIL: Yes, we discussed it. I think I applied only to five. I got admitted to all of them, and I decided on Berkeley for a lot of reasons actually.

ASPATURIAN: I know you mentioned that during your time at Penn you took a side trip to New York City. Did you travel to Boston; were you able to get down to D.C.?

ZEWAIL: Yes, New York and D.C. Boston, no, not at the time, but we did go to Canada. We went to Montreal, and also we camped at one of these mountains up north in Canada. There were a number of trips that we did as a group. I also went south one time because we were collaborating with somebody at the University of Virginia and took the train there. West, no, we didn't go. But I'll tell you one thing I loved that now doesn't exist, I

don't think. In America at the time when you traveled by car, as a group for example, in every town and community you find a *fantastic* steakhouse. And we go in; it's a simple meal. You pick up your beef, and I love this Idaho potato, you know the big one.

ASPATURIAN: Slathered with stuff? The sour cream, the butter, the whole thing?

ZEWAIL: Absolutely. Well, at my age at that time. I miss it here actually, to be honest with you, because now to have a steak you have to go to a fancy place, but back then, there were so many of these steakhouses on the East Coast.

ASPATURIAN: I remember those also from my childhood. Anything else you'd like to say before we leave Philadelphia? You got through your PhD pretty quickly.

ZEWAIL: I got my PhD, and I was extremely happy of course to be a doctor of science. Was there anything else in Philadelphia that I want to remember? Philadelphia in those days, by the way, was a bit rough. We lived on the northern side of town, which was not easy until they built what they called the graduate towers, which are centrally located on the campus, and that was beautiful. We took a small apartment there until I finished the PhD. But prior to that, we were on the northern side of the city. It was rough, quite rough. I recall my wife crying several times because people would be drinking on the corner, and I would come home late, working until two or three o'clock in the morning. Life was not easy. But life to me was fantastic. I'm excited about my science, I am doing great things at the frontiers and all of that stuff. But for us as a family, the beginning was rough. Of course, the good news was my first daughter, Maha**.** She was born, and, you know, it was a snowy day—the snow, I remember, was so heavy. I don't have a car, and I have to go to the hospital and so I stopped a policeman, and I said, "This is the situation, what should I do?" So they were kind enough to call for me a car. And Maha was born in the University of Pennsylvania hospital.

ASPATURIAN: An American citizen.

ZEWAIL: An American. And our second child, Amani, all four of them. They have the right to have dual citizenship.

ASPATURIAN: Yes. Any child born here automatically becomes an American citizen. Which is nice, too.

ZEWAIL: It was also evident to me that if you really want to achieve and do well in American society, you have to work, and work hard. When I went back to Egypt at a later time, I encountered the concept that America is a rich country that would provide everything and so on. What I have told them then is this: You have to work, you have to work.

ASPATURIAN: Did you ever think you might want to go back to the Middle East for a postdoc—go back to the region for a year or two at least?

ZEWAIL: Well, all of that thinking occurred when I was in Berkeley.

ASPATURIAN: I see. Then we'll deal with that next time. So, we'll leave you about to board the plane for the West Coast and—

ZEWAIL: A whole new life.

ASPATURIAN: A whole new life. Berkeley in the 1970s.

AHMED ZEWAIL

SESSION 3

June 27, 2015

ASPATURIAN: I want to go back for just a minute to your time in Philadelphia. You talked in the first interview about the good fortune of timing in your education in Egypt. And then at Penn, Professor Hochstrasser was pioneering this new area in laser spectroscopy. Do you think there was an element of good fortune in that too—that you just happened to choose him and to be accepted into study with him?

ZEWAIL: Well, for a number of reasons I feel the star was definitely prominent in the sky for me. First of all, the laser was invented in 1960, and Professor Hochstrasser was trying something extremely difficult in those days—to get the laser to operate in what we call the picosecond domain, a millionth of a millionth of a second.

ASPATURIAN: That was the fastest speed?

ZEWAIL: That was the fastest because we were moving now from the world of microseconds and even nanoseconds into the picosecond. And there was a feeling that if you reach that time scale, you would be able to study processes that are not just fast but faster than anything we had seen before. And so he was trying hard, and I recall very well as his graduate student that there was also was some pioneering work in this area by Peter Rentzepis at Bell Labs. Professor Ken [Kenneth B.] Eisenthal was also working on this at Columbia. All of them were doing very interesting work in that area. For some reason, as a graduate student, I felt it was not there yet for me to be working in that field, and that I would rather work at the frontiers of spectroscopy, on solids and materials and the like. What I did when I came to Berkeley was picosecond work, and then, when I came to Caltech, of course, we did the femto. So it is amazing that even though I was watching this happening at Penn, I was also of the opinion that the technology was not there yet, and that the signal is not robust and prominent, except in few cases. So I did

the spectroscopy research at Penn, but it was also fantastic to be in a group where you could see this other development going on.

ASPATURIAN: So, let's talk about your arrival in Berkeley, California, with your wife and child.

ZEWAIL: I arrive at Berkeley, and I see pretty quickly three major changes in my life or forces that can affect my life. One is scientific, one is cultural, and the third is political. Penn definitely provided a shift in my scientific thinking, and that helped me a lot to think about future ideas. But, scientifically, Penn was what I would call the small-science environment, centering on the individual professor who is working with his own group. The equipment is not necessarily huge; it is generally modest and so on. On my arrival at Berkeley, I see something like the Lawrence Berkeley Laboratory up on the hill, with huge facilities and its history of discovering new elements. To me, that was big science and how to do big science. The thinking is just different, and I felt the faculty is running around as if each one will get the Nobel Prize. There is a force, there is a pride that they want to achieve the best in the world.

Then there were the cultural differences. Philadelphia, and where we were living, was a quieter transition, or a simpler transition, for a person coming from Egypt into more or less a conservative society. I mentioned to you some of my host families and how wonderful they were in the way they received us. I never heard them saying, for example, foul language. Never.

ASPATURIAN: It was a genteel environment.

ZEWAIL: It was a genteel environment, and I could readjust. But the transition from Philadelphia to Berkeley was huge.

ASPATURIAN: Did you have an inkling of what it was going to be like?

ZEWAIL: No, no. All I know is that people say Berkeley is liberal. But I don't know the magnitude. I arrive there, graduate students every second are "swinging," you know.

[Laughter] It's a very loose environment, but *bright*. These are *bright* students and postdocs. I recall once doing an experiment late at night, almost 2:00 am or 3:00 am, soon after I arrived. While I was working, a graduate student by the name of Mark streaked down the hall. Now, neither in Egypt nor in Philadelphia—I even did not know the word! What is "a streaking"? I know streaking in a formal way, but I don't know streaking in the human way. That he would be naked and just be racing past my laboratory.

ASPATURIAN: Why was he doing this?

ZEWAIL: There was no particular thing. It's just to "scare" me. For him, it's natural, it's fun. For me, it made me ponder: Why would a graduate student do this? At first I was alarmed because I was alone in the building on the third floor. So with things like that, it was not easy to readjust quickly. And I never totally readjusted—I never streaked for example. [Laughter] But then, of course, I had the chance, with my wife, to go and see Berkeley. Telegraph Avenue, lots of hippies on the street. It's a very different environment from anything I had ever seen. So that transition was big, culturally.

The third aspect was clearly the political. For example, I was at Penn when Nasser died, and of course Nasser was a major presence in our lives, so when I heard the news I wore a black tie for the day out of respect. Many, many students came to offer condolences, saying, "We know that he was important for Egypt, and now things will change," and so on. So they were very, very nice in this regard. Professor Hochstrasser himself understood that and respected the feelings. At Berkeley, there was hot debate because some of the postdocs and students were extremely liberal in their views and also pro-Israel, and so—you know how sometimes, emotions could create collisions about their feelings and my feelings, but you will be amazed that these people now are good friends of mine.

ASPATURIAN: No, not amazed.

ZEWAIL: There was a professor there, Alex [Alexander] Pines, who's now a good friend and when we talked about this, we also talked about the Enlightenment in the seventeenth

and eighteenth century. You want to try to reason, to have understanding. I feel a certain way, you feel a certain way, but we can try to see the different points of view. There was also a postdoc there who's now a professor at Stanford; we communicate and we talk with each other, so reason has taken over.

ASPATURIAN: Did science function as common ground in all this?

ZEWAIL: Yes, I think science, and—what we'll come to later, what I call science diplomacy.

ASPATURIAN: Yes, we've talked about this in the past.

ZEWAIL: In other words, in this case science was really the mediator or the catalyst.

ASPATURIAN: Did you feel that you learned something and that they learned something from these dialogues?

ZEWAIL: Oh, yes, definitely. And there was a genuine interest to see how this Egyptian feels about these political issues, and about his science. I wanted to know what they were doing also. In fact, one of the interesting experiments we did at Caltech built on what Alex Pines has done scientifically. And he is very charming, very bright. So at Berkeley we used to discuss science because his science was impacting mine and Harris's. Science here was mediating our differing political views.

So Berkeley really was an eye-opener in every respect, scientific, culturally and politically.

ASPATURIAN: One of the things that occurred to me thinking about this interview is that at Berkeley at this time, you had this very anarchic spirit but this very sophisticated research focus. There must have been an interesting tension there.

ZEWAIL: It was stimulating, very stimulating. Because another unique thing about Berkeley is that it really is a top institution. When I talk to you about the graduate students and postdocs, these are the cream of the crop.

ASPATURIAN: Yes. So this was your first exposure to big science. How did that manifest itself for you?

ZEWAIL: It manifested itself in the sense that when I was trying to design experiments at Caltech, after two years of a Berkeley postdoc and fellowship, I was not scared, I was not fearful. I felt I had been in the big leagues and so I was not fearful in any way. Not intimidated by how complicated the lasers, how complicated the ideas. At Berkeley we wrote a series of papers, myself and Chuck—Charles—Harris. I even wrote a paper by myself, single author. So when I got to Caltech, I wasn't intimidated by the complexity of experiments or thinking in a big way about theory. Charles Harris also played a role in that. Even in the environment of Berkeley, if he himself had had a small-science mentality, of course I wouldn't have been able to do what I did. But he was always asking big questions—big questions beyond chemistry, actually, and going into physics. The papers I wrote with him were published in physics journals. You see, even though I was in the chemistry department I was branching out already.

ASPATURIAN: How did you come to choose him or he to choose you?

ZEWAIL: He made me an offer before I went to Berkeley. When I was finishing up at Penn, I applied as I mentioned [*Session Two*] to five places, and one of them was to work with Charles. They all made me an offer, but when I looked at the work that he was doing and the institution itself, comparing it with the others, I said to myself, "this is the place," and that's how I went. The choice was mine in the end.

ASPATURIAN: I looked him up; he had a very interesting pre-Berkeley career. Apparently he deliberately flunked out of Cornell, out of boredom—did you know this story? He knocked around for a few years, wound up at Stanford, where he was an outstanding student. He had a very interesting life.

ZEWAIL: No, he went to MIT.

ASPATURIAN: It was MIT. That's right.

ZEWAIL: Charles is creative. I have no doubt that he was a good student. He epitomized Berkeley in the same way that Robin Hochstrasser represented Penn. Robin was a traditional, conservative professor—the big prof. Charles is liberal minded, going his own way in all directions. Even today, all of a sudden he will get interested in equations of the universe and spend a couple of years on that.

ASPATURIAN: So you continued your laser work with him. What research were the two of you doing?

ZEWAIL: What we were interested in by the time I went to Berkeley—and this is the onset of research that has lived with me until today—was a major concept that was really foreign to chemists. The concept of coherence. Normally, when we have a glass of water and the molecules of water are going around, they are moving incoherently. No one molecule knows about what we call the signature, if you like, of the other molecules. They are *uncorrelated*. So, for example, one water molecule can move to the left, another one can move to the right. Now if these motions were coherent, if one goes to the left, the other must go to the left.

ASPATURIAN: They would move in lockstep.

ZEWAIL: In unison. That concept, I was thinking about it from the day I left Penn.

ASPATURIAN: Why?

ZEWAIL: Maybe I should mention, that when I came from Egypt, I didn't want to take my courses only in chemistry, so at Penn I was also taking courses with famous people in physics—Bob [J. Robert] Schrieffer, for example, who received a Nobel Prize for superconductivity. In fact, it is this correlation of electrons that causes the

superconductivity. I took a class with him, and I was very much interested. So I was listening, reading; it's my own interest to find it really fascinating.

ASPATURIAN: You were already doing some synergistic thinking—I see.

ZEWAIL: Yes. And really it was also part of my interest in working with Charles Harris, because he was interested in the coherence, but of a different type—coherence of what he called solids, solid materials. Most of the studies I did with Charles used MRI—magnetic resonance. So when I worked with him, we did experiments that utilized some of the coherence concepts in solids that he was known for, and that gave me a lot of push toward thinking about how you would create and study this with laser beams, where you're going to optical frequencies that are very, very high. And when I was ready to apply for faculty jobs, I told the hiring committees that what I wanted to do was not magnetic resonance coherence but optical coherence. I had some ideas about doing it on specific systems to learn how this unison that I was talking about works.

ASPATURIAN: Specific molecular systems?

ZEWAIL: Specific molecular systems that will allow you, if you can be successful in this, to obtain something extremely important. For example, if you take two molecules of water, I wanted to determine experimentally how fast it will take, say, this molecule A to get out of phase with molecule B and become incoherent. So that is fundamental information I am getting.

ASPATURIAN: Were you the first researcher to think of taking this principle and applying it to a chemical environment?

ZEWAIL: Yes. I would say for the systems really, truly of chemical and biological impact at the time, yes, I was.

ASPATURIAN: You were interested—

ZEWAIL: —Early on. Because we're talking here about 1976. Other physicists were doing many things with lasers, but when I arrived at Caltech—and we'll come to this later—then this concept just blossomed in a variety of directions until it reached the limits by which we can see atoms in motion. And that's the Nobel research. So there was a clear progression, but the concept was always there. That's why Doug [Douglas L.] Smith [in the Caltech Office of Public Relations] wrote this article, which I really enjoyed, called "Coherent Thinking" [*Engineering and Science,* Vol. LXIII, 1994, No. 4; http://calteches.library.caltech.edu/3990/]. That is the progression that went with me. And, in fact, at the end of those two years at Berkeley, I was thinking about going back to the Middle East, obviously including going back to Egypt because as the top student, I already have a guaranteed faculty position there.

ASPATURIAN: That's right, they kept it open for you.

ZEWAIL: Kept it open for me as a young professor. And it was Charles who told me that this really would be a mistake. And I said, "Why?" And he said, "Have you seen the rest of the United States?" I said no. I give him credit for this. He said, "You really should be applying only to the top universities."

ASPATURIAN: He understood that the nature of the work you were doing could not be successfully pursued in Egypt.

ZEWAIL: Exactly. That is what I think he was thinking too. So he was the one. He said, "Look, go for interviews. See what's going to happen. You will see different things. And then at the end, if you don't want to stay here and decide to go back, that's fine."

ASPATURIAN: You do mention in your autobiography that at this time you took a trip to Iraq. Apparently they were courting you?

ZEWAIL: Yes.

ASPATURIAN: What was that like? What happened?

ZEWAIL: Iraq was building in a massive way, so I got an invitation for me, my wife, and my daughter to visit there. So, you know, it was curious—well, not exactly curious but very comfortable. Inviting us, flying us first class, as I remember; telling us we can stop in Beirut, we can do this and that. So by the time we arrived in Baghdad, it really was unbelievable. Staying at very nice hotels, cars and chauffeurs coming to pick us up.

ASPATURIAN: The red carpet treatment.

ZEWAIL: The red carpet treatment. And I met Saddam Hussein. He was the country's vice president, I think, at the time. Extremely interested in science and technology. He wanted to build this and that, to be unique in the Middle East that way. They don't know of course the details of what I do, but when they heard I'm at Berkeley and that I work with lasers—and lasers were very important at that time for advanced technology—he made me an offer, and it was a red carpet offer. But I felt that that's not for me. I felt that even with the title of director—

ASPATURIAN: You would not have the intellectual freedom?

ZEWAIL: Intellectual freedom, and I may want to work in an area that is not of interest to them. So I decided not to accept.

ASPATURIAN: When you say that Hussein was interested in science and technology, did you feel that this was a personal interest or that he was representing the views of the regime as a whole?

ZEWAIL: You know I don't think it was just the regime because it persisted with him until he died. I remember going to a meeting in in Amman, Jordan—Dema was with me—and we sat there and we heard talks by scientists from Iraq, Syria, and other countries in the Middle East. By far the best talk on the level of world-class science—of course, Israel was not there—was from Iraq. There was no doubt that they were building up for it. Now, the world saw this as a buildup to successfully separate uranium to develop a bomb, all that stuff, but the base they were building was a scientific base.

And then I came back to Berkeley. And then, as I said, Charles had asked me to apply in the United States, and I do, to Harvard and Chicago and Caltech.

ASPATURIAN: In your memoir, you say that you applied to Caltech and a few other places two years in a row—the first year not very seriously, and then a second time. Am I correct in that?

ZEWAIL: I think this is true, and I'm trying to remember.

ASPATURIAN: Did you come to Caltech for the first series of applications?

ZEWAIL: I came to Caltech, and there is something that I have to tell you about that that you will enjoy. I come to Caltech and give a talk; it was during a tour of several institutions—Harvard was one of the others. And giving the talk—they tell me now that I had a style—I told them that I was working, or proposing to work on, as I recall, coherence and that actually this work was based on a theory developed by Feynman–Vernon–Hellwarth [Richard P. Feynman, Robert W. Hellwarth, and Frank L. Vernon, Jr.]. Vernon and Hellwarth were either grad students or postdocs at the time. In fact, I talked to Feynman [Tolman Professor of Theoretical Physics, 1965 Nobel laureate in physics, d. 1988] about that theory when I became a faculty member. In our business of the lasers it was called the FVH Theory. So I went to the blackboard while giving my talk, and when I said the name "Feynman" I tried to write it on the board, and all of a sudden there's a blank. I couldn't spell Feynman! I looked into my audience, and I said, "Of course, you all know how to spell Feynman." And they all laughed. Of course, I wasn't making a joke; I suddenly didn't know it. But then, Caltech was slow to respond to my application—it was one of the slowest, if not the slowest.

ASPATURIAN: You had gone to all of these schools. Harvard, and you mentioned Princeton, I think?

ZEWAIL: I went to Harvard; well, maybe Princeton was in the first round. There was a hostile interview at Princeton. But Harvard, Chicago, Rice, Northwestern, Illinois, and

maybe one or two others all made me an offer, except Caltech. But I got sort of a vibration or impression from one professor who later became my friend, now my dear friend, Vince [Vincent B.] McKoy [professor of theoretical chemistry, emeritus]. I got the impression from Vince—of course he was Professor McKoy to me at the time—that I would be the choice. So I'm waiting for Caltech to respond, and I already have these other offers. So I called.

ASPATURIAN: You called him?

ZEWAIL: No, I called the chairman of the search committee. And I'll say this for the sake of history: I called the chairman.

ASPATURIAN: And who was that?

ZEWAIL: Professor Aron Kuppermann [professor of chemical physics, emeritus, d. 2011]. He's dead now. I called him and I said, "You know, I'm considering this and that." He said—he's a very nice guy— "Well, you're a fine candidate, but I think if you're in a hurry, you should go ahead and accept another offer."

ASPATURIAN: What was his field?

ZEWAIL: Chemical physics.

ASPATURIAN: Same as yours.

ZEWAIL: Same as mine. But I didn't understand this because, again, it did not make sense to me given what I knew from Vince and given that the Caltech audience at my lecture had seemed excited about my work. It was a vibe. So I called Professor McCoy, and exactly what I said was, "I'm going to accept another offer, but before I accept I thought of contacting you because I got the impression that I was someone that you are seriously considering. I just spoke to Professor Kuppermann—" and I told him my conversation with Kuppermann.

ASPATURIAN: Did Caltech know you had these other offers before you called Vince McKoy and basically said, "I'm going to Harvard or Chicago"?

ZEWAIL: They had known for sure I was interviewing at these places. But this was the first time they now were put on the spot. Who was the chairman of what we still call the staffing [i.e., the recruiting/hiring] committee? It was Harry Gray, Professor Gray! [Beckman Professor of Chemistry] McCoy called Gray and said, "I just got this phone call; I don't understand what is going on there."

ASPATURIAN: What's holding things up?

ZEWAIL: What's holding things up. So Harry went—you know Harry.

ASPATURIAN: I do.

ZEWAIL: "That cannot be the case!" Then he called the division chairman, who at that time was John Baldeschwieler [Johnson Professor and Professor of Chemistry, emeritus]. And then Harry called me, and he said, "Please, *please* don't accept anything. I know that you got offers from Harvard and Chicago, but we want you to visit again. You are the best! You are the king!" You know Harry. Fantastic in terms of the spirit. And so, that's when I came back with my wife and my kid. Boy it was a red carpet. They put us in the Hilton, I remember.

ASPATURIAN: Where had you stayed when you came by yourself? In the Ath [the Athenaeum, the Caltech faculty club]?

ZEWAIL: In the Ath. [Laughter]

ASPATURIAN: Of course.

ZEWAIL: And Vince always reminds me [laughter] that I had a free account to order anything I wanted, so of course I invited the faculty to talk with them, and I think I had

dinner once with Vince and once with Harry, I can't remember. But apparently the account was well utilized. I remember very well that when we arrived the secretary of John Baldeschwieler saw to it that there was a babysitter for my daughter, Maha, and I remember that we had a lovely dinner at the Chronicle Restaurant with many faculty members. They were all trying to say you are one of us and we want you, you see. They made me an offer that was very good. And quite frankly I made a table [i.e., wrote out a tabulation] of the offers from five universities.

ASPATURIAN: In fact I took a picture of it [the table is reproduced in *Voyage Through Time*]. I have it in my phone in case we want to refer to it during the discussion.

ZEWAIL: [Laughter] I think Caltech scored 93 or something.

ASPATURIAN: I noticed that on the tenure metric you gave Harvard a 3.

ZEWAIL: Of course.

ASPATURIAN: And that is because they're notorious for cutting their assistant professors loose.

ZEWAIL: They were at the time notorious for that kind of thing, and actually in my opinion, it didn't help them. Caltech was making me feel that you are one of us, and we wish you the very best. So in the end, I accepted Caltech, and I have never regretted my decision. I have been fortunate since that time to receive numerous offers, but it always comes back to feeling that Caltech was—is—my home.

ASPATURIAN: Was there any sense for you that Caltech in some ways combined the best of Penn and Berkeley?

ZEWAIL: Yes, in a way. What was really most important—I had this insight or intuition that for me it was Caltech. When I visited Harvard, Professor E. Bright Wilson, who is a very well-known person, took me around. He's a gentleman. He was, I think, either a

student or a postdoc of [Linus] Pauling [Nobel laureate in chemistry, 1954; Nobel laureate, peace, 1962; d. 1994]. So he's a Caltech person. Chicago was fantastic as a school, but the environment was not necessarily what I wanted**.** What I really loved about Caltech is it's small, it's focused, and I saw how everything—at that time—was done with class. As an institution, it was small, focused, and classy.

ASPATURIAN: And the reach was enormous.

ZEWAIL: Enormous. You know how Richard Feynman was once recruited by the University of Chicago, which offered to double his salary or something like that. He was asked, "Why wouldn't you leave Caltech and take this offer?" and I think—to paraphrase—he said, "At Caltech, if I moved a meter or two, I would be in collision with somebody who will excite my interest."

I could see what he meant when, for example, I saw how interactive faculty are when they talk with each other, and I loved the classy way I saw the Institute doing things. Small things. To arrange for us to have a babysitter when we arrived—it was remarkable. Most schools would not do something like that. Small stuff, but I really thought it meant a lot. I also saw the *oomph* of science, the power of science that exists here, even though the Institute is very small.

ASPATURIAN: Had you had any interactions as a postdoc with the Caltech chemistry faculty before you came to campus?

ZEWAIL: Not really. Not really.

ASPATURIAN: So your awareness was solely by reputation.

ZEWAIL: Solely by reputation. And the kindness when I visited. I'll give you another example that I saw when I gave my guest lecture. They made a schedule for me, two solid days of meetings with essentially all the faculty in chemistry and chemical engineering. By the time I was going to give my lecture at four in the afternoon, I was extremely exhausted. So at 3:30 I was supposed to visit with Professor Peter Dervan

[Bren Professor of Chemistry]. I go to Peter's office, and what does he do? I found a glass of water and two aspirin.

ASPATURIAN: He understood.

ZEWAIL: He understood because he had been interviewed about two years before that. Where else would you find something like this? And Peter has become one of my very best friends on the campus in all the years I've been here. He's a brilliant scientist in his own area, and yet he's a wonderful human being and colleague. Caltech just had the upper hand.

There was one thing that you might call a negative, but for me it was positive, I must say. Chemical physics at Caltech had a tradition with people like Pauling; Pauling was a giant. And then Wilse Robinson, who was really a king in his own area. Another was Harden McConnell, who was absolutely a giant in his field. There was a tradition of this. But when I got the offer from Caltech, Harden McConnell was no longer here; he had gone to Stanford. Pauling is not here. Wilse Robinson decided to go to Texas. And so experimental chemical physics at Caltech was somewhat weak compared to, say, Chicago and other places.

ASPATURIAN: You saw that as a challenge rather than an obstacle?

ZEWAIL: I saw it as a challenge. Exactly. Somebody else might have said, "You know, it's a dry land and I need to be able interact with the people who will decide on my tenure" and things like that, but I saw this situation as a challenge and an opportunity in the sense that I could, if I do well, maybe follow in the footsteps of some of these people.

ASPATURIAN: So you came to Caltech from Berkeley in what year?

ZEWAIL: 1976. I think I came in May.

ASPATURIAN: You came just before the start of the summer break.

ZEWAIL: Because I was eager and in fact I ordered equipment while I was at Berkeley, and I already had two graduate students.

ASPATURIAN: You took two graduate students with you?

ZEWAIL: No, from Caltech. When I gave my talk at Caltech [during the recruitment phase], these two students came to me and said, "We are first-year grad students, interested in your work, and we would like to—" They were actually here, and so I'm ordering equipment with them and getting ready for the first experiment.

ASPATURIAN: We touched on this a little as you describe what led you to decide to come to Caltech, but that was nearly forty years ago. What was the Caltech environment like at that time?

ZEWAIL: The Caltech environment, you mean in terms of—

ASPATURIAN: Campus culture.

ZEWAIL: I have to tell you that for the sake of history this should also be recorded here—my ideas on the system at the time. Ed [Edward M.] Stolper [Leonhard Professor of Geology, Caltech provost, 2007–2017; interim president, 2013–14] and I sometimes have lunch together because we are good friends, and we talk about the "Techers"—the people who really understood what Caltech is about—and I believe people like Ed and myself are in this class. We understood what Caltech is about. As an assistant professor, I could take the telephone and call the president of Caltech. I can take the telephone and call the Benefits Office, and I will get Jessica on the phone, and she will say, "Oh, hello, Dr. Zewail, how are you doing?" And I am nobody. And "How can we help you?" She either will come to my office, or I will go to her office, and the problem is handled for me in ten minutes. I still recall today, forty years later, the man who was handling grants by the name of Al [Allan J.] Lindstrom [administrator of sponsored research].

ASPATURIAN: I remember that name.

ZEWAIL: Al Lindstrom and his one assistant—Mary, I think, was the name. I will get something from NSF [National Science Foundation]; I don't understand it and all of that stuff, and I call Al. "Oh, hi, Ahmed," he will say, and "Ahmed, don't worry about it, we'll take care of it." Okay. I did one experiment immediately after I came down from Berkeley, and Bill Schokey, who used to be in the machine shop, was so excited to see a faculty member like this young guy full of enthusiasm that he would come in on Saturdays to help me. So this is the atmosphere of Caltech forty years ago. It's remarkable. The other thing is that they instilled in me some concepts about what you might call the "Techers"—first of all the family style of interaction at Caltech. Faculty, administration, and staff. Our staff was part of our family. We are not in corporate America.

ASPATURIAN: Yes.

ZEWAIL: I'm giving you the atmosphere. We're not in corporate America, right? Then, the excellence. We were after excellence. We are not going to recruit somebody unless they are really tops. Third, we cannot do everything. So whatever we are going to pick up has to be something that is world-class and that we are unique for. If you look in the division of geology and planetary science, you'll see that. The great, outstanding people. If you look at astronomy, you will see that. You mention a name like Jesse Greenstein [DuBridge Professor of Astrophysics, emeritus, d. 2002], and everybody knows who this is; in engineering, you mention a name like Carver Mead [Moore Professor of Applied Science and Engineering, emeritus]. We cannot do everything, but the world outside knows that this place in Pasadena is so unique. I once had a Russian visitor when I was an assistant professor**,** who became a good friend. When he came to Caltech, he couldn't believe it. He told me, "I expected that this campus would be a whole city."

ASPATURIAN: On the basis of the accomplishments.

ZEWAIL: Accomplishments and the names. So there were some unique ingredients and more than anything, the atmosphere. Bureaucracy was not there—

ASPATURIAN: It was a very transparent organization for many years.

ZEWAIL: Exactly. Bureaucracy was not part of our landscape at that time—or our culture, shall we say. This is the Caltech that I spoke about when I got the Nobel Prize. This is the Caltech where, when we were doing our research and my tenure committee sent out for letters about it—you know, they solicited fifteen, sixteen letters—and the world was telling them that you have somebody doing something important, I got tenure in less than two years, although officially it was two years. In other words, they valued what I did. They gave me the opportunity, and they valued our accomplishments. This is Caltech.

ASPATURIAN: What were your initial research initiatives when you started at Caltech?

ZEWAIL: Again, it was the concept of coherence, and the question was, how would you do it with optical lasers?

ASPATURIAN: How would you study it, or how would you induce it?

ZEWAIL: How do you induce it and then observe it.

ASPATURIAN: I see.

ZEWAIL: Because with this earlier example I give to you, it's not clear how fast the molecules will lose the coordination between one another or how fast each one will move independently after that.

ASPATURIAN: You wanted to see how the molecules go from order to chaos in some sense?

ZEWAIL: Basically! From an ordered state into a chaotic state. Of course I have a background in mathematics from the days in Egypt. I had love for physics. So through this I was really bringing physics concepts and techniques into chemistry, and later

biology. And so the idea itself was crystal clear to me: If I can get a laser and use some modified techniques—which we did develop at Caltech—we could measure this phenomenon, observe this in real time—in real time! At the time the only way to deduce these properties of molecules and materials was from indirect methods. All indirect. So my question was, how can we do this?

ASPATURIAN: This was your thinking as you arrived at Caltech?

ZEWAIL: Oh, yes. In fact, it was in the proposal I made for Caltech when I applied for a job. Now, luckily, I had a Caltech physics undergraduate working with me. And that's another thing I want to emphasize to you; and it should be in headlines when we talk about Ahmed Zewail's life, not necessarily in diplomacy, but certainly in science: A–I had the best brains surrounding me; B–it sometimes intimidated me, walking around campus and seeing Feynman and [Murray] Gell-Mann [Millikan Professor of Theoretical Physics, emeritus; Nobel laureate in physics, 1969] and [Max] Delbruck [Board of Trustees Professor of Biology, emeritus; Nobel laureate in physiology or medicine, 1969; d. 1981], and others like them; and C–I attracted to my group the best brains—and maybe this is a bit of credit for me that I knew how to get them excited.

ASPATURIAN: You knew how to motivate them and inspire them.

ZEWAIL: How to motivate them and then inspire them to tackle very difficult problems. This really was evident when I got the Nobel, and some of my former students called and left messages saying, "We remember one day coming to your office and being charged with excitement," and this and this and that. So it's not Ahmed Zewail; it's Ahmed Zewail and company. That really should be emphasized. And so I had this physics undergrad.

ASPATURIAN: And his name?

ZEWAIL: Kevin Jones. Brilliant. Brilliant.

ASPATURIAN: Physics, not chemistry.

ZEWAIL: Physics. And I had a graduate student for this coherence research I'm talking about—Tom [Thomas] Orlowski, who had wonderful hands experimentally.

ASPATURIAN: He was a chemistry student?

ZEWAIL: He was a PhD chemistry student. Of course there were many others. I'm just talking about the nucleus. With Kevin I work on the theory of what I have in mind, and he works on the theory.

ASPATURIAN: This is an undergraduate who's working on the theory?

ZEWAIL: Undergraduate. We published, I forgot now, maybe eight or ten papers, something like that.

ASPATURIAN: How did you find him?

ZEWAIL: Well, he was attracted to me.

ASPATURIAN: He came to you?

ZEWAIL: He came to me. They told him, there's a new guy here.

ASPATURIAN: I should ask how did he find you; you were in chemistry, right?

ZEWAIL: Yes. It's very interesting. It says something about these guys also.

ASPATURIAN: And also about Caltech.

ZEWAIL: Yes. We are small. Collision frequency, high. These are smart people choosing their problems. They know that I am working in this general area. Tom was

going to work or had started to work with Wilse Robinson, but Robinson went to Texas. So he came to me.

ASPATURIAN: You inherited him in a way.

ZEWAIL: Inherited him. And so we started the first of the experiments, and with Kevin I would do theory. I used to go with Kevin—what is the place for hamburgers and everything?

ASPATURIAN: Burger Continental?

ZEWAIL: No, no. This is late at night at the end of Cordova [Cordova Street in Pasadena]. We had hamburgers there at three in the morning after we formulated something, and we are excited and we're talking about it. So here's an undergraduate and here is a professor at Caltech, and we're doing this. Tom Orlowski was unbelievably productive, with talks and simulations, and we published a series of papers. In one of them I may have stretched the interpretation a little bit, but I fixed it. The general theme was really to articulate these ideas about how to map out coherence in molecular and material systems. We succeeded in, I would say, a year and a half.

ASPATURIAN: Which systems were you looking at? Which molecules?

ZEWAIL: Well, for example, there was the specific molecule pentacene—these are five benzene rings next to each other. Anthracene, also, three of these benzene rings and so on. We were looking at materials at low temperatures—solids and gases—and we just mapped things out. We provided new ways of looking at these. But the time resolution—and I want you to know my strategy—of this sort of thing was nanosecond.

ASPATURIAN: Not even a picosecond.

ZEWAIL: Not even a picosecond.

ASPATURIAN: You were trying to establish principle?

ZEWAIL: Principles and the concept. Bravo. But in the lab, facing this, I was setting up one pico- and one femto-laser system.

ASPATURIAN: Femto technology had been developed?

ZEWAIL: It was at the threshold.

Zewail with laser setup in the laboratory, October 1999. Photo by Joseph Umbro

ASPATURIAN: Was it also being worked on at Bell Labs, as well?

ZEWAIL: At Bell Labs and also in a company called Elsevier**,** which I developed very good relations with over the years. In fact, they established a prize in my name nationally.

ASPATURIAN: So it took you a year and a half to demonstrate proof of concept.

ZEWAIL: Proof of concept.

ASPATURIAN: No wonder you got tenure so quick.

ZEWAIL: And so, I'm quite sure if the letters to the tenure committee had been in any way negative, obviously they would not have promoted me but—. As a matter of fact, I'll tell you a funny story. The [chemistry and chemical engineering] division was going to meet on a certain hour in the afternoon to decide on my tenure. I didn't know about it, but that day I went to Burger Continental to have lunch. The owner of Burger Continental—

ASPATURIAN: Gary Hindoyan.

ZEWAIL: He whispered in my ear that today is a big day. I said, "What big day?" [Laughter] He said [drops voice to a whisper] "You will know." So this is Caltech. There must have been somebody who knows that these Burger Continental guys like me very much.

ASPATURIAN: And somehow the news got to Gary Hindoyan before it got to you.

ZEWAIL: Of course, they didn't tell him the results or anything, but that they were going to meet. And so it really was super-exciting. And I like the way you said it; it's demonstrating the principles involved for such phenomena. And in my other lab, the femto lab, I had a postdoc, and I had two graduate students—one of them is at Chicago now—and we were learning and setting up what I believe were the first femtosecond lasers outside Bell Labs. Of course it wasn't a very short femtosecond timescale; it was like 400 femtoseconds because that was the technology. And I wanted to be moving with the technology. So I had one laser that can give me about half a picosecond [i.e. the 400 femtosecond laser; 1000 femtoseconds=1 picosecond *–Ed.*], and I had another laser that can give me 50 femtoseconds.

ASPATURIAN: I want to detour for one moment into how your scientific thinking develops. What was it that led you—

ZEWAIL: In that area?

ASPATURIAN: Yes. If you can express it.

ZEWAIL: I'll tell you what people say because it's very hard for me to talk about myself. I believe that the people who are lucky to achieve on a big scale are usually guided by some insight. We don't know how to define it. So, you know, I could have gone and done work on gas-phase chemistry or worked in some area of electronics, for example, but what was very intriguing to me is why molecules behave the way they do.

ASPATURIAN: Had you been asking yourself that question even before it became obvious that the technology might finally make it possible to carry out studies at that level?

ZEWAIL: Well, you may recall the combustion experiment that I did in my bedroom and being intrigued at that age by this transfer notion. [*See Session One*] If you think about Pauling, for example, he was just intrigued to find how the shape of molecules—the structure—affects their properties. Simple question. So the insight I'm trying to tell you about is, how do you distill all of this into one or two simple but perhaps fundamental questions? And then when you succeed in doing that "simple" thing, you'll find that the impact is rather huge. So it's how do you ask the right question. After the Nobel, why would I insist on opening up another whole new area? It's insight, but I have in mind a few fundamental questions, and I'm zooming in.

ASPATURIAN: Do you start from the standpoint of the questions always, or sometimes do you look at the developing technologies and say, ah-ha, that allows me to—

ZEWAIL: You know I have seen people who develop technology, but they don't have problems to tackle with it.

ASPATURIAN: Somebody else decides what the applications are.

ZEWAIL: And unfortunately they don't get the benefits of it. I am of the kind where it's the questions that I'm intrigued with, and I know what to do basically, but then my eye is on technology.

ASPATURIAN: That's what I was getting at.

ZEWAIL: And I can build it, and I can do it. But I don't want to be stuck with the idea of technology because I have seen this with so many people. Look at the beautiful things that Galileo did. Galileo did not invent the lens; Galileo did not invent the telescope, which is mistakenly said in many textbooks. It's wrong. But Galileo knew the power of the telescope and used it in an important problem.

ASPATURIAN: That's right. He trained it on Jupiter.

ZEWAIL: Jupiter. So this is really, at least in my case, what I value. Another example is Pauling, who started by using X-ray diffraction techniques. He was aware of all this when he went to Germany, and when he saw the development of electron diffraction there, he brought it back to Caltech and one of his graduate students built an apparatus similar to the one in Germany; but Pauling had his eyes focused on the question of structures and properties.

ASPATURIAN: At this time, at your early period in Caltech, had you met Pauling?

ZEWAIL: No. I met Pauling later [*Sessions Four and Five*].

ASPATURIAN: We'll get into that. We've just gotten to your tenure; shall we stop now?

ZEWAIL: I think so.

AHMED ZEWAIL

SESSION 4

July 1, 2015

ASPATURIAN: You had mentioned last week that at some point you wanted to talk about the Egyptian singer Umm Kulthum. You talked about her earlier [*Session One*] as a source of inspiration as well as entertainment, and you write about her in your memoir. I was thinking that since the 1980s are kind of your miracle decade, if you want to call it that, this might be a good time to talk about how she affected your thinking. She seems to have had an influence on the way you did your work.

ZEWAIL: Right—for some reason, as I grew up. During that time, the 1950s and 1960s, she was the superstar of the Arab world, not only Egypt.

ASPATURIAN: But she was Egyptian?

ZEWAIL: Oh, yes. From the pure delta of Egypt, actually from a family of farmers. Her story by itself is a fantastic one because nobody thought that she could come from a very small village and make it all the way to Cairo, to be among the top people in her profession, and then to become the number one performer in the Arab world, you see. So on the first Thursday of every month, for the fall, the winter, and spring—she didn't sing concerts in the summer—the entire country, every home in Egypt, will be sitting next to the radio listening to her. Essentially every home will be doing this. Either you go to the live concert in Cairo or you listen on the radio.

ASPATURIAN: Once a month?

ZEWAIL: Once a month. So in the whole year, there will be six or seven concerts. And in every concert, she will have three songs. Usually two are older songs that she sang before, and one is new. And each song will be like an hour or an hour-and-a-half, and of course there is a recess for about half an hour.

ASPATURIAN: An hour-and-a-half devoted to a single song?

ZEWAIL: A single song. And people, the audience, are going with her, very much excited by this, so they ask her to repeat again, and she repeats again.

ASPATURIAN: She must have had a very powerful voice to be able to do this.

ZEWAIL: Very powerful voice. And there's another thing about her that was incredibly unique. Because she came from the village, her father was, what do you call it, a teacher maybe, of the *Quran*, and so she actually memorized the *Quran*. The *Quran* is written in a formal Arabic language and for 1400 years it has not changed. And so her pronunciation of Arabic is so correct.

ASPATURIAN: Classical Arabic.

ZEWAIL: Classical Arabic. It's like having somebody writing or talking again in the language of Shakespeare, for example. It's very formal. Very clear, and also very powerful. And so in some songs, she will sing in classic Arabic. She was incredible. When she died, there were an estimated five million people on the streets of the Arab world; people are weeping. She had a huge impact from Kuwait to even Saudi Arabia. It just was all over the Arab world.

ASPATURIAN: Did her songs tend to have particular themes? I'm sure love, heartbreak.

ZEWAIL: Yes. Exactly, exactly. One part. The other part was Arabic poetry.

ASPATURIAN: Ah.

ZEWAIL: For many, for people who don't even know poetry, when they hear it in formal Arabic, it resonates with them. For me, then, personally, I grew up listening to her, so I got into this habit as a boy of having her songs in the background on my radio while I'm

solving mechanics problems or whatever I was working on. And up to now, in my office here.

ASPATURIAN: She was like your soundtrack.

ZEWAIL: It's a soundtrack, and also it's relaxing. I just acquire some sort of relaxation when I hear her. When I came to the United States and learned more about classical music, her effect on me, it's like Mozart, for example, which I like. I don't necessarily appreciate loud music.

ASPATURIAN: You did not like rock?

ZEWAIL: No.

ASPATURIAN: Not the *Beatles*?

ZEWAIL: No, not really, no. It's wonderful and everything for my children. But my own taste was always on the classical music side. I think the only exception there will be the jazz. I like jazz.

ASPATURIAN: You like the more complicated music.

ZEWAIL: Probably. And I like the softer tone of these. So there can be no doubt that she had a huge influence.

ASPATURIAN: It sounds like she took traditional elements and elements of high culture and put them into a type of popular vernacular.

ZEWAIL: I think that's a good way of saying it. Omar Sharif, you probably know him—

ASPATURIAN: Yes, of course. Not personally, no.

ZEWAIL: He was once asked, why is it that everybody in the Arab world is enchanted by or loves Umm Kulthum. I think his answer was very good. He said it was because she sang to every one of us. That's the point. That's the point. You know, you have a poem, you have a love story, you're out in the desert, whatever it is; she had the major power to express it.

ASPATURIAN: I listened to some excerpts of her singing on YouTube. Her phrasing is very interesting.

ZEWAIL: That's it. That's it. Phrasing is the right word because she was also so clean in the phrases. That you cannot miss.

ASPATURIAN: And also the notes she hits. Some of them are quite uncanny, I can see. And so you continue to listen to her.

ZEWAIL: Right up to today.

ASPATURIAN: How about your kids? Do they have any—

ZEWAIL: They know very well about her. They tease me about the fact that I still listen to her after fifty years or so. But they are Americans and born here and would not relate emotionally to some of the things that she's saying.

ASPATURIAN: Do your kids speak Arabic?

ZEWAIL: Yes. My sons Nabeel and Hani speak Arabic. Dema's father was a big scholar in Arabic, and he was the head of the Arabic Academy in Syria. So the Arabic in their home was very strong and very pronounced. So both boys, actually.

ASPATURIAN: That is terrific. They're fluent in both English and Arabic. A lot of professional and career opportunities—

ZEWAIL: Right, right. Exactly. And they can relate.

ASPATURIAN: So let us return to you at Caltech in the early 1980s. You've received tenure; you're an associate professor about to become a full professor. You went back to Egypt for the first time in 1980, '81?

ZEWAIL: Yes, something like that. I went because—it's a very interesting story. I think I mentioned to you that the acting president of Alexandria University, Dr. El-Sadr, when he signed my papers, said, "You're not coming back." [*See Session One*] Years go by, and he becomes very much interested in establishing a research institute at the University of Alexandria on the international level, and, to make the long story short, when he asks whom he should be contacting, they told him, "Ahmed Zewail is at Caltech." So he came here to Los Angeles, and they invited me to Egypt.

ASPATURIAN: Did he remember who you were?

ZEWAIL: Oh, yes. He was a very sharp man.

ASPATURIAN: He sounds like it.

ZEWAIL: A medical doctor, actually. A fantastic man. So I went and met him here, and he said, "I am setting up this program, and I must have you help me with the vision and so forth." And so, the same president who said I would not be coming back to Egypt invited me to come to Alexandria again. So of course I went and saw my family and my friends. When I met with him, we planned the first international conference on photochemistry and photobiology, and that was held in Alexandria. Of course we took the participants to Cairo, we went to the pyramids, Aswan, and Luxor. But that was really a major conference that we had. As a matter of fact, I think that about four of the people that I invited later went on to get Nobel prizes. It was really exciting also to be able to bring people to Egypt and give them a chance to experience the culture. Many of them were my friends in the discipline. So that was my first encounter in trying to help my mother country. I think that was the beginning of it.

ASPATURIAN: What was it like for you? You had come to America about a dozen years earlier, now you are returning as a tenured professor at the California Institute of Technology, with a very promising research program.

ZEWAIL: It was an amazing experience and also being here at Caltech gave me the confidence, you know, to say to them, "I can help." In other words, I'm not in a weak position, you know. Also to see the contrast at that time between what's happening here at the frontiers of science and what's happening there. Even socially, I saw the beginning of some changes. So this was incredible, as you said, a trip to see the contrast in the situation here at Caltech and at the university in Alexandria, for example, and between the two countries as a whole.

ASPATURIAN: Was [Anwar] Sadat [president of Egypt, 1970–1981] still alive at that time or was it [Hosni] Mubarak [president of Egypt, 1981–2011]?

ZEWAIL: I think it will still be Sadat.

ASPATURIAN: I can't remember; maybe he was assassinated in '81 [October 1981]. But he and Mubarak took the country in quite a different direction.

ZEWAIL: Very different. Very different.

ASPATURIAN: And you say you were beginning to see some signs of this.

ZEWAIL: What I saw socially is what they call in Egypt "infitah**,"** meaning it's an open-door policy. So if you have money, you can come to Egypt and build a factory and hire employees and so forth. It's good to have the free market, but I think the problem there was that as the rich got richer, the poor got poorer. And as a result of that, you have corruption, you have other problems, and that was not too good. In other words, it was not planned right. You can have the free market, but you have to plan it right.

ASPATURIAN: I believe Nasser was irreproachable as far as personal corruption went?

ZEWAIL: There is no doubt as a person, he was very honest and also corruption free.

ASPATURIAN: That's what I understand. So when we left off the other day, you and particularly two of your students, Kevin Jones and Tom Orlowski, had demonstrated a proof of concept regarding—

ZEWAIL: Coherence. Right.

ASPATURIAN: I found an article that you'd written in 1980 for *Engineering and Science* in which you talk about, I think, the beginnings of this work. ["Laser Selective Chemistry: A New Challenge for Chemists and Physicists," http://calteches.library.caltech.edu/3256/1/laser.pdf] It was a very interesting article. One of the things I noticed, though, was that you touch very lightly on coherence.

ZEWAIL: [Laughter]

ASPATURIAN: You do not mention it in great detail. But I think for you it is already emerging as something—

ZEWAIL: As something fundamental.

ASPATURIAN: Yes. That's a good word. I wondered why it was not—

ZEWAIL: I tell you why: Because coherence is not easy to explain to people, and its power is also not easy to get across. Even in the work that was recognized by the Nobel, if you ask the majority of people at Caltech about it, including other Nobel Prize winners, they will say, "Oh, yes, Ahmed got the Nobel because he was the first to take snapshots in a millionth of a billionth of a second."

ASPATURIAN: Right.

ZEWAIL: But that's not really—

ASPATURIAN: That wasn't the conceptual breakthrough.

ZEWAIL: The conceptual framework in the work is the concept of coherence, and what I call getting around the uncertainty principle. But there was also the technical achievement that made everybody say, "Wow!"

ASPATURIAN: That's much easier to understand.

ZEWAIL: Yes, much easier.

ASPATURIAN: Soon after you came to Caltech, you put together a funding proposal that you found out later was reviewed by someone who said, "If Zewail accomplishes even ten percent of what he proposes, he should win the Nobel." What was in this proposal?

ZEWAIL: Well, you know how it is when you are young—and of course, you know, Caltech is recognizing me and the scientific community is recognizing me. So, when you write a proposal and you are a person with lots of ideas, then you write honestly about the fact that with these lasers and with these techniques and conceptual framework, we can do this, and we can do this, and we can do that.

ASPATURIAN: I see. This was an NSF [National Science Foundation] proposal, I believe?

ZEWAIL: Yes. So when the proposal went out to reviewers, I got, I think, four "excellent" reviews, and two "very good." One of the "very good" reviewers made that comment, and I'll tell you how I know, because we are not supposed to know what is said, just how we are scored. But when the Nobel Prize was announced, Fred Stafford, who had been the director at that time [NSF program director for solid state chemistry], sent me those comments. What the reviewer said was "he [Zewail] wants to do everything on this planet basically; if he can do ten percent, then he will get—" [Laughter]

ASPATURIAN: You mentioned also that there was a lot of skepticism, at Caltech and elsewhere, over your initial proposals with coherence, and that when you did your initial studies and coherent phenomena emerged, it came as something of a surprise. But hadn't you been looking for it?

ZEWAIL: Well, first thing, just to clarify, we're talking now about the beginning of the femto experiments. The earlier proposal was really about demonstrating the conceptual framework with the nano and pico. But at the same time, we were building two lasers to try to reach the femto regime. In a 1985 paper ["Femtosecond Photofragment Spectroscopy: The Reaction ICN → CN + I," published in *the Journal of Physical Chemistry*, 89(24) November 1985], I wrote in the last paragraph that we saw coherence when nobody thought that you'd be able to see it in a very large complex molecule. I had heard people talking against it and all of that, but at Caltech, we really didn't mind saying that, and we built a molecular beam in a vacuum chamber, and the molecules we worked with were big—anthracene and others. The idea was to isolate these molecules from the rest of the world so they are not undergoing collisions with each other at all, and we can record their activity one at a time. When we did that, we saw beautiful coherence phenomena, and that really contradicted what people were saying—that the complexity of these big molecules will completely destroy that internal coherence.

ASPATURIAN: It'll swamp the coherence?

ZEWAIL: Swamp the coherence. That was not true. We wrote a series of papers from 1981 to '85, and at the end of that one '85 paper, I wrote a paragraph saying if we can—*if we can*—shorten the laser pulse further into the tens and twenties and so on of the femtosecond regime, we should be able to observe the motions of atoms themselves.

ASPATURIAN: Earlier when you first wrote a paper about this in '81, it aroused a lot of skepticism. What were people saying?

ZEWAIL: Well, they could not believe that if you take a molecule like anthracene, which is loaded with vibrations—it can vibrate in many, many ways—that you would be able to

see coherence. They thought that you would be smearing up the coherence in such large molecules. But I didn't believe that, I really didn't believe that. I believed that coherence will always exist, but the question is how do you find it, how do you observe it.

ASPATURIAN: Was the skepticism hostile or was it just—

ZEWAIL: No, no.

ASPATURIAN: Typical scientific caution?

ZEWAIL: It was typical. A few people did not get the point in the beginning of the femto experiments in 1985, 1987 even. 1987 is when we published the paper.

ASPATURIAN: I remember. That's when I first became aware of your work.

ZEWAIL: Yes, and that was really a breakthrough because we could see the atoms then. Not long before we had been looking at coherence in the molecules, and then it became coherence between the individual vibrations in the molecule. And now we reached the atom.

ASPATURIAN: You got your level of sensitivity down that far.

ZEWAIL: We got the level of sensitivity to a time scale where we could actually observe the atomic motion itself. Now, at this point, I think it wasn't skepticism but a lack of understanding. So I had the pleasure—it was at a conference that I organized here at Caltech in February 1986 at the Athenaeum—of sitting with two Nobel prizewinners, one from Harvard and one from overseas, who just could not understand how a femtosecond pulse is going to make us observe this phenomenon. There was another person actually from Caltech, independently of this meeting, who told me the same thing.

ASPATURIAN: You don't want to mention the names of these people?

ZEWAIL: I will mention the two outside Caltech, since it is oral history. One was George Porter, later Lord Porter. He made contributions to time-resolution observations at the microsecond scale and got the Nobel Prize. But he really did not get the concept of coherence and uncertainty. And Dr. Herschbach—Dudley Herschbach—is a very smart chemist, so I was surprised that he did not also see it clearly.

ASPATURIAN: Do you think chemistry at that time was inherently a more conservative discipline and this made it difficult for people to grasp some of these things?

ZEWAIL: Well, I think even one of my Caltech colleagues, when they were talking about promoting me and giving me tenure, said to his friends, "I wish Ahmed could do something that will be relevant to chemistry." In other words, these people didn't really see early on that this will lead to fundamental observations. What is more fundamental than—what was the Nobel quotation about seeing the atom and considering this as a revolution for chemistry? [From the 1999 Nobel citation: "This year's laureate in Chemistry is being rewarded for his pioneering investigation of fundamental chemical reactions, using ultra-short laser flashes, on the time scale on which the reactions actually occur. *Professor Zewail's contributions have brought about a revolution in chemistry and adjacent sciences* {italics added}, since this type of investigation allows us to understand and predict important reactions." *–Ed.*]

ASPATURIAN: I'm thinking of something Richard Feynman said when he first presented his version of QED [quantum electrodynamics] at a Shelter Island conference [1947], and his audience didn't grasp it. He said—you may know this quote—"My machines came from too far away."

ZEWAIL: [Laughter] Yes, yes. And then right away after the facts, many of these people will say it is obvious.

ASPATURIAN: Of course. Of course. "It's trivial."

ZEWAIL: It's trivial, yes. That's a natural thing.

ASPATURIAN: Did any of this cause you a crisis of confidence at any point?

ZEWAIL: No.

ASPATURIAN: Nothing.

ZEWAIL: All my life I have never—there's nothing that can stop me if I really believe in it, and I did believe in it. I would do what's called "back of the envelope" calculations, and I was confident. It never stopped me.

ASPATURIAN: Whom were you working with at this time, here at Caltech and outside? I know Richard Bernstein became a close colleague. Let's talk about some of your collaborators.

ZEWAIL: Well, the fundamental collaborators I had here were my students and postdocs. There's no question. And as I mentioned to you before [*Session Three*], there is no way I can claim the success alone. It was really a group of people. I can inspire them and I can get the original ideas, but these people were an army, and we were all marching.

ASPATURIAN: Coherently.

ZEWAIL: Coherently, exactly. [Laughter] But every now and then, we got people here, for example, as scholars in the Sherman Fairchild Scholars Program that I talked to; I was their host. So people like John Polanyi, Nico [Nicolaas**]** Bloembergen—these both are Nobel laureates by the way—I wrote reviews, articles, with both of them while they were here.

ASPATURIAN: Is this in the 1980s?

ZEWAIL: That's in the 1980s. That was really a very good thing because they come from different perspectives. John Polanyi is respected in chemistry. Nico Bloembergen was a professor of physics at Harvard. He and I wrote about our thinking on coherence and

how to break bonds in molecules. But the one collaboration that really was deep, and that became close on the personal level also, was with Dick [Richard B.] Bernstein. Dick was one of the most honest scientists and very, very thoughtful and very straight. You couldn't find in Dick Bernstein a single hair of lack of integrity. Here is a man who for thirty years was pioneering efforts in finding out how chemical reactions take place, either how bonds break or how they form. And he did that with techniques that he set in front of the whole world.

ASPATURIAN: Chemistry as it occurs.

ZEWAIL: Really, chemistry as it occurs. I have a video of him saying that for thirty years we have been trying to do this by indirect methods.

ASPATURIAN: These would be spectroscopic methods?

ZEWAIL: Actually he used collision methods in molecular beams. So, for example, you have an agent A and you have an agent B and they hit each other, he looks at what's coming out, C, in products. From knowing how much product you form, you can try to invert back.

ASPATURIAN: You infer from that what the process was.

ZEWAIL: You infer from that what happened during the process to A and B. He said, talking about my work, in front of the whole American Chemical Society and everywhere that he spoke, "Ahmed Zewail has shown us for the first time the real act of chemistry."

ASPATURIAN: Meaning, "We can move past inference for the first time." What year was this, Ahmed, do you know?

ZEWAIL: Oh, it's 1986, '87. Until he died in 1990. We used to sit down on this couch, he and I, and go through problems, and the solutions we expect of some problem. We wrote papers together.

ASPATURIAN: How did the two of you meet?

ZEWAIL: It was very interesting. I think I had just gotten tenure. He was at UCLA and on our visiting committee.

ASPATURIAN: For chemistry?

ZEWAIL: For chemistry. Typical of Dick, he walked in and he said, "Hi, I'm Dick Bernstein." I said, "Of course I know you." I had never met him before, but I knew his name. He said, "What are you working on these days?" So I went to this board that you are seeing right now. I showed him about six or seven different things, again, being enthusiastic like in the NSF proposal. I wrote, and then I remember Dick saying, "Now, if I want to nominate you for the National Academy of Sciences, I can't write these seven things. What is the closest to your heart that you want in there?" That taught me something very important actually. That you cannot do seven things at the same time with depth. You really have to select what it is that is significant and also close to your heart. He did tell me a story later when we became friends about a famous guy who heard Dick, when he was young, giving a talk about everything under the moon and told him the same thing.

ASPATURIAN: So after that you became active collaborators?

ZEWAIL: Oh, yes. Active collaborators and very good friends.

ASPATURIAN: I think you have mentioned elsewhere that the two of you together coined the term femtochemistry? How did that come about?

ZEWAIL: This for sure was at his house in Santa Monica. Dick said, "You know there's got to be a name for this field. It's not just that you can do it with this and that, but there's got to be a name so everybody will know." I can't recall exactly whether I said, "What about this?" and Dick said, "That's great," or whether Dick said it, and I said, "That's great." But it came as a result of this interaction.

ASPATURIAN: And it worked. It was a good name. The big breakthrough came in 1987, I believe.

ZEWAIL: In 1986 I was in a meeting in Rochester, New York. I was invited by Shaul Mukamel, a scientist who was at the University of Rochester. It was a meeting arranged by the Air Force, and so there were a small number of scientists there, in addition to people from the Air Force. I showed the idea of the nano and pico and how we can probe coherence and so on, and then at the end, I said, "Want a slide?" I said, "If we can go to the femtosecond scale by doing this and that, we'll be able to see—" Of course in those days, we showed transparencies. And so after I finish my talk, two program directors from the Air Force Office of Scientific Research, Larry Davis and Larry Burrgraf, come to talk to me, and they said, "We are very much interested in this."

ASPATURIAN: Had you expected this?

ZEWAIL: No, no! I knew there would be a high density of good scientists there, and I wanted to talk about my new, exciting real-time studies. I didn't know that these air force guys would be there. So they came to me and said, "We really would like to support your program. Could you write us a two-page proposal about what you said you want to do with the femtosecond research." So I came back to Caltech, rushing, writing two pages right away, sending it to them, and they immediately wrote back and said, "Could you send a more detailed proposal; we are fine with what you wrote." I did that, and they said, "We'd like to offer you the budget you suggested, and we will get you what you need to build the laser." It was just unbelievable.

ASPATURIAN: Did you ever find out what it was about your talk that got them interested in supporting you?

ZEWAIL: Well, even today it's beyond me, because when they came and talked to me, they said that what I was proposing was not necessarily in their areas of research, but they realized immediately that this was a whole new direction for shortening the time frame for these observations and getting to the femto level. But my friend, Shaul

Mukamel, who is now at UC Irvine, would always complain, in public even, that he was the one who organized this meeting with the idea that he would get money from the Air Force, but I was the one who ended up getting the money! So to this day, I can't really answer your question.

ASPATURIAN: Had you written any sort of proposal to anybody else, any other funding agency?

ZEWAIL: No. With NSF I always had funding, but they couldn't allocate something on the order of $400,000 or $500,000 to build a state-of-the-art femtosecond laser system. They can't grant me this much funding on one proposal.

ASPATURIAN: I see. That just wouldn't work. It would have to be piecemeal.

ZEWAIL: It would have to be piecemeal. But these fellows didn't mind at all.

And so [Marvin L.] Murph Goldberger [professor of theoretical physics; president of Caltech, 1978–1987, d. 2014] was the president of Caltech at that time. And Fred Anson [Gilloon Professor of Chemistry, emeritus] was the division chair. Both of them, for history, understood the value of what I'm doing. So Fred decided immediately to give me lab space to do what I wanted to do, and it happened to house the X-ray equipment of Linus Pauling, and he had to take hard decisions there because some people wanted to keep it as it is. So they took out the equipment. Fred really felt that since Pauling had studied the structure of the chemical bond and we were now doing research on the dynamics of the chemical bond that there was a nice historical symmetry there. So the feeling was that if we can put Pauling's equipment in a different and smaller place, then Zewail can expand in this space. Fred managed to do this, the rehab and all of that. I was walking with Murph from the Athenaeum—Murph is a physicist—

ASPATURIAN: Yes, of course, quantum physicist.

ZEWAIL: I explained to him the idea of trying to see the atoms in motion. He immediately got it. And then he said, "So what do you need? I said, "Well, the money is not here yet—"

ASPATURIAN: You mean the Air Force money?

ZEWAIL: Yes. But they had told me officially that my grant had been approved. Murph said, "Don't worry, we'll have an account for you; go ahead and order stuff until the money comes in." [*See also Session Seven*] And that's Caltech.

ASPATURIAN: I was just going to say, do you think this could have happened anywhere else?

ZEWAIL: No, this is Caltech. The president himself understood what I wanted to do. He was excited about it. He had trust in me that he could allow that. The chairman, Fred Anson, didn't mind taking some hard decisions because he also has confidence in the future of this field. And it was incredible; in a couple of months, by 1987, we had the first laser pulse coming out in the femtosecond time scale. We had a small party where the president and the division chairman and other people came to see the pulse coming out from our laser. I would like to mention something else from that time that is also historically very important. A friend of mine here at Caltech by the name of Tom [choking up]—I feel bad, you know, that he died, the one that you did the oral history with—

ASPATURIAN: Tom [Thomas A.] Tombrello [Goddard Professor of Physics, d. 2014; http://oralhistories.library.caltech.edu/206/].

ZEWAIL: I just feel bad that he died.

ASPATURIAN: Terribly sad.

ZEWAIL: So Tom Tombrello has played a role actually in all of this without people knowing. Tom loved what I was doing. He understood the way I go about my science.

ASPATURIAN: Which he must have liked.

ZEWAIL: Conceptually and technically. So he called me.

ASPATURIAN: This was in '87?

ZEWAIL: This is '86. So he called me, and he said, "Ahmed I just met someone who used to be an undergraduate here at Caltech, and he went to Cornell to do a PhD, and he wants to come back now to Caltech as a postdoc." Then he said, "The only group at Caltech that would be appropriate for him is yours." I said, "Why do you say that, Tom?" He said, "Well, this guy is brilliant with his hands, and I know that you are going to need that in a big way." You see, he understood.

ASPATURIAN: He was very good with that.

ZEWAIL: He said, "You must see Mark Rosker. You are going forward in a big way and this will be very good—to have him with you." And he told Mark that the only group he should go to is Ahmed Zewail's. So we arranged for a meeting.

ASPATURIAN: This young man was a physicist?

ZEWAIL: A physicist, getting his PhD in applied physics at Cornell. He walks in, very nice guy, very smart, and I like him. And I said, "You are on as a postdoc." Because Tom said that. And this was a fellow who had the golden hand with the femtosecond technology and lasers. And I had a graduate student by the name of Marcos Dantus.

ASPATURIAN: I knew Marcos a little bit.

ZEWAIL: And as you know, the year he graduated, he got the Clauser Prize for the best PhD thesis, and he even shook hands with President Bush, the father [President George H. W. Bush was the Caltech commencement speaker in 1991 *–Ed.*]. So Mark and Marcos came to my office, exactly in the place we're sitting now. And as Marcos recalled when he was saying nice words about me and the Nobel Prize, I said to both of them, "We have seen this and this and this; we have seen coherence; but the time has come now to see the breaking and the making of the chemical bond." I drew it on this board, and I said, "Let's start on the breaking of the chemical bond." I suggested a molecule.

ASPATURIAN: Which one would that have been?

ZEWAIL: Called the I-C-N. I, iodine, carbon, nitrogen. We wanted to see how the iodine molecule will divorce from the CN molecule in real time. I mean, this has never been seen. People had asked, How long do these bonds take to break? I had proposed how we would do it. We had the labs that, as I mentioned to you, were occupied by Linus Pauling's equipment. We didn't have anything much to put in them, and that's when the Air Force stepped in—so you can see how it all comes together—the right people, and then we have the right money and also the right environment at Caltech that would allow me to go ahead and order equipment and get started before the Air Force money comes.

ASPATURIAN: Physically where were these labs located?

ZEWAIL: Sub-basement of Noyes. Exactly as it still is today. And so Mark and Marcos set up the first really beautiful laser; we could generate about 40 femtoseconds out of it, and we began to do the first beautiful, first experiment—

ASPATURIAN: This is again with the ICN molecule?

ZEWAIL: ICN.

ASPATURIAN: Why did you choose that?

ZEWAIL: I chose it because, until today, always, when I try to see a phenomenon, I try to get the most fundamental and simple one.

ASPATURIAN: Ah-ha. Of course. Makes sense.

ZEWAIL: Because you don't want to come to the end and say it *may* be this. I remember it vividly. I cause my students heartburns. I gave them a hard time I must say—both of them. Once we made the first observation, I was concerned that it may be an artifact.

ASPATURIAN: The first apparent bond breaking?

ZEWAIL: Apparent bond breaking. Why was I worried that it might be an artifact? A, because it has never been seen before. B, what if it is an artifact, and here we are claiming something very big, never seen before, which would make a huge media splash, and then people will find that it's not real.

ASPATURIAN: Exactly. You wanted to be sure.

ZEWAIL: Otherwise it's not good science. So—even today Marcos will tell you about this—we must have done fifteen or so control experiments. So I would be sitting here, saying, "It may be the effect of the electric field noise in the laboratory. Why don't you guys try to do this and this and this?"

ASPATURIAN: So you ran a series of experiments to eliminate all of these potential flaws?

ZEWAIL: No question, no question. As I said, they got tired of me because I'll tell you, the last thing was I said, "Are you sure this is ICN? Did you really buy this?" Marcos said, "Well, it was in the bottle in the lab." I said, "That's not enough. Why don't you buy today a fresh sample of ICN and repeat the experiment again?" Both of them looked at me as if—well, indeed, they bought another bottle, and they did it, and we saw that. So the effect was enormous. I remember I was living at 1000 East California. I was

living in a second-floor condo, and I wake up in the morning and I said, "It is now time to write this communication," and I wrote it.

ASPATURIAN: What month are we talking about?

ZEWAIL: This is maybe the early part of 1987—February, March, something like that. I have the original.

ASPATURIAN: I'm sure you do.

ZEWAIL: It's short. I still have my own marked up copy.

ASPATURIAN: Which journal?

ZEWAIL: *Journal of Chemical Physics*. And it appeared in something like in two pages. That's also the paper that was quoted by the Nobel people. Because I wrote it calmly: "We now have direct observation—femtosecond direct observation—of transitional states of chemical reactions." And it had both Marcos and Mark as coauthors ["Real-Time Femtosecond Probing of 'Transition States' in Chemical Reactions," M. Dantus, M. J. Rosker, and A. H. Zewail, *J. Chem. Phys*. 87, 2395, 1987].

ASPATURIAN: Did you talk to your colleagues at Caltech about it immediately? Do you recall what they were saying?

ZEWAIL: Yes, I think they knew, and I talked to people like Vince McKoy and others, but they knew that it was something big that we were doing. Dick Bernstein was of course involved. After that, I think it was 1988 when we started collaborating not only on breaking but making a chemical bond.

ASPATURIAN: Did you start with breaking first because you thought it would be easier to track, whereas making bonds is more complicated?

ZEWAIL: Exactly, exactly. You're coming at this with a well-known molecule, and you're seeing the atoms moving, so this was terrific.

ASPATURIAN: Was that the year also that you were elected to the National Academy of Sciences, '87? Or was that a year or two later? It was not long after.

ZEWAIL: Well, that's a very good question.

ASPATURIAN: I should have looked it up before I came.

ZEWAIL: I can look it up. I'm not sure. [It was 1989. *–Ed.*]

ASPATURIAN: Because I remember my friend Kathryn Phillips wrote an article about you and your NAS election for *Science* magazine, in which you were called the femtosecond king.

ZEWAIL: [Laughter] This femto, really it's amazing; people loved that technically. You talk about a millionth of a billionth of a second, everybody's excited.

ASPATURIAN: Well Tombrello in a way hit it on the head in his oral history when he said Harry Potter [in his 2010 oral history interviews, Tom Tombrello invoked Harry Potter to describe Zewail and the significance of his work: "He's our magician, our Harry Potter!" *–Ed.*] I don't know if you're familiar with Harry Potter.

ZEWAIL: I'm familiar because my children see all of that stuff. To complete the story about Tom's impact on my life here at Caltech, I should mention that he sent me, and I don't know why, four or five people, and every time, every one, it was a big success. And he would tell them, "You don't want to go anywhere else." To just tell you about this, when we were honoring Tom at his campus memorial—

ASPATURIAN: Yes, I was there.

ZEWAIL: Then you saw Milo Lin speak about Tom. Milo Lin was a graduate student of mine, but Tom sent him to see me as an undergraduate, and in graduate school he did fantastic work with me. I nominated him to get the Miller Fellowship at Berkeley and then he went to Berkeley, and now he's a faculty member in Texas [University of Texas]. He said during his remarks that he had told Tom he was thinking about going into high-energy physics, but Tom saw in him that the real excitement was for biological sciences. He went to Tom and he talked to him for an hour, and then Tom looked him straight in the eye and said, "Don't do string theory, that's not what's in your heart. Go to Zewail."

ASPATURIAN: Tom talks about this in his oral history. He was very proud of having had this insight and sending him to you.

ZEWAIL: Right, right. Then he came. We did that indeed—biological science—and Milo became very successful in that area. Tom really played a great role in this.

ASPATURIAN: When you were, as you said, working your two students Mark and Marcos very hard, did they indicate that they ever thought you'd just gone over the top? You know, excessive attention to detail?

ZEWAIL: No, I think the way they looked at it is that I am a very enthusiastic person, and I'm also careful.

ASPATURIAN: You have to combine that enthusiasm with rigor.

ZEWAIL: On the one hand, I can inspire them. And I can be enthusiastic and I can be friendly, but I have to be rigorous. And that's what I still tell all of my students: *Science is a serious profession*. It cannot be done by saying, "Well, it's maybe this or maybe that, and that's okay now." You cannot do that. Really good science has to be rigorous, very rigorous.

ASPATURIAN: In 1987, what was the reaction to the news of what you'd accomplished?

ZEWAIL: I think in the majority of the community our results were very well accepted; there was a genuine feeling that here is a breakthrough in terms of the real-time resolution and so on. A few had a different theoretical approach to the problem, and of course if the world picks up on our approach because we were pioneers for this, then of course their method will be basically obsolete. So they had some concern and so forth. But that was the theoretical side. And very quickly we and others did theoretical work and showed that these other models were not the case. I didn't see any great resistance to that. In fact, there were quite a number of editorials and op-eds all over the world saying "Great stuff!" and so on. So the wave was very intense.

ASPATURIAN: Did you start hearing the words Nobel Prize at this point?

ZEWAIL: Yes. The first was in a letter from a German scientist in 1986. This was the first time I had heard that the work I was doing will be of the Nobel quality. But then when we had the '87 breakthrough, this same person wrote something to the effect that there can be no doubt. To be frank with you, I received numerous, numerous notes after the 1987 experiments and many others that we did, along with the theoretical work. These were from people saying either "I nominated you" or "You are deserving of the Nobel Prize." And there were also other signs. From 1987 on, I was receiving all the major prizes, which are pre-Nobel Prizes. But I got so many notes from colleagues who wanted me to know. Of course, they are not supposed to tell me, and they are not supposed to say anything but, you know, they're hinting that this is unique work and it's deserving of the Nobel Prize.

ASPATURIAN: Had the Nobel been on your mind at all through the mid-'80s when you were doing this? I mean, in his book *The Double Helix*, J. D. Watson makes it sound like he and his colleagues never thought of anything but the Nobel Prize. Obviously this was an exaggeration, but how about you?

ZEWAIL: No, I think that here is the honest truth about this: I told you about my excitement and drive toward science when I was growing up in Egypt and how I didn't know about the Nobel Prize. [*See Session One*] The Nobel was not on our screen.

ASPATURIAN: Not on your radar.

ZEWAIL: On our radar. But you know I was just excited to gain more new knowledge and to do this and do that. Certainly when I started at Caltech, I never thought of the Nobel because I hadn't done anything of that magnitude. But beginning in 1987, when you have all these people writing, writing, writing, and saying "you deserve it," you become conscious of it. So after that, when October comes, especially in the later years, as my wife will tell you, I will try to be out of town. The reason for that is because many of my colleagues at Caltech are expecting it—and certainly the public relations office is ready for it.

ASPATURIAN: Of course. They've geared up for it for the previous three months.

ZEWAIL: They will come and shake hands with me and say, "We are sorry it didn't happen this year, but we're sure it will happen next year." So I felt it's like when my father died. I didn't want that. So usually I was out of town. Except 1999. [*See Session Five*]

ASPATURIAN: We'll get to that. I'd like to talk about the follow-up experiments that you did, and I think then we'll close out this particular session. You mentioned that you began with the bonds breaking and then moved on to watching the bonds form. Over what time frame did all of this occur?

ZEWAIL: Oh, it was extremely rapid.

ASPATURIAN: In other words once you had the technique down—

ZEWAIL: Oh, yes. So, say you have a molecule that's made of two atoms. Pauling has suggested that when they are very close to each other, the structure is what we call ionic, meaning that oppositely charged ions will form a bond. For example, in sodium chloride, the sodium is plus and the chlorine is negative, and that's how we get table salt. For me it suggested a very interesting idea. What happens if we were to energize this type of

molecule? And what we showed was so vivid and so clear that when I used to give lectures about this, people would say—and I could hear them, even while I was lecturing—"Wow!" It was amazing, because we *showed* that in this particular case, you can start with a molecule like NaCl [sodium chloride, i.e. salt], and we are able to observe a motion as the bond is trying to break. And at a certain distance, the electron jumps from the sodium to the chlorine—or, in our case, the iodine. It jumps into that. But when it jumps, the oppositely charged ions attract each other again, and so the chemical bond makes about ten [gesturing]—

ASPATURIAN: It oscillates?

ZEWAIL: It oscillates. And finally the bond breaks.

ASPATURIAN: This had not been understood before.

ZEWAIL: No, it had never been seen before. You can't see it unless you have the femtosecond observations.

ASPATURIAN: There was no theoretical appreciation that this might be happening?

ZEWAIL: No.

ASPATURIAN: That must have been very exciting.

ZEWAIL: Super exciting. Super exciting. And then we went to the bond formation, for example, between an OH molecule and a CO molecule and so on. So we went into this system, a bigger system, and later we did some very big systems. So that's evolution and that's the nature of things. And of course with the theory, with experiments, it was really truly a thrilling time. Every experiment is leading into new territory.

ASPATURIAN: Every single time.

ZEWAIL: Yes, yes.

ASPATURIAN: It's like opening a new wavelength on the universe.

ZEWAIL: Yes, that's a nice way to say it—and you know, in fact, I had a slide showing that with femtochemistry you can do clusters, you can do gases, you can do liquids, you can do all this, and every time you do something on that time scale in that domain, you create a whole new area.

ASPATURIAN: Were the implications of this work for biology recognized immediately?

ZEWAIL: Not immediately, but, for example, following our work, there was a very nice femtosecond study at Berkeley [1991] looking at the molecule responsible for vision, called rhodopsin. They followed on the observations we did here of the twisting of the chemical bond. What they found is that this rhodopsin actually twists the bond in 200 femtoseconds. The first photon that we see leads to an immediate signal, and the idea there actually is that it does this coherently so we don't lose the amount of the light that we are getting. ["The First Step in Vision: Femtosecond Isomerization of Rhodospin": http://www.eleceng.adelaide.edu.au/thz/documents/schoenlein_1991_sci.pdf] So it was a very, very important story, too, and that's a biological system.

ASPATURIAN: How did you feel when you realized what you had accomplished after not quite a decade of work on this? When it all just came together in '87, and you could think, "I've done something nobody else has done, and it's going to have enormous implications."

ZEWAIL: You know, I'm one of these guys that—I don't stop. Even, clearly, after the Nobel.

ASPATURIAN: No, that's right. You used it as a springboard to something else.

ZEWAIL: Right, right. Springboard to something else. I just don't stop because it is my excitement. It is my internal excitement. It is not driven by the money that I will get or from the Nobel or from the recognition, all of that. Of course, we are all human and I loved it when—you know, some people say, "I didn't want the Nobel because it's a lot of publicity." I don't know about that—I loved it. I loved the idea that our work has been recognized by the highest prize of the world. But I don't sit on my laurels; I'm moving to other stuff. So as to how I felt. I felt, "No doubt we have made a field, a whole new field," and that was real excitement. To me, the most exciting thing is that the field is spreading. There are books and books on femto and all of that, but I was extremely pleased that the Germans are getting into it, the Dutch, the Japanese, many people around the world

ASPATURIAN: In '86, '87, before the breakthrough, when you were putting the technology together and bringing the science to bear, did you ever have a sense of, it's not going to work? Were there ever—

ZEWAIL: Hmm.

ASPATURIAN: Any setbacks that threw you momentarily?

ZEWAIL: Conceptually, I was convinced.

ASPATURIAN: Ah, you had confidence.

ZEWAIL: Yes. Because I built on all of that thinking that I mentioned to you. Conceptually, and based on back of the envelope calculations—it has to work. But the kind of thing that could have happened is that the molecules do not cooperate in creating interesting science. So, for example, this molecule that I mentioned to you, using the table-salt analogy, surprised us in the sense that there is love and hate ten times—ten oscillations—and then the bond breaks. Of course, this was enormously interesting and exciting. It could have been a setback that the bond would simply break and do nothing intriguing, but that didn't happen. The systems cooperated in many ways to create really

exciting new phenomena, and we wanted new phenomena. That was what took place in the early days.

ASPATURIAN: Is there anything else you'd like to say before we close out this session?

ZEWAIL: I think you've covered how it began and how we approached it conceptually. There's one thing I might mention, which is that there is now known to be a conceptual aspect that people at the time perhaps did not see. In 2001, I wrote a paper published in *Nature*; I think the title was "The Fog that was Not There and Why" ["The Fog That Was Not," *Nature*, July 19, 2001]. If you have a femtosecond resolution, that time scale is extremely short, so short that there is an uncertainty relationship between time and energy. There were people, very famous people, who thought that because that time interval is so very short and the energy so very large, it will be too large compared to the quantum states of the molecules in general. And therefore there would be smearing out.

ASPATURIAN: You would swamp the quantum states?

ZEWAIL: You'd swamp the quantum states, and you would lose all the important information. They were wrong. It *is* true that the shorter the time, the larger the energy, but I realized that if I can have these quantum states all in phase with this pulse of the femtosecond, then I can localize the atomic nuclei in space. And that was not really easy for people to see. You can show that easily on the back of the envelope if you know the uncertainty principle. Because there are two uncertainty principles: One between time and energy, and the other one between distance and momentum. If you just for a moment say that the momentum and the energy are similar, then once you have a very small time and large energy, you'll have a larger momentum and small distances. Small distances, meaning that I can take observations down to the atomic scale, and that's why I can see the atom in motion.

ASPATURIAN: Why do you think certain people found it so hard to appreciate this?

ZEWAIL: They were all focused on only half of the story, namely the relationship between the energy and the time. That's not quite right. If you work it out, and even if you do formal theory, you'll find that the only way to localize the nuclei in space is to have the femtosecond timescale.

ASPATURIAN: And when it was demonstrated that this could be done, what did they say?

ZEWAIL: It's trivial! [Laughter]

ASPATURIAN: It's trivial! Let's end on that.

ZEWAIL: Let's end on that. [Laughter]

Some material in this session was originally recorded during Interview Sessions Five and Six.

AHMED ZEWAIL

SESSION 5

October 6, 2015

ASPATURIAN: When we left off last time, we were in the late 1980s and you had just had your successful results in femtochemistry. In your memoir, and I believe elsewhere as well, you say, "Unpredictability is the fabric of discovery." I wondered how you thought this applied to your breakthroughs in femtochemistry.

ZEWAIL: You're asking a very important question that I even have written op-eds about in *Nature* and elsewhere. Today I was reading the latest issue of *Nature*, and somebody had written an editorial that said scientists should be basically directing their work to the service of society by making the discoveries that are relevant. The problem is I don't know what's relevant! I think that 90, and maybe 100, percent of the best scientists I know don't know what's "relevant" either. What's great about unpredictability is that your mind is free to think. If I already know where everything that I'm thinking about is going, then why do the research? It is the beauty of unpredictability that we find things that we did not anticipate. Of course you have to have the research in the hands of intelligent and good scientists—all of this goes without saying. In 2010 I had a piece in *Nature* ["Curiouser and Curiouser: Managing Discovery Making:" http://www.nature.com/news/2010/101117/full/468347a.html] about managing research too heavily, which is my concern about where we're going in this country. I think if you manage it—if you say, for instance, "nanotechnology is where we're going"—it's not good for the greatest minds. Imagine telling Richard Feynman that he has to write papers on nanotechnology! It was Richard Feynman who inspired nanotechnology [R. P. Feynman, "There's Plenty of Room at the Bottom," American Physical Society address presented at Caltech in 1959. *–Ed.*]. It worries me that funding is going more and more into mission-oriented type research. This country had the great vision to divide mission-oriented research from curiosity-driven research.

ASPATURIAN: Fundamental research.

ZEWAIL: Fundamental. And that's what we really have to keep. So, to me, unpredictability is really the core, or the vehicle, for making discoveries, because it's curiosity about the unknown, and it leads you in different dimensions than you have thought of before.

ASPATURIAN: I see, yes. A couple of years after your initial femtochemistry breakthrough, you became the Linus Pauling Professor. How did the professorship come about?

ZEWAIL: Fred Anson was the chemistry chair, and Tom [Thomas E.] Everhart [professor of electrical engineering and applied physics, emeritus; president of Caltech, 1987–1997] was the president at the time. I think it was clear to both the chair and the president that our work was going extremely well, and people were of course telling them that this may get the Nobel and so on.

ASPATURIAN: The professorship was a new one, I think.

ZEWAIL: Yes, I am actually the first one. Fred and I had also just organized an eighty-fifth birthday symposium for Pauling in 1986—Linus was born in 1901—and then one for his ninetieth birthday five years later. So my association with Pauling then became very clear; and there is a story here for history. Pauling left Caltech [in 1963] very upset.

ASPATURIAN: So I understand.

ZEWAIL: And he didn't come back to the Institute for many, many years, and of course in the outside world everybody was saying, "Caltech mistreated Pauling," and so forth. I was young, full of energy, so I did go to Fred Anson and said to him—as division chair but also a friend—"This impression will be really a disaster for history. Linus Pauling and Caltech *is* a chemical bond." I said that I was thinking about organizing a campus celebration for his eighty-fifth birthday and that we would invite top-notch scientists. I must say, Fred was enthusiastic. Then I went to Murph Goldberger, and I requested the

budget, and Murph immediately said there is no problem. So I had the idea to invite people like Francis Crick and Max Perutz.

ASPATURIAN: Both of whom built on Pauling's work.

ZEWAIL: Exactly—the proteins. I had those two, and Alex [Alexander] Rich. I had three or four speakers for structures, and three or four for dynamics—the world we're now going into. Richard Bernstein and couple of others. We had a one-day symposium in Beckman Auditorium. And that was the day of the return of Linus Pauling to the campus.

ASPATURIAN: After how many years? Twenty, twenty-five?

ZEWAIL: Something like that yes. And so he came. He gave a lecture—beautiful, as usual—about X-ray crystallography. But when we had him out to dinner at the Athenaeum, he got it all off his chest. He complained about the way his colleagues had treated him here and this and this and that. But what is good is that he got it off his chest, and after that it became easy. I have correspondence with him for the next five years, and then we also had the ninetieth birthday celebration.

Linus Pauling and Zewail, February 1986

ASPATURIAN: How had you originally met him?

ZEWAIL: I actually met Pauling from a distance in a conference, but the first time I really met him was here, in '86. On this couch. I was describing to him what we had done in femto, and so forth. And Pauling had this tendency—and this *is* Pauling—where you talk to him about anything, and he will say, "Well, in

1932, I wrote a paper on that." [Laughter] But it was a happy occasion, and I personally feel this was a great thing I at least contributed to.

ASPATURIAN: So in 1990 they gave you a professorship in his name.

ZEWAIL: When it came to the professorship, both Fred Anson and Tom Everhart knew when they came to talk to me about a chair that I didn't want a name that I didn't know. On the campus there was a Millikan Chair, but no Pauling Chair. I'm not sure if the Feynman Chair was already there or not. [It was established a year earlier, in 1989. *–Ed.*] But anyway, they offered me the Pauling Professorship. Maybe it was also catalyzed by the offer I had from the Max Planck Institute in Germany. [*See also Session Seven*]

ASPATURIAN: At the time you became the Pauling Professor, the chair was chemical physics, but in '95 you became the Pauling Professor of chemistry and physics. Did that signal any particular change?

ZEWAIL: I think the key thing there is that I always have been interested in physics and as a matter of fact, I probably could have been a mathematician. Because of the school [i.e. University of Alexandria] I went to, I became really interested in it [*See Session One*], but I also realized that math is pure, the purest of the pure. But I really love physics, and even the contribution we made in chemistry is really not in the chemistry of new chemical reactions and so forth. If you look at what we did, it's really the physics of molecules.

ASPATURIAN: Yes, you were down in the micro world.

ZEWAIL: Right. How do molecules behave, how can we control them—these are physics issues. Even the laser part of it was also physics. So when the physics faculty met to consider my title, I think it was Tom Tombrello who introduced my case, and they voted on it; this is of course the way we do things at Caltech. The vote was positive and then, David Goodstein [Gilloon Distinguished Teaching and Service Professor, and Professor

of Physics and Applied Physics, emeritus], who is a friend, called me. [Laughter] And he said on the phone, "Congratulations on your promotion."

ASPATURIAN: That sounds like him.

ZEWAIL: My "promotion" to professor of physics. He didn't consider a professor of chemistry to be that much. I just bridge the gap between the two, and I enjoy both of them.

ASPATURIAN: In 1989 you were awarded the Faisal Prize [King Faisal International Prize] and you went to Saudi Arabia, which turned out to be not only professionally but personally meaningful. I was thinking about it, it's almost like an *Arabian Nights* [*One Thousand and One Nights*] story.

ZEWAIL: [Laughter] Right. It is, actually, it is.

ASPATURIAN: Very appropriate in terms of location. I think that was the first major prize you were awarded?

ZEWAIL: I think so. I was fortunate enough that I received essentially all of the relevant physics and chemistry prizes that are in my field. Essentially all of that was coming our way. It always makes you feel good that at least colleagues are recognizing our work in nominating committees and things like that. But I think it's fair to say that, yes, the first major one was the King Faisal Prize. It's a romantic story because I was in Cairo at the time it was announced. And then Tom Everhart called me, and he said, "We just got the news that you are receiving this, and we'd like to have a party for you when you come back to Caltech." And I said, "This is really great of you, Tom, to call," and I went straight from Cairo to Saudi Arabia, not anticipating that I would meet my future wife in Saudi Arabia, out of all these places.

ASPATURIAN: Indeed. Was it Riyadh you went to?

ZEWAIL: Riyadh. They treated us fabulously. Of course you also get a sum of money, but the receptions, everything, were very warm. But then to my surprise, Dema's father, Chaker Faham, who was well known in the Arab world for his studies of literature, was also there, receiving the Faisal Prize in literature. [Dr. Chaker Faham, served at various times as Syria's minister of education, ambassador to Algeria, president of the University of Damascus, and president of Syria's Arabic Language Academy. He died in 2008. – *Ed.*] But at the ceremony, at the meetings, in the lobby of the hotel, and everywhere, there was this beautiful lady; and the romantic story is that up to the last minute, the one who was going to accompany her father and mother to Saudi Arabia was her brother, a doctor. At the last minute, a change happened, and Dema replaced him. [Laughter] So that's how it happened. I met her there, and the rest is history.

Ahmed and Dema, October 1999

ASPATURIAN: How did you find Saudi Arabia? Did you have a chance to see any of it?

ZEWAIL: Oh, yes. First of all, I was familiar with Saudi Arabia. I was helping them before I received the prize in terms of building laser institutes, and they got my advice on certain educational aspects. So I was familiar with the environment there. But for the prize, they took us to the desert, and they treated us with typical Arabian hospitality under the tent. As a matter of fact, at the ceremony I met the future king Abdullah [Abdullah bin Abdulaziz Al Saud, d. 2015], who was at the time the crown prince, and he's the one who gave me the prize. And so we had a chance as laureates to tour around and see what's going on there.

ASPATURIAN: How long were you there?

ZEWAIL: I think a week.

ASPATURIAN: Did you have feelings about the education, the culture?

ZEWAIL: Well, Saudi Arabia is not Egypt.

ASPATURIAN: No, it's not.

ZEWAIL: For thousands of years, obviously long before I was born, Egypt has been exposed to the rest of the world. The French were there; the English were there. And of course the Suez Canal brings all these continents together. That's one of the problems, just to detour, that the Muslim Brotherhood has had with Egypt in the modern age. They don't understand the nature of Egyptians. Egyptians can go to the mosque to pray on Friday, but they would like to be free and exposed to the rest of the world the rest of the week. You cannot just tell them: "You're going to be an Islamic state**,** and if you don't obey . . ." They resent it. So Egypt is really different from Saudi Arabia. A woman of course in Egypt can drive. It's not a big deal. In Saudi Arabia, she doesn't. There are restrictions in Saudi Arabia that are very different from the Egyptian way of life. My understanding is that now they are trying to ease this somewhat, but it's going to take some time.

ASPATURIAN: Did the King Faisal Prize make a big splash in Egypt and the rest of the Arab world? It must have raised your profile.

ZEWAIL: Well, at the time my profile was rising, I would say. But I don't think it was received in Egypt like, let's say, the Benjamin Franklin Medal.

ASPATURIAN: Okay, we'll get to that.

ZEWAIL: It's ironic but it's true. For the Benjamin Franklin, the whole country lit up. So, no, I wouldn't say the Faisal was a big splash. I was on the newspapers' front page, with a *small* photo.

ASPATURIAN: "Native son makes good" type of thing.

ZEWAIL: Yes, that's right.

ASPATURIAN: When you received the Wolf Prize in '93, did you have any hesitation about going to Israel?

ZEWAIL: Well, I said when I was interviewed at that time—

ASPATURIAN: Were you in Egypt again when the prize announced?

ZEWAIL: No, I was here. But there were two things that I said for Egyptian national television. First of all, there was the peace treaty with Israel between Sadat and Begin. And Egypt had an ambassador in Tel Aviv. Egypt was flying airlines into and from Tel Aviv. So clearly I'm not going against the diplomatic relations of my mother country, whose passport I carry. I mean, imagine if Egypt was at war again with Israel, for example; it wouldn't be appropriate to go there. So that was the first thing, and the second, which I told a very important Egyptian reporter in Canada, was that I would hope that we can separate science from politics and use science to solve problems of politics. So that was really my attitude toward this, these two things. And, in fact, when I arrived in Israel, I was met by the Egyptian ambassador at the Egyptian foreign ministry, and I didn't encounter any prejudice or anything. I was treated purely as a scientist. And I received the award alone—it was unshared—so it was clear that they were feeling the impact of my work. So I really didn't feel, shall we say, uncomfortable or uneasy. I did it with conviction because of these two points.

ASPATURIAN: How long were you in Israel?

ZEWAIL: A week.

ASPATURIAN: I believe you write in your autobiography that you received the prize in the Knesset?

ZEWAIL: Yes, I did.

ASPATURIAN: Did you have an opportunity, either in Israel or Saudi Arabia, to interact with the nations' scientists?

ZEWAIL: Of course, I knew the very active scientists in the two countries, and the Israeli scientists had an advantage, namely, that they have very good connections with the United States.

ASPATURIAN: Yes, they do.

ZEWAIL: There isn't a conference in the U.S. where they aren't either presenting a talk or sitting in the audience, so I had had lots of chances to meet and see them and hear what they have to say. It's amazing how they formed such a base of science in such a short time. I was the first in our region [i.e., the Middle East] to get the Nobel Prize in a science, but the Israelis now have two or three [six since 2004 –*Ed*.].

ASPATURIAN: Yes, I know of two who won in chemistry a few years ago. And [Alexander I.] Varshavsky [Smits Professor of Cell Biology] should have shared it with them that year for biology [i.e., physiology or medicine], but he did not, which was very unfortunate.

ZEWAIL: And he deserved it. But, so, with regard to Israel, I did not feel that there was a problem.

ASPATURIAN: What did you think of Israel, what little you saw of it?

ZEWAIL: Well, I found it—it's not Egypt either. It's small. I found the taxi drivers are very aggressive. [Laughter] They reminded me of New York City. Wouldn't you agree?

ASPATURIAN: I would agree.

ZEWAIL: And in fact I have a story because in Israel I had a chauffeur. And the guy put on some Arabic music as we drive. Now he doesn't know where I am from. He didn't look at me with even a smile; he looks in the back and says, "Where you from?" Not, you know, "Could you tell me please where you're from." No, no, no: "Where you from?" I said, "Los Angeles." He looked at me and said, "No, no, no, no; tell the truth." [Laughter]

ASPATURIAN: That does sound Israeli. Very direct. You mentioned you were the first from the region to win the Nobel Prize in science, but I imagine you were probably also the first from the region to win both the Faisal and the Wolf prize?

ZEWAIL: Well, it's hard to talk about myself, but I believe I am. I actually was the only one to receive the Nobel in science from the entire Arab world and also the Muslim world, with the exception of Abdus Salam, who has since died. He shared the physics prize [in 1979].

ASPATURIAN: Oh, yes, for the electroweak interaction.

ZEWAIL: Exactly, yes. And that's it. I mean right now, out of 1.3 or 1.4 billion people, only two; that's sad. But I also believe that I was only one in the region who received the four major prizes leading up to the Nobel in chemistry—the Faisal, the Benjamin Franklin Medal, the Wolf, and the Welch.

ASPATURIAN: The Welch Award in Chemistry. It came next, I think, in '97.

ZEWAIL: That's really an American prize, and boy! I serve now on the board of the Welch Award, and they have five Nobel Prize winners who judge, so before I got the Nobel Prize, they were judging my work.

ASPATURIAN: Now with the Benjamin Franklin Medal, one of the things you say in your autobiography is that Franklin is a personal hero of yours.

ZEWAIL: I even have his statue.

ASPATURIAN: You have his bust here in your office.

ZEWAIL: And also in my other office. I think the reason I value him immensely is because, as you know, all my life—at least for the last forty years or so—I've been interested in the interaction of science and society. And Benjamin Franklin epitomized for me this kind of thing. You know, he can—what do you call those spectacles?

ASPATURIAN: The bifocals, I think.

ZEWAIL: The bifocals and also the lightning rod. So he's an inventor, yet when he writes, he's one of the most eloquent people; and he was involved in writing both his country's constitution and the Declaration of Independence. It's the kind of thing that I value immensely.

ASPATURIAN: He was a scientist-statesman. One of the first. One of the few. There aren't many.

ZEWAIL: Exactly. When I was invited to speak at the American Philosophical Society, which Franklin established in Philadelphia, I gave a speech about him and the evolution of his ideas, and how this was extremely important for America. You know this guy goes to Paris, where he's wining and dining and everything, but at the same time he's bringing lots of ideas back to America. When I received the Benjamin Franklin Medal, I realized also that the list of names on the medal roster is incredible because of how far it dates back. The Wright Brothers are on there, so many others.

ASPATURIAN: It was established in the nineteenth century [1824], I think.

ZEWAIL: Yes, and it's just incredible in terms of the names that are on it. When they announce the newest winner each time, they just mention a dozen or so previous winners, and you see Einstein, Marie Curie.

ASPATURIAN: Why was it, as you mentioned earlier, that this particular award caused so much excitement in Egypt?

ZEWAIL: That's a very good question. I won the medal in the spring of 1998, and an Egyptian journalist in Washington, D.C., published the story in the famous Egyptian newspaper *Al-Ahram* that Dr. Zewail has won this medal and this is very important. Maybe the country was ready for it, but there was also the recognition that, "Oh, yes, that's Benjamin Franklin of America!" This is a purely American fellow and a purely American prize.

ASPATURIAN: American validation.

ZEWAIL: And it's American validation. I went to Egypt that summer, and I could see the reaction. They gave streets my name; there's a whole square in Alexandria in my name. They renamed my high school after me. Really, the whole country lit up. I mean, this was incredible.

ASPATURIAN: At that time, when you were there, having won this award, did you visit the universities and talk to the students and so on in connection with this? Were you invited to do this?

ZEWAIL: I have spent a lot of time, especially in Egypt, going to massive auditoriums. In 2010 I gave a lecture at Alexandria Library that was attended by something like 5,000 people. I would also lecture in the opera house in Cairo and all the students would come.

ASPATURIAN: Yes, I remember you telling me a few years ago that people who think that the Egyptians are not interested in science and in progress should hear about this level of attendance.

ZEWAIL: Exactly. That's why I invest a lot of energy in this. I knew the young people are thirsty for this. Have you ever heard of a scientist going to an opera house and giving a lecture on the opera stage before an audience that is full and silent? I was talking about

science and society, lasers, development, and progress. By the way, this was during the Mubarak era, and I know that they were very, very worried when I spoke because the security forces were everywhere. People were applauding and clapping in a very strong way because they wanted to hear me. Mubarak didn't like this—he and his son. But I had a fantastic response, and when I appeared also on the national television, they tell me millions of people were listening.

ASPATURIAN: Millions of people tuned in.

ZEWAIL: So I have tried to do something with this, with the impact of education and science. I think we did. I think we did something.

ASPATURIAN: After the Franklin Award, of course, we come to the 1999 Nobel Prize. You must have known from this series of awards that this was going to happen. You said in an earlier interview session that you made a point of trying to be out of town most of the time during Nobel week, but you happened to be in Pasadena that year, and you also mention in *Voyage Through Time* that Dema hadn't slept very well that night. So, I wondered, did you have some sort of indication it was coming that year?

ZEWAIL: Well, there's no question—I would not be saying the truth if I didn't acknowledge that when you get all of these major awards, along with election to societies and so on, that people are expecting you to get the Nobel. But I know of two cases of scientists where every October they don't sleep, and they're waiting for the whole thing and it doesn't come; and it has, in my opinion, ruined their lives. So I tried hard not to do that. That doesn't mean that I didn't think about it. I mean, our breakthrough was in 1987, so the anticipation kept building so that by the middle of the '90s or so, people were saying "this year, this year," and how do I know this? I get letters. People are writing, although they are not supposed to [i.e., speculating or supplying information about the Nobel Prize deliberations of the Swedish Academy of Sciences –*Ed.*].

ASPATURIAN: I know, but I understand that it happens.

ZEWAIL: But they want to be really believing in you and to assure you that you deserve it, that you're nominated. So in the beginning, I stayed here; I said, "Well, maybe it will happen." But then it didn't, and afterward I would run into, let's say, Bob [Robert L.] O'Rourke [head of the Caltech Public Relations Office, 1986–2009, d. 2011], who was a good friend. Bob always said, "These crazy guys, they should have—" You know his personality.

ASPATURIAN: Yes, I remember it well.

ZEWAIL: And then he would say [drops voice to a conspiratorial whisper], "It will be next year." So I felt that it's like I have somebody who passed away, and everybody's sympathizing with me. I told Dema that from now on, around October, I will make sure I am giving a lecture somewhere else. I did this for probably four, five years, and the year it happened was the year I didn't have a specific thing going on elsewhere. That night—I'm trying to remember—we did go to dinner and a movie. Then I slept.

ASPATURIAN: Do you remember what movie?

ZEWAIL: Yeah, it was this movie about when they went to Iraq.

ASPATURIAN: Oh, *The Three Kings*?

ZEWAIL: The Three Kings, yes. And then Dema couldn't sleep. So she went to the garage to get milk for one of our kids, and when she was in the garage the phone rang. So I wake up, I took the phone and then, you know, it was a call, and there were, I think, three members of the Academy [Royal Swedish Academy of Sciences], along with its secretary general, who said, "Congratulations, Ahmed, you very well deserve it." Now, Heidi, after this—well, I was not yet shaved because obviously I had just woken up.

ASPATURIAN: What time of the morning was this?

ZEWAIL: They called, if I remember, about six our time. And my research group, by the way, was always staying up the night before the chemistry prize because they were always quite sure that it's got to be *this year*. And so by the time the call ended, the announcement had appeared on the Web, and I got a call from one of my daughters. The other one could not get through because the line is busy, so I called her, and—"Congratulations, dad!" and all of that. Of course I got calls from Cairo, major newspapers, all of this, so by this time, it's about eight in the morning. Bob O'Rourke has already called David Baltimore, the president [Millikan Professor of Biology; Caltech president, 1997–2006; 1975 Nobel laureate in physiology or medicine], who was on his way to the airport to fly to Washington. So Bob told him, "Turn around; we're going to have a press conference in about one hour."

Zewail in his office the morning of the Nobel Prize announcement, October 12, 1999

ASPATURIAN: I remember getting a call early that morning [from the Office of Public Relations]: "Heidi, come in."

ZEWAIL: [Laughter]

ASPATURIAN: I said, "I am coming in." They said, "Come in *now*."

ZEWAIL: [Laughter] So David Baltimore turned around with the driver and told him, "Go to Ahmed's house," because he knew our house. He came to the house [laughter], knocking on the door, and I wouldn't open it for David because I thought he's a reporter.

ASPATURIAN: This was before the cellphone was so common, so he couldn't call you and say, "I'm out here."

ZEWAIL: Exactly. So then I came to the Ath for the press conference. I had a cold that day; and I said, "The cold is over now; therefore, I recommend the Nobel to cure it." It was a great moment at Caltech, and for Caltech, for all of us, and I mean that, Heidi; we were all just so excited about it. Later, at the celebration dinner at the Athenaeum, I said, and I meant it, that there is no other institution in the world, *in the world*, that can take a young assistant professor and within about eight or nine years, he and his group can do Nobel-prize-winning research.

ASPATURIAN: This is going a little off the narrative, but do you think that is still true?

ZEWAIL: I think on the whole we still try to do this with our younger people, but the atmosphere now at Caltech and in the whole country has changed in the so-called age of information technology. You know, at that time, I knew every single person that I dealt with at Caltech, from the machine shop to the electronic shop to you to everybody. You know me, and you know what I do; you stop by and say "Hi," and this kind of thing. Nowadays, it's different. I think, relatively speaking, maybe this is still possible at Caltech because of our size and everything, but—I was so lucky.

ASPATURIAN: In your timing?

ZEWAIL: I was so lucky in my timing in that I come here and form a group with an empty lab that was not even painted yet and a small office next to my lab. This was in 1976.

ASPATURIAN: And within a decade—

ZEWAIL: A decade because, as I mentioned to you, '87 was the year of the critical work that was cited by the Nobel committee. A decade. Unbelievable. At other institutions, it might take twenty years, thirty years. As a matter of fact, that's consistent with the Nobel, because if you look even this year at the laureates, one of them is eighty-five. The lady from China is past eighty [Youyou Tu, 2015 Nobel laureate in physiology or medicine for the development of "a novel therapy against malaria." *–Ed.*]. I mean, you wait. You wait until you receive this in thirty, forty years. So, Caltech. I was just so fortunate. So fortunate.

ASPATURIAN: Were either of your parents still alive at the time you won?

ZEWAIL: Yes, my mother was. Of course what she saw is how the Egyptians were receiving me. She was just in awe. [Laughter] We never expected this.

ASPATURIAN: Was your uncle still alive, your mother's brother?

ZEWAIL: No, that's sad.

ASPATURIAN: That's so sad.

ZEWAIL: I would have loved to have him here; he would have come to Stockholm.

ASPATURIAN: What was the reaction in Egypt and throughout the Arab world?

ZEWAIL: About the Nobel?

ASPATURIAN: Yes, of course.

ZEWAIL: I'll tell you one thing: I was in Stockholm, and Egypt's ministry of information sent some of their top interviewers. And they bought the time on the air to broadcast the entire event from Stockholm. Now that costs tons of money. I'll tell you what they told

me. They said that during the award ceremony you could not find people on the street because everybody was glued to the television or the radio, just like when Umm Kulthum had a concert. [*See Session Four*] [Laughter] And I think this was true. I don't think this was exaggerated because they had been under a horrible system for a decade. Mubarak had not really been the greatest in the last ten years or whatever, and people are feeling, "Look, this is *Egypt* and it deserves more than that." And all of a sudden—

ASPATURIAN: I understand.

ZEWAIL: There is a ball of fire here somewhere; everybody lights up. And they did. And when we arrived at the airport, there was such a crowd that we could not get out. My kids were so scared because there were tons of people and cameras at the press conference. They immediately told me that I would get the Grand Collar of the Nile.

ASPATURIAN: Yes, we'll get to that.

ZEWAIL: And as you know, this is the highest honor of Egypt, only given to kings and presidents and people like that. Everywhere that I went, honorary degrees, from Alexandria, from everywhere—it was all over the country.

ASPATURIAN: I was amused by your account of, how in Stockholm your younger son fell asleep during the award. Your older son got so exasperated he called you a chicken, I think.

ZEWAIL: [Laughter] Okay. The younger son, Hani, it was unbelievable. He was sitting next to his mother while all of us were on the stage receiving, one after the other, the honor. For some strange reason, according to his mother, he was awake the whole time; it was only when I stood up [laughter] that he went to sleep. So today I still give him a hard time about that. But before I went to Stockholm, Nabeel, the older one, was with me when I was invited by the Caltech trustees to their meeting at Palm Springs. You know, they were celebrating us and saying very complimentary things. On our way in to the dining area, Harold Brown [professor of physics; Caltech president, 1969–1977]—

ASPATURIAN: The president emeritus.

ZEWAIL: Right. He and I were walking together, and Harold was talking about Caltech—you know, he's one of the brightest minds I ever met. Nabeel was young, and he kept pulling my jacket sleeve while I'm trying to talk to Harold, and finally I said, "Don't do that." He looked at me and said—how did I write it? "Dad, you stupid chicken," or, "You're a bad chicken."

ASPATURIAN: "You're a dumb chicken."

ZEWAIL: That's the word—"Dad, you are a *dumb* chicken."

ASPATURIAN: Where did he come up with that turn of phrase?

ZEWAIL: I have no idea, but it was so cute that I wrote it in my autobiography. So Harold looked at me, and he said, "Ahmed, you're just a dad." And he's right.

ASPATURIAN: I also liked your description of the email proposal of marriage that arrived for your daughter Amani. Complete with CV, I think you said.

ZEWAIL: Right, after the prize was announced. It was from a dentist in San Francisco.

ASPATURIAN: A dentist?

ZEWAIL: A dentist in San Francisco. He was very serious. He wrote to me. He sent the CV. And then I used this, boy, to irritate my daughter.

ASPATURIAN: How old was she?

ZEWAIL: At the time, maybe eighteen.

ASPATURIAN: A little young to be considering marriage to a dentist in San Francisco.

ZEWAIL: Right. But then I irritated her by saying, "Oh, I agree with this because it'll benefit my teeth." [Laughter]

ASPATURIAN: At the time, after you had won the Nobel, what was going through your mind in terms of what it might mean for you personally, professionally? What were you thinking once you had a chance to clear your head?

ZEWAIL: To be frank, I knew I had to decide what it is I am going to do next.

ASPATURIAN: Okay. It's interesting that you thought of it that way.

ZEWAIL: Yes. Because I am one of these guys who likes to be clear in my mind. And so I had a choice. I can go to all kinds of dinners and speak about the weather in Africa and this and that, and stop science, basically. I think people will forgive me for that. They will say, "He's done enough." But I didn't feel like doing that. I was fifty-four. I said to myself, "This is not me, I have to work." So I decided on three things. One: "I want to continue with science, but I have to find a new frontier. That's Number One, and that I will do at Caltech." [*See Session Six*] Two: "I want to help Egypt and the region." And that really was important to me, and I felt that the Nobel would help. It can open new doors; it can help with presidents and emirs and all of that. And the third thing that I enjoy, in the entire Western world as well as in the East, is giving lectures to the youth. I enjoy showing them the beauty and the power of science. And so I did that all over the world, from Asia to Europe to the Middle East to America; everywhere I did that. If you look at my list of invited lectures, it is just all over the map, and it's not scientific only. And so these are the three things that I decided on. And right up to today, I am very content with that.

ASPATURIAN: Your acceptance speech was lovely. You wrote that yourself?

ZEWAIL: Oh, absolutely.

ASPATURIAN: I thought it was very interesting that you began by noting that the goddess Isis was the prototype for the figure on the Nobel medal. ["Let me begin with a reflection on a personal story, that of a voyage through time. The medal I received from his Majesty this evening was designed . . . to represent Nature in the form of the Goddess Isis—or eesis—the Egyptian Goddess of Motherhood. She emerges from the clouds, holding a cornucopia in her arms and the veil which covers her cold and austere face is held up by the Genius of Science." http://www.nobelprize.org/nobel_prizes/chemistry/laureates/1999/zewail-speech_en.html]

ZEWAIL: I looked it up because I was intrigued. I thought this is something significant, and when I looked it up, I thought what a great story.

ASPATURIAN: Yes, very appropriate. You were awarded the Grand Collar of the Nile the following year?

ZEWAIL: No, in the same year. The same year as the Nobel.

ASPATURIAN: So it must have been toward the very end of the year.

ZEWAIL: On December 10th, I received the Nobel. I believe it was December 20th that I received the Collar.

ASPATURIAN: In your acceptance speech for that, you seem to have laid out a number of themes that went on to be the backbone of what you've been doing for the last fifteen years.

ZEWAIL: Exactly.

ORDER OF THE GRAND COLLAR OF THE NILE ADDRESS

Ahmed Zewail, December 1999
Presidential Palace, Cairo

Your Excellency Mr. President, Mrs. Mubarak; Mr. Prime Minister; distinguished Ministers, scientists, and guests:

Kull 'am wa-antum bi-khayr [Greetings] *on the special occasions of the holy month of Ramadan, the blessed Christmas, and the beginning of the seventh millennium in the history of Egypt. This is a day I will cherish forever. It is a great honor for me to stand before you to receive the Order of the Grand Collar of the Nile, the highest decoration in our beloved Egypt. This honor symbolizes an award to all of science and to all fellow scientists.*

I left the country more than a quarter of a century ago, and from the beginning my goal has been to acquire knowledge—knowledge of science and the universe. The awarding of the Nobel prize in the sciences—a first in the history of Egypt and the Arab world—underscores what the people of this nation can achieve on the international level, if they have the proper milieu for utilizing their skills and abilities.

I am only one of the many sons of Egypt, inside and outside the country, who have made significant advances in science, medicine, literature, art, economics, politics, and other fields. Ever since the dawn of history, Egypt has continuously contributed an enormous amount to the world's store of knowledge.

As I said earlier this month in Stockholm, if the Nobel prizes had been awarded six thousand years ago at the beginning of Egyptian civilization, or even two thousand years ago when the Library of Alexandria served as the beacon of knowledge to the world, Egypt would surely have received a significant portion of these prizes. Nor can we forget the pivotal role played by Arab scientists, whose research was like a shining torch for the dark pre-Renaissance age in Europe.

Mr. President, with this honor you have reconfirmed your strong desire to develop and support the sciences in Egypt. The world today stands on two primary supports that are the foundation for power, influence, and progress. These two supports are advanced scientific knowledge and the productivity of the people in line with this knowledge base. The developed world of today relies on science and productivity to change

the standard of living and to be positioned as a world force on this planet.

For developing states to attain a similar level of progress and development requires the building of a science base and a scientific culture. With these keys, it is possible to escape the "import mentality," the trap of relying on importing goods only for consumption, and it is possible to join in technological competition with the outside world in the new system of globalization. Such a powerful scientific base needs true and unified participation—the Egyptian people need to believe in the role of science in creating a new and advanced position for the country.

Egypt now has the ability to take that great scientific and technological leap forward that will boost it into the twenty-first century, because of the success of your wise leadership, Mr. President, in courageously embarking on the difficult task of building the infrastructure and strengthening Egypt's political position in the world. In my opinion, the scientific renaissance in the time of President Mubarak has an important historical dimension for prosperity and peace for Egypt and for the Middle East. It is the foundation for preparing healthy generations in a society that can be guided by rationalism and can cope successfully with the age of globalization.

Mr. President, the telephone call I received from Your Excellency at my home and the thousands of messages I received from the people of Egypt and from the Arab world, after the announcement of the prize, have kindled in me feelings of joy and pride in belonging to this nation. In many of these letters and in meetings with young people, I noted an overwhelming thirst to acquire knowledge and achieve excellence on the international level. For the sake of these national treasures—our youth—I hope that I can help by encouraging them and by inspiring them to the benefits of science as a means to serve the country and humanity at large.

I have been honored by many scientific and international organizations for what I have achieved with my research group at Caltech, but the honor I am receiving today has a special meaning for me. It underscores the strong bond I have to this great country. It also opens wide the doors of hope for a renaissance in scientific and technological development in Egypt. This is not much to ask for such an ancient country, whose historical roots have blossomed into many great civilizations. Moreover, Egypt has multitudes of capable people eager to achieve at the best level possible. Although the complete scientific base

is not in place at the present time, I am sure that within a very short time it would be possible to establish it on a world-class level. When this scientific and intellectual power is achieved, it will become the base for a modern renaissance, which will be not less than that which took place in Europe and Asia, where science played a dominant role in leading those nations from the dark ages into the luminous age of science.

Mr. President, I cannot find words that can express my real feelings to thank you for such a special honor. I can only offer you my sincere gratitude, and hope that Allah will protect your work and achievements for the betterment of our beloved Egypt. I would also like to convey my sincere thanks and appreciation to the loyal people of Egypt. Finally, I believe that we all should work together as a team with persistence and integrity and with a positive and optimistic attitude to raise high the flag of Egypt, the mother of civilizations, among the civilizations of the modern world.

TRANSLATED FROM THE ARABIC, FROM *VOYAGE THROUGH TIME: WALKS OF LIFE TO THE NOBEL PRIZE*

ASPATURIAN: Was this your first extended acquaintance with Mubarak?

ZEWAIL: Yes. And in fact it was during that time, between the Nobel and the Grand Collar of the Nile, that I saw him twice. I showed him the overall plan that I had for what is now being called Zewail City.

ASPATURIAN: And how did he react to that?

ZEWAIL: Well, you know in the beginning, he was very responsive. He was very enthusiastic about the idea. He knew very well that I had thought of it, but then when politics got into it, and I had the popularity, he wanted to have his son in that popular position. Then there was a clash.

ASPATURIAN: What were your initial impressions of Mubarak? He was quite a bit older than you, I think, and had been in the job for a long time.

ZEWAIL: Oh, yes, oh, yes. Well, you know, in my opinion, he's solid. Not necessarily brilliant, but solid. He is patriotic. He fought in the military. He worked very hard in the Air Force of Egypt. I also believe that in his first ten years as president he worked very hard to improve the infrastructure of Egypt. The water, the electricity, all of these things. He's not Nasser. Nasser—if he just appears on a stage, the impact is immediate. But Mubarak was a hard worker. I think his failure was mainly in the last ten years—and I wrote this in 2011 in an op-ed in the *New York Times* ["Egypt's Next Steps": http://www.nytimes.com/2011/02/03/opinion/03iht-edzewail03.html] when I ask him kindly to step down from the presidency. I think it was Mrs. Mubarak who got it into his head that his son should be the president.

ASPATURIAN: That he would be the founder of a dynasty.

ZEWAIL: And I think he didn't do much of anything during that period, and he became inactive and then as you know happens in any political system, the group around him—

ASPATURIAN: Everyone ossified.

ZEWAIL: Exactly.

ASPATURIAN: The idea for what became Zewail City, which you proposed to Mubarak in 1999—how long had this kind of been percolating in your thinking before you raised it with him?

ZEWAIL: Before I went to him? I'd say about five years. I was waiting because I had to formulate it right. And in fact, I have documentation about many prior trials of first trying to do something with different universities and organizations.

ASPATURIAN: You thought first in terms of liaisons between Egyptian and other universities?

ZEWAIL: Yes. But then from 1999, it took fifteen years—and I'm after it. I wasn't "sleeping." I was fighting for it, giving lectures to the public about it. But, of course, I never said "Zewail City." I was talking about building the science base—that's the word I used until, I must say, the revolution of 2011.

ASPATURIAN: What initially did you outline to Mubarak that he was enthusiastic about?

ZEWAIL: I told him that there is no way just by creating another university that you would be able to change the climate of research and development in the country. And that what Egypt is most fortunate in are its human resources. But in order to capitalize on this, we need a first-rate science and technology university, such as MIT or Caltech. Of course Caltech was the one really in my mind, but also the idea of research institutes, à la the Max Plancks. I said that this model is what will serve the country and its needs in the best possible way. And as part of that, we will create a technology park that will take all of these discoveries and send them out to modernize Egyptian industry. And he liked that very much. He liked the vision. It wasn't just "let's build another university."

ASPATURIAN: Did you feel at the time that realizing such a vision would also require an overhaul of the secondary school structure in Egypt to serve as an appropriate feeder for that kind of higher education?

ZEWAIL: Now you're really touching on things that I thought about a lot. I realized that if you try to go tomorrow and say, "We want to restructure all secondary schools, high schools, and so forth," A, you don't have money for this; and B, you already have a situation that's not perfect. And to fix it, you're going to have all kinds of forces against you. So I had the idea to do this in steps, first to create what I called a center of excellence and make it a beacon to shine and *then* bring in teachers and high school students and help them in the summer and all of that. Slowly but surely, you will be changing the culture around education, and the transformation will be much easier, and money will be much easier. Because, you see, now you have set up the standards. In fact in Zewail City, right now, we have standards of tenure that are very strict, and if you go there and visit, it's like Caltech. It's not like the air conditioning is not working and the

scientists can't do their experiments, no, none of that. Everything is moving forward, because I wanted to make sure that when somebody comes from another university and visits there, they learn immediately what it will take to publish in let's say, *Science* and *Nature* and make a real impact. So I have a plan for the high school and the secondary school level too, and I'm almost confident that it will work, but first—

ASPATURIAN: You wanted to establish a model at the higher level.

ZEWAIL: A model. And that's why I'm waiting for these two hundred acres. The size of Caltech. A new campus of Zewail City.

ASPATURIAN: Is this in Alexandria? Or Cairo?

ZEWAIL: Cairo.

ASPATURIAN: Why did you choose Cairo rather than Alexandria?

ZEWAIL: Because no matter what we do in Egypt, it's the capital.

ASPATURIAN: I see, I see. It's just the mindset.

ZEWAIL: Mindset. Exactly. So with the new campus, I have a feeling we can help education countrywide.

ASPATURIAN: For many scientists, the Nobel Prize is the pinnacle and—you know—after that they don't think in terms of new realms to expose themselves to. In your case, it seems to have been precisely the opposite.

ZEWAIL: You know why? And you can ask my family, but I'll summarize it to you: I don't look at my CV. I just don't. In other words, I'm still young enough at heart to get excited over a paper I'm writing or a small discovery and so on. It is not like I have focused all this time on putting things on the CV, and now that's finished.

ASPATURIAN: I think it's interesting that for you, this very major award seemed less like a peak accomplishment than a peak opportunity.

ZEWAIL: Exactly. It is a *peak* opportunity. You put your finger on it. It is true. That's why when scientists, even including Richard Feynman, say, "I wish I didn't get this prize," I don't believe that, really. The reason I don't believe it is not that they are lying or anything; it's just because—look, you can also do something with it. I wouldn't be able to see, for example, the prime minister of South Korea and learn something useful if I didn't have it. So don't tell me that there is no opportunity there. No, I feel that it's a peak opportunity.

ASPATURIAN: Okay.

ZEWAIL: Sounds good!

ASPATURIAN: Nice session.

Some material in this session was originally recorded during Session Six.

AHMED ZEWAIL

SESSION 6

October 20, 2015

ASPATURIAN: In Voyage *Through Time*, as you talk about femtochemistry and ultrafast sciences, one of the things you say is, "Originally I did not expect a rich blossoming of this field." When did it begin to occur to you that you could move in so many new directions using this new technology?

ZEWAIL: Well, you know, in our business, it is not sufficient for you alone to be doing the science. In order to really have an impact, you have to see that many other laboratories around the world are using your ideas and the field itself, to the point, for example, that there is an international conference on the subject of femtoscience and femtochemistry and femtobiology. And an international conference *is* now happening every other year, and it has been fantastic—rotating around from Spain to Switzerland to America. The next one will be in Cancun [Mexico]. All of that. So you have to have the impact beyond your own group, but in the beginning I didn't see perhaps the speed at which this was going. At the time that the femto research was really ramping up, there was an analysis that, I think, showed that our research group was getting the highest number of citations per paper or something of that nature. But at the start I didn't see how fast it was going to go, and now it's everywhere.

ASPATURIAN: After you got the Nobel, did you immediately begin to work on the ultrafast electron microscopy? How did that come about exactly?

ZEWAIL: Well, actually, it also evolved. Because I was really excited. You see, just to explain it—with the femto observations, in a way, we're controlling the time for the process. But we couldn't see how the atoms in space are organized. So it's like I know that Heidi came across the 210 Freeway to here, let's say in ten seconds.

ASPATURIAN: That would have been nice.

ZEWAIL: That would have been nice, right—in ten seconds. So I measured your time because I know when Heidi started and when she ended, and I can time that with our new techniques. But I don't know anything about what happened during this process. Did Heidi stretch her hands? Did Heidi sit down on a bench somewhere for a fraction of a second? Because I didn't see what we'll call the space part of it—the shape of what you have done in space. So by the end of the 1980s, what's in my mind is that we have achieved visualization of the temporal behavior, but what I was after now is to get the joint temporal-spatial—what in physics we call the space and time element. And that is the fundamental level, that's the end of it. That's why you see us calling it four dimensions in a lot of books we publish. As you know with physics, any point in space is defined with X, Y, and Z. Once I know those, I can draw the map on you. You see? So, by 4D, we mean we have the three points in space, and of course we have the time, which we already know how to record, so then it's four dimensions.

ASPATURIAN: Did this concept occur to you in the way you have just outlined it to me? Did it come to you mathematically? Did it come as you were considering the potential applications of the technology?

ZEWAIL: I knew—and I said it at the end of my Nobel paper [i.e., in "Real-Time Femtosecond Probing of 'Transition States' in Chemical Reactions," the 1987 paper cited by the Swedish Academy] that if can get the space aspect as well as the time, then this will be another stride or giant step forward. And I think, quite frankly, it's the ultimate step. So the question, then, is how did we into this? We started in a modest way: In the year 2001, which is two years after the Nobel, we published a paper in *Science*.

ASPATURIAN: You and your team?

ZEWAIL: My research group. We published a paper ["Direct Imaging of Transient Molecular Structures with Ultrafast Diffraction," *Science*, January 19, 2001] that was the beginning of us saying we now can get the structure. By structure, what I meant here is a spatial arrangement. We now can get the structure of a very small molecule that's undergoing an elimination reaction**.** We were not yet at microscopy, and it's quite

remarkable how the microscopy came about. I'm not sure how much detail you want me to go into.

ASPATURIAN: I think for the purposes of this, an overview would be good. And I'll ask questions.

ZEWAIL: Right. So we made this observation.

ASPATURIAN: You were able to do this without the microscopy?

ZEWAIL: Without the microscopy. We used diffraction.

ASPATURIAN: I see. And it pointed the way.

ZEWAIL: It pointed the way, exactly. So we were able to observe molecules in the gas phase; they are not interacting with each other. And then we did crystals, also guiding the way. Finally, one day, we were thinking about doing the microscopy, but we thought first of doing it with diffraction; that's what we knew. It didn't work. The microscope was not focused, and we couldn't get it to do it properly.

ASPATURIAN: Was this a microscope you already had?

ZEWAIL: Yes. I was so grateful at the time that I had written a proposal to the Moore Foundation. Because by the time you have everything you need with these microscopes, it's costing about $2 million. Very expensive. And granting agencies don't fund at that level. I remember, Gordon Moore [chair of the Caltech Board of Trustees, 1987–97; trustee chair emeritus] was visiting Caltech, and he attended a presentation I gave. And he said, "Can you do this with funding from the government?" Then he answered his own question and said, "I don't think so. I don't think the government will support you for what you're dreaming about."

ASPATURIAN: When was this presentation: 2001, 2002?

ZEWAIL: No, now we're moving to about 2005. [*See also Session Seven*]

ASPATURIAN: So this was after you had demonstrated that it was possible to look at very small molecules using your technology?

ZEWAIL: And also looking at very small crystals. Using diffraction. And then I gave a presentation in which I said that if we can do this with microscopy, that will open up possibilities in materials science and biology.

ASPATURIAN: That was a very big moment. That was also the year the physical biology center [Physical Biology Center for Ultrafast Science & Technology] was established here.

ZEWAIL: That's exactly right. I think the funding started in 2006 with the Moore Foundation support. But what I wanted to say is that the microscopy techniques conceptually did not work the same way as this guiding approach that we had been doing with the diffraction. There is a good reason for this. What we were doing involved electrons, and electrons are all negatively charged and therefore they don't like each other, they repel. Finally, it occurred to us that if we can lower the number of electrons to only one, I wouldn't have them repelling each other.

ASPATURIAN: Were you the only group in the world working on this?

ZEWAIL: Oh, yes. And in fact when I coined the phrase "four-dimensional electron microscopy," I wanted this to be patented, and we got the first patent on this. That concept was developed completely at Caltech, and the patent ["4D Imaging in an Ultrafast Electron Microscope"] was granted in June 2012. Prior to that there was also this other patent, "Method and System for Ultrafast Photoelectron Microscope." That's the one that was granted to me and postdoc Vladimir Lobastov in 2006.

ASPATURIAN: Why do you suppose no other institutions rushed immediately ahead this way? They did not have the intellectual or instrumental foundation that you did here?

ZEWAIL: Well, it's the combination of things that you have to have. Of course, after it works—

ASPATURIAN: That's a different story.

ZEWAIL: That's a different story. Our technique of using only a single electron was so powerful that it extended the regime of time and space to where we could go to even the femtosecond or attosecond timescale and take the space parameters to a picometer. So there was the potential to do all of these applications, and they have now been done.

ASPATURIAN: The single electron is a much more powerful probe because there's no mutual repulsion involved?

ZEWAIL: Exactly. And that's why *Scientific American* asked me to write about this ["Filming the Invisible in 4D, *Scientific American*, August 1, 2010], and you can see that here every single electron is recording. So we had, I think, this clever idea to build up the image by avoiding the repulsion that exists between them. *Science* magazine also asked me to write about this. I must say they were wonderful, those guys in *Science*. So the core of this, the key concept, is single-electron imaging in space and time. So this was the idea.

ASPATURIAN: When you named the center the physical biology center, had you already begun working with biological molecules?

ZEWAIL: Yes. In 2007 I had the Welch Conference in Houston ["Physical Biology: From Atoms to Cells," 2007], where we invited people like David Baltimore and Lee [Leroy] Hood to reflect on where biology is going, where physics is going. I had a wonderful collection of papers, and in 2008 we published them in the book *Physical Biology* [*Physical Biology: From Atoms to Medicine*, Imperial College Press, 2008]. I was quite sure that the impact would come when we began to image the physics of biological systems.

ASPATURIAN: What was the first biological system you imaged, and when, do you remember?

ZEWAIL: I think the first one was to show that we can image a whole cell. I would say maybe around 2007.

ASPATURIAN: It was again to demonstrate that you could do it?

ZEWAIL: To demonstrate that we could get a whole cell. Now I think we have three of these microscopes downstairs. My former postdocs and graduate students are professors and assistant professors all over the world, and they are building these technologies, which gives me pleasure. I count here maybe about twelve places where this work is under way. FEI, the major industrial company for producing microscopes, has now licensed the technology from Caltech and is selling it all over the world. I'm so pleased, because Caltech's name is there as the pioneer of this whole technology.

ASPATURIAN: The students and the postdocs who collaborated with you over the years on this remarkable science—did they come to you or did you choose them? I mean you obviously had an exceptional group of people working with you for decades.

ZEWAIL: I did. I did. Heidi, I consider myself lucky because it is known about me at Caltech that I'm a serious scientist. It doesn't mean that other people don't do great science, but there are people who do it with a different style. It is *known* about me that I'm serious and that when you write a paper I like, I will sometimes have you go up to ten or twelve versions of the paper. It's well known about me. But science is serious, and we can't be loose with it. It requires energy and seriousness. But I have been very fortunate. I will complete forty years at Caltech next May—four-zero. And I have had students and postdocs of the first class—close to four hundred people.

ASPATURIAN: Did you choose some of these yourself, or did they mostly come to you?

ZEWAIL: Well, the way it works is that they apply. In fact, just before you came today, I was sitting with De Ann [De Ann Lewis, administrator, Physical Biology Center, 2003–2016] going through stacks of applications, and we made offers for two postdocs, who are coming—right away—and we're looking at another two. They apply. And here's the beauty of it: As you know I have interests in science and in public affairs. When I talk about science, it's easy. When I talk about public affairs and what I believe should be done in the world, I show a slide with all of these 400 names and the countries they came from, all over the world; and then I say, "That's the beauty of science. If this was about politics, Country A would be against Country B, and this guy should not be here, and so forth. But look at what we can do at a place like Caltech, with scientists from the Middle East to Europe to Asia to America." No, I have been very, very fortunate so far in the years I have been here. I have to say when they are here, they feel they are working hard, and the attitude is "we have to be careful," because I am a *very serious* scientist, but I get a lot of letters afterward. It's like your children. [Laughter] I get a lot of letters saying this was the best time of my life—to be at Caltech.

ASPATURIAN: Do you have particular qualities you look for in the people you decide to work with?

ZEWAIL: Yes. Obviously if you apply to Caltech, you are scholastically one of the top people. But I look for a touch of creativity, if I can. I also look for abilities. And the last thing, which I tell even my own children, is this: You could be brilliant, but if you don't put in the energy, the output is zero. So I look for people who are dynamic and hard workers because in the end that will produce the best for them and for us.

ASPATURIAN: Have there been particular standouts over the years whose names you'd like to put into the record?

ZEWAIL: Oh, it's a huge number, just in academia alone. I have former students and postdocs who are now professors in Chicago, Princeton, Duke, everywhere. They're all successful people. And it is nice they either continue on with the research we've done here, or they branch out into medicine, into other fields. I'm proud of them.

ASPATURIAN: In 2008, I believe, you designed a new microscope with two lasers. I was reading about this. How did that expand the field?

ZEWAIL: Well, once you got the principle—proof of concept—then the branching is huge. If I show you how many techniques we wrote about and published after that, and in very reputable places—*Nature*, *Science*, *PNAS* [*Proceedings of the National Academy of* Sciences], many of the frontier journals—you can see how the branching then becomes ideas coming from all over the place. There was something else we did that was really interesting and which I show in many of my lectures. The Kavli [Nanoscience] Institute here built a nanoharp and a nanopiano.

ASPATURIAN: Out of what?

ZEWAIL: Out of silicon let's say. And you have these keys where you vary either the width or the length, and when we activate this with a pulse, we see the keys working. This is on the nanoscale. And then we can control the keys; we can make a single key go up and down. So the applications are all over.

ASPATURIAN: What has been the reaction among biologists to the introduction of these technologies and the potential impact on their discipline?

ZEWAIL: I think that people who are used to looking at the big picture have been quite excited about the approach. For example, David Baltimore, who was the president of Caltech at that time, said, "This is terrific; you have to go for it." But if you come into contact with the people who are working day and night in these areas and are accustomed to using other methods in their research, they would like you to help answer very specific questions they are investigating**.** That has not happened yet. It takes time. It takes time.

ASPATURIAN: Do you now have biologists per se working with you as graduate students and postdocs?

ZEWAIL: Yes. I have tried to get them for the biological applications. We now have three areas. We have biological applications, materials applications, and then we have the development of new techniques.

ASPATURIAN: In the materials area, I was interested to read about your imaging of graphite.

ZEWAIL: To give you an idea, suppose in the microscope, you have succeeded in visualizing with a single electron graphene or graphite, sitting like this [gesturing, to indicate layers]. Well, we can get a lot of data and publish it. But then you come up with a technique where, if you rotate the microscope continuously, you can image the object in three dimensions. And that's called tomography. That's what they would do for you and myself if they were to take a picture of the heart for example. They will rotate the detector around you, and that becomes 4D tomography. Our paper describing that technique was published in *Science* ["4D Electron Tomography," *Science*, June 25, 2010]. So the techniques come one after the other to complete the story of what to do with this microscopy.

ASPATURIAN: Are there institutions now that have gone into this in a major way with the laboratories and the research groups?

ZEWAIL: Oh, yes.

ASPATURIAN: And I imagine you collaborate with them now, too. They are all headed by your former students?

ZEWAIL: That's the point. It's ongoing with my former students, and they are all wonderful. I have a guy in Switzerland. Here, you see, [reading] "a timely invitation by Imperial College Press to publish this monograph is appreciated as the field is now well established, with laboratories around the world, including those in Minnesota, Purdue University, Harbin [China], Osaka [Japan], Giza [Egypt], Luzon [Philippines], Göttingen [Germany], among others . . ."

ASPATURIAN: Everywhere.

ZEWAIL: So, yes, it's spreading. And, of course, some of us have new ideas, and others will follow.

ASPATURIAN: I found a quote of yours in which you talked about the 2008 "second-generation microscope" as a universal microscope, calling it much more versatile. What are you doing now? What is the state of the art with this new versatility?

ZEWAIL: Well, the real state of the art—it's interesting that you mention that—is in a paper that we just published about a week or two weeks ago. In this paper we describe photon gating in 4D electron microscopy.

ASPATURIAN: Photon gating?

ZEWAIL: Gating. That means—what? It means the way we photograph something; just to simplify, let's say graphene or graphite. Initially we send a light pulse to the material. Its atoms respond by starting to move and vibrate, but then at the same time, you send an electron pulse and that electron pulse is the one that's doing the imaging. So the two pulses meet with each other, and we know exactly when they meet and when they separate. We can determine this in the laboratory. But in the past there was no control on the electron pulse in terms of its width. It was always determined by many factors in the microscope. But we found that if in addition to the light pulse that excites the material, we send another timed light pulse that comes at exactly the same time with that electron pulse, together—

ASPATURIAN: You pin the electron pulse.

ZEWAIL: Right. So we can now gate it.

ASPATURIAN: I see. That's what the gating is.

ZEWAIL: We can now gate it. Then, at that point, we have an electron pulse of a very well defined, narrower width, which we hope can take our observations down even to the attosecond.

ASPATURIAN: That's faster than the femtosecond?

ZEWAIL: That's faster. It's a sub-femtosecond.

ASPATURIAN: What kind of processes would that allow you to study?

ZEWAIL: Electrons in materials. So, for example, you can kick out an electron from the material you're looking at and see how long it will take it in space and time to propagate.

ASPATURIAN: One thing that caught my eye in the *Scientific American* article was that you mention the utility of these techniques in studying photosynthesis. Have you done that?

ZEWAIL: No, I haven't done that.

ASPATURIAN: I just thought that was very interesting. You said the photon kick that starts the process is in the femtosecond regime.

ZEWAIL: No, we haven't done that. The one, to be frank, that I have my eye on and where we have already started observing a number of systems—small systems—is the so-called protein folding.

ASPATURIAN: Oh, yes, that's a very interesting field.

ZEWAIL: Trying to understand how these thousands of atoms behave, how they unfold and fold. I also wrote about this in the *Scientific American* piece. So this is what I have my eye on.

ASPATURIAN: What specific processes or substances are you looking at with that?

ZEWAIL: You know, a major disease called Alzheimer's—

ASPATURIAN: Yes. The amyloid plaques—they think these are related to misshapen proteins.

ZEWAIL: Misshapen proteins. I had a postdoc from Cambridge, Anthony Fitzpatrick, who's a neuroscientist working on this, and we published two papers.

ASPATURIAN: He's looking at the beta amyloid plaques?

ZEWAIL: He looks at the amyloids and how they change as a function of time. Our hope is to understand why they aggregate for example—that's a very interesting question—and how stiff they are. We can now measure that.

ASPATURIAN: So these are direct biomedical applications?

ZEWAIL: Oh, yes. And we are proud of it.

ASPATURIAN: Before we close out this portion, where do you see this field that you invented going? Where would you like to see it going?

ZEWAIL: I think particularly in these two areas—one in the biological sciences, and the other in the whole nanoscience of materials. That's where I see it going. Really with the nanoscience, we want to study how things behave. We can make nowadays a lot of nanostructures, but we don't know how they function.

ASPATURIAN: With that level of sensitivity, do you think these techniques could also be used to help design better nanomaterials?

ZEWAIL: Of course. Right. Absolutely. Because as you know, once you understand the concept and the phenomenon, then the ability to control the design always follows—and then the designers follow.

ASPATURIAN: To customize nanotechnology.

ZEWAIL: To customize because then you can say it's better to design with this or that frequency, and so on.

ASPATURIAN: Ah-ha.

ZEWAIL: So we are very excited about this second field.

ASPATURIAN: Do you have biomedical funding now for this?

ZEWAIL: Besides the Moore Foundation, we initially had a grant from NIH [National Institutes of Health]. It was divided between me and another colleague here, but we really did not continue with it; we just stopped. I think what I would like to do, once we get heavily into some of the biological research that we have in mind and into the biomedical sciences, is to get a major grant from some private foundations, because I'm afraid that government support of basic research is not what it used to be.

ASPATURIAN: Are you collaborating with any biologists here at Caltech?

ZEWAIL: We get a lot of help from my colleagues in biology—Rob Phillips [Morris Professor of Biophysics and Biology] and David Baltimore and other people—because there are things we don't know sometimes. For example, we are working on a virus, and we don't know how to handle these samples, so we have to go to the experts and see what they tell us. That's the beauty of Caltech, actually.

ASPATURIAN: Well, your work has evolved into very interdisciplinary undertakings, but I suppose Caltech made that easier?

ZEWAIL: Much easier.

ASPATURIAN: Would you like to move on and talk about some Caltech personalities?

ZEWAIL: Sure.

ASPATURIAN: I have a partial list here. Maybe we can start with some of your chemistry colleagues, Harry Gray, for example.

ZEWAIL: Well, Harry's always great fun to have around. [Laughter] I remember one time I had an offer from outside, I think it was Chicago, and I was thinking about it, and Harry was the division chairman at that time. So he came to me. He puts his hand on me—you know Harry.

ASPATURIAN: Yes, I do.

ZEWAIL: He puts his arm around me, and he says, "Oh, you can't go. I know your salary is low, and it really should be like Feynman's." Now, at the time, I was like an assistant professor or something, and I knew of course I can't be earning Feynman's salary. [Laughter] So that's Harry. He really makes you feel good. He's a lively person around our division, and he's also always thinking of what's best for Caltech. That's Harry. [*See also Session Three*]

ASPATURIAN: Have you ever collaborated with him?

ZEWAIL: No, not with Harry.

ASPATURIAN: You're working in rather different areas. Rudy [Rudolph A.] Marcus [Kirkwood and Noyes Professor of Chemistry; Nobel laureate in chemistry, 1992], whom I believe you've mentioned in the past.

ZEWAIL: Rudy is close in terms of our interactions over the years. As a matter of fact, I like to take credit for bringing Rudy here.

ASPATURIAN: Oh, would you like to tell that story?

ZEWAIL: I met Rudy when I was looking for a job as an assistant professor around the country. [*See Session Three*] The system was different from nowadays where you have people applying for hundreds of positions. In those days my advisor was saying apply to the top six or something.

ASPATURIAN: I remember you saying that your Berkeley advisor was very helpful in this.

ZEWAIL: One of the places I visited was the University of Illinois. Rudy was there, and I had a terrific time with him. I mean, we spent the whole time talking science, and the exchange was quite rich. And so after Caltech hired me, and it was, I think, around the time I received tenure that we were thinking about recruiting a theoretical chemist. About three or four names came up, and one of them was Rudy. I was just so excited about it, and so I was involved in the dinners and in having [his wife] Laura visit here, and the talks he gave and so on. And since then, really, our relationship has been warm and based on respect. I knew that his work one day would get the Nobel Prize, even if he got it at the age of, I forget now, but was probably sixty-something.

ASPATURIAN: It was 1992. Yes, I remember writing the article about it.

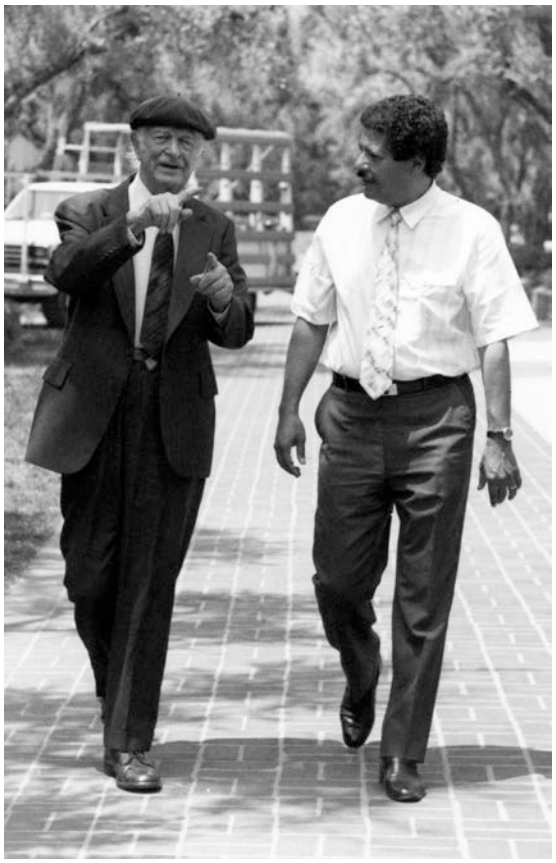
ZEWAIL: I knew it would happen, and I knew his work quite well. Likewise, he was aware of my work was and very sure that *I* would get the prize. There's the fact also that he's hardly a meter from me to the left [i.e., just down the hallway], so we can always talk. It has been a wonderful relationship.

ASPATURIAN: Was it hard work to get him to come here?

ZEWAIL: No. Because A–why live in the Midwest? And B–it's Caltech!

ASPATURIAN: And Southern California, also a lure.

ZEWAIL: Right.



On the occasion of Zewail being named the Linus Pauling Professor of Chemical Physics July 1990

ASPATURIAN: You talked earlier about having Linus Pauling come here for two symposia. Did you have any other thoughts about him that you wanted to put into the record?

ZEWAIL: I think I told you about how in organizing the symposium I felt that it would be a historic mistake to have everybody saying that Pauling left Caltech permanently upset with the faculty and trustees. [*See Session Five*] And I think it's fair to say that I was the one who went to the chemistry division chairman and the president and said, "You know, this would be a big mistake," and so we did something about it.

ASPATURIAN: Was it hard for Pauling to come back, do you think, or was he happy to finally put it all behind him?

ZEWAIL: My own feeling is that Pauling loved this place. And really, deep in his heart, he knew that the best work he had ever done was at the California Institute of Technology. Therefore, when the occasion came for him to come back, I think he just was so pleased, and he wanted to get his feelings about his treatment out of his system—to say, "I did not expect to be mistreated in this way, but for sure, the best work I have done was at Caltech." You know he went to UC San Diego for some time and to Stanford and had his own institute [Linus Pauling Institute at Oregon State University], but all of this was completely different from being a professor of chemistry at Caltech. He never called it that, by the way; he didn't like to say "Caltech." He's always saying,

"the California Institute of Technology." If you look at this picture across from you on the wall—

ASPATURIAN: There he is.

ZEWAIL: And it shows actually signatures by people at the first symposium [1986].

ASPATURIAN: Jack [John D.] Roberts [Institute Professor of Chemistry, Emeritus, d. 2016], okay. Let's see—oh, Max Perutz**.** Norman Davidson [Chandler Professor of Chemical Biology, Emeritus, d. 2002]. It's very nice.

ZEWAIL: Pauling's influence on me really is that he's a conceptual guy. One thing I liked and admire very much about him, and I hope I have followed him in this, was his sense that you can't explain something unless you yourself have an almost complete understanding of what you're going to talk about. So when Pauling talked about chemical bonding, it seemed that it's simple, and it's because he knows *all* the mathematics and everything else that's behind it. I think this is characteristic of some of the best scientists, because not everybody can explain deep phenomena with simplicity.

ASPATURIAN: That brings us to another scientist who was very much of that opinion, and that was Richard Feynman. Did you interact with him?

ZEWAIL: I only interacted with Feynman twice. Once was here at this board when at one time he called Harry Gray, who was then the division chairman, and said, "I'm bored; you guys have some problems in chemistry?" So Harry told him, "There is a new fellow who's doing exciting work; you might want to talk to him." I called him and said, "I can come, Dr. Feynman, to your office," and he said, "No, no, no, I'm coming." So he came; I told him about an interesting problem we were working on. "Oh!" You know how he does. "This we can do by doing this and doing that."

ASPATURIAN: Was he right?

ZEWAIL: Yes, in the physics description of it. But Feynman did not believe in putting graduate students on problems, he told me. He said, "if I want to solve this or that problem, I'll do it by myself." So he really didn't have too many graduate students.

The other time was when he used to come to the round table lunches at the Athenaeum, and so we had a chance to talk about a variety of things. These are the two recollections I have.

ASPATURIAN: How about Murray Gell-Mann?

ZEWAIL: Very interesting man, brilliant. His style of lecturing is not like mine. I tend to be more like Pauling and Feynman. Murray liked lots of equations and rigorousness, all of that. But you know, he's a very nice person.

ASPATURIAN: Yes, I found that.

ZEWAIL: I remember going somewhere, I forget where now, to receive an award, and he was in the audience. I didn't know him before that, but afterward he came and he hugged me. I felt his warmth; he's very nice. So I don't really know him on the deep personal level, but I was very impressed by what he did.

ASPATURIAN: We've talked a little about Tom Tombrello. Would you like to say anything more?

ZEWAIL: Tom was a very special, very, very special person. I think Tom was one of these guys who had the eyes or nose to look across the entire Institute and see where Caltech is going, and what are the most exciting things going on at Caltech. But unfortunately Tom would express his views very sharply. And as a result, sometimes, that caused a little friction. But I can tell you that the division of physics, math and astronomy, PMA, owes a lot to Tom. As chairman, he did a marvelous job in hiring and retaining people who could have gone somewhere else. And Tom, he has a nose, he can go somewhere and say that this fellow or that area should be part of Caltech. So that is

Tom Tombrello. I think I mentioned to you earlier the postdocs and students he sent to me. He sent me more than one.

ASPATURIAN: We talked earlier [*Session Four*] about Milo Lin, who was an undergraduate. And also Mark Rosker, who was a postdoc.

ZEWAIL: Tom was fantastic in this regard. There are very few like him at Caltech. His real love is Caltech; and therefore if he saw that there is any deflection from what Caltech is about, it made him crazy. And he was honest, straight.

ASPATURIAN: He called it like he saw it, that's for sure.

ZEWAIL: That's exactly right. There are some other names really that have had some important influence—for example, Francis Clauser [Millikan Professor of Engineering, Emeritus, d. 2013]. He was part of the Athenaeum round table, along with Jack Roberts, Rudy Marcus, and others. I have to say that this had a huge effect on me.

ASPATURIAN: How so?

ZEWAIL: Well, I used to go there to eat.

ASPATURIAN: When did you start joining in?

ZEWAIL: I think that right after, or a year after, I came to Caltech in '76, because it was so stimulating. One hour at lunch, and I am hearing about economics, politics, physics, aerospace—I mean, you name it, we are discussing it in this one hour. And the leader of the table really is Francis Clauser; he's the one who sort of stirred the pot. He always liked to have discussions with me about the Middle East and his opinions; and I'd say, "I don't agree."

ASPATURIAN: Do you remember what his opinion was?

ZEWAIL: Well, for example, on going into Iraq in 2003. His opinion was that the Iraqi people would be holding flags to welcome the Americans. And I said, "You know, Francis, you cannot be right. No matter what you do, people are going to be upset that their country is being destroyed, and there are going to be factions, Sunni and Shia and all of this stuff; there will be no flags." Things like that get raised at the round table.

I also interacted with Max Delbrück. I was so scared of Max, you know. Max came to me one day, with his glasses like this [showing them canted downward].

ASPATURIAN: This must have been early in your career.

ZEWAIL: Yes, 1978. He was working on plants with lasers, and he asked me a question about that, but it was intimidating, because he doesn't say "Hi" even. He came to my office, and he said, "What about if I excite this and that with a laser?" But he was doing beautiful experiments in that regard. Maybe in the next session we will continue with this because there are personalities like Arnold Beckman [chair of Caltech Board of Trustees, 1964–74; trustee chair emeritus, d. 2004] and Gordon Moore.

ASPATURIAN: Are you running out of time?

ZEWAIL: Yes, because it's twenty minutes to twelve. And I have a lunch. Maybe we can do this next time?

ASPATURIAN: Yes. Shall I ask Maggie [Magnolia Sabanpan, administrative assistant] about your schedule?

ZEWAIL: Yes, because I will have to talk to Maggie actually this afternoon about two important meetings—with the President's Office and with you.

ASPATURIAN: [Laughter] Okay.

AHMED ZEWAIL

SESSION 7

November 21, 2015

ASPATURIAN: We were going to continue today discussing some of your colleagues at Caltech and your relationship with the university over the last forty years—kind of a general retrospective of your Caltech career. Two of the people you mentioned you wanted to speak about were Arnold Beckman and Gordon Moore. So why don't we start with them?

ZEWAIL: With Dr. Beckman, I was actually shocked to meet him so soon after I came to Caltech because I was an assistant professor. At the time he was trying to establish a laser center for medical purposes**.**

ASPATURIAN: This would have been in the late 1970s?

ZEWAIL: Yes. He had in Irvine a medical center that he supported, and he was proud that it was using lasers. The idea was to use them for medical diagnosis and treatment. So when he heard that I am hired at Caltech and working with lasers, he invited me down to Irvine. I drove down to the center, parked the car, and he and the director of the center met me personally and showed me around. I was really impressed; I am an assistant professor and he's doing all of this. Then, in another surprising thing, he said, "Let's have lunch," and I said, "That's great." So he took me in his car, nothing like a BMW or Mercedes-Benz or any of that stuff. It's an old, American car, and he drove me to a salad bar. [Laughter] He took me there, and here is Arnold Beckman giving me a plate and some salad, and we sat at a normal table and talked about things. He thanked me and took me back to where my car is: "Bye-bye, bye-bye." The whole thing was shocking to me because he is Dr. Beckman. He can buy a country, or he can buy a whole chain of restaurants if he wants to. So anyway, I just valued very much how an incident like this tells you he is not looking for fame or going to the best restaurant in Irvine. He was an unassuming, simple man, proud of his achievements and contributions to American

society. Very much so. He had some rules, you know. One of them—I forgot the others—that I thought was really interesting is, Don't take yourself too seriously. And I believe in that—I think I believe in that. First, if you have a Nobel or anything like it, and it goes to your head, it's the beginning of the end, because you are not going to do anything further. Secondly, you'll be arrogant, and people won't like you. So he put his finger on it: Don't take yourself too seriously.

ASPATURIAN: Did he tell you this at this lunch?

ZEWAIL: Yes.

ASPATURIAN: In what context did this come up?

ZEWAIL: You know life has certain aspects to it; perhaps one can summarize these in certain rules. I think that one may be rule No. 7 or something. Beckman was really in his own way a giant. Not only in doing some simple technologies that have affected the whole world, but also in his generosity, whether it's for hospitals or universities. He just was incredible. You know, after our first meeting, whenever he came to Caltech, he knows me and I know him, just like he knows Peter Dervan and Harry Gray and people like this. And so I used to sit with him and talk with him about the world. One thing you learn from such people is that they can reduce all of this to simplicity. In other words, he will not look at the world in a very complex way. He told me a story, for example, about the Japanese. There was one time that I was telling him that we do things in technology and sometimes we find companies that take this and develop it. And then he said, "When we designed the first spectrophotometer to measure the spectra of, say, blood we did it using a lamp" that was, I think, green. He said that when the Japanese saw that, they did a very slight modification, just changing the color of the lamp, and then it became a competitive product. But he was calm about it. It wasn't something insulting. So I valued this very, very much. His wisdom and his contributions to both technology and Caltech.

ASPATURIAN: How often do you recall seeing and interacting with him from then to 1990, after you had had your major breakthrough? Did he come by the lab?

ZEWAIL: No, he didn't come to the lab, but he's invited of course to almost every major event at Caltech, and in the arrangement of the seating I'll be next to him, also my wife. When Dema came, he was sharp enough to recognize right away that it's me *and* my wife at these events. When I got the Nobel, he was very thrilled. He wrote to me, and the trustees, including him, invited us to Palm Springs.

ASPATURIAN: Did he function for you in any sense as a role model on any level? You were both chemists, of course.

ZEWAIL: You know, in the oral history we did so far, I told you that one of the things that perhaps characterized me is that I like simplicity. To me, this is very, very important, whether I am dealing with science or dealing with people.

ASPATURIAN: You like to apply first principles in all aspects of life.

ZEWAIL: Yes. And I saw that in him. I saw that in Beckman and also in Gordon Moore.

It's amazing the way these people operate, you know. I'm just reading a book about Gordon and about the fifty years of Moore's Law, and it's the same thing—the simplicity, the essentials. There is a connection. There is a connection even when I go to Egypt in the diplomacy role. It's the same thing: I want to get the things done, but in a very simple way. I'll talk to the doorman; I will talk to people on the street. I think that Beckman and Moore are these kinds of people, they don't pretend.

ASPATURIAN: Not pretentious?

ZEWAIL: Not pretentious. That's exactly right. I forgot to mention something else about Beckman. This happened when I became the chairman of the overseas conference in Egypt. [*See Session Four*] It was in the early 1980s, and in those days, a thousand dollars is big stuff. I wrote a note to him asking whether it was possible that Beckman

Instruments can contribute, and I got, I think, $3,000. He was generous, even for international projects.

ASPATURIAN: How did you meet Gordon Moore?

ZEWAIL: He was, of course, the chairman of the board of trustees [1993–2000]. In my scientific career, I've been lucky enough to receive offers to move me from Caltech. And so Moore heard when he was board chairman that Germany was after me to become a general director of the Max Planck Institute.

ASPATURIAN: Yes, I think you mentioned this. When was this?

ZEWAIL: Probably the early 1990s. The Germans were after me for several years before the Nobel, so it's probably that time-frame. The president was Tom Everhart. And the vice president for [business and] finance was David [David W.] Morrisroe—another person that I value at Caltech, even though there were some troubles involving him; I don't know what they were. He was in finance, but there can be no question in my mind that he understood with clarity what Caltech is about. He would be at the Athenaeum round table almost every day. I remember the very nice white shirt he would wear, and he would say, "Hi, Ahmed," this and that. But he understood Caltech. I had a lot of interaction with him. He told me once over lunch that Caltech is very small and we cannot afford to lose the superstars. He said there would be some departures, "but I have to do everything to keep the superstars. It's as simple as that." And therefore, if I call David and say, "I have a new grant, but I need to rehab the laboratory," the first thing he would say was, "What do you think it's going to cost?" I would give him a rough number, and he would say, "That's okay, don't worry about it. We'll do it for you." He did not nitpick one single thing. He was not counting the nickels and all of that. He really was an incredible man in this regard. So when he heard—I mean, this is the vice president for finance; what does he have to do with a guy like me getting an academic offer? But the first phone call I got after getting this German offer was from him, and he said, "I do not want you to do anything before I have a chance to take you to the best lunch."

ASPATURIAN: Not a salad bar.

ZEWAIL: No, with Morrisroe there was a style; it's unbelievable. There used to be a Pasadena restaurant called The Chronicle.

ASPATURIAN: Oh, of course.

ZEWAIL: So he arranged for a fantastic lunch. He took me there—it was just me and him—and talked about Caltech and the fact that, you know, "We can't do it like the Germans, but we have other ways to help." Then at the end he said, "I wanted to have this lunch before Tom Everhart has a chance to meet with you." [Laughter] Of course, Tom was very nice, too. His wife took Dema out.

ASPATURIAN: Doris Everhart.

ZEWAIL: And they talked, you know, and then Tom took me to dinner.

ASPATURIAN: This must have been an offer you were seriously considering.

ZEWAIL: Yeah, it was serious. There were many reasons I didn't want to leave Caltech, including the guilt feeling I had about all the work that we did that the Germans would benefit from because I knew that people were talking about the Nobel and all of that. But it was the money. I just felt—the funding is drying up. In fact, I told David that: I can't build the thing of my dreams, the next step—

ASPATURIAN: This was federal funding, I assume, because this was when the spigot started to turn off.

ZEWAIL: Squeezing, exactly. And you know I just thought it seemed impossible that I would be able to get a couple of million dollars from the federal government to build this new machine. And here the Germans are saying, "We will give you so many millions every year to do this."

ASPATURIAN: A tempting offer.

ZEWAIL: It was. And we had to discuss it on the level of the family, because we feel American here, to the maximum. I never felt in this country that someone was denying me this honor, shall we say**,** of being an American citizen. Even at Caltech, I was involved absolutely to the top level—the top committee of choosing a president, for example. So David Morrisroe came, Tom Everhart came; and then all of a sudden two people are knocking on my door—Tom Everhart and Gordon Moore. This was the first time I met Moore one-on-one. So he sat down on the couch, and he said, "You know, we don't want you to leave. You tell me what's involved, and we will help." We had a dinner together at the Huntington Hotel, which is now The Langham [in Pasadena]. And it was during that time that I was trying to convince also him to do something for Egypt—if he can. And then he gave me his coordinates—his phone number and so forth.

I remember two incidents, which happened later but which are completely in accordance with what I told you about Beckman. One day Moore himself called me and he said, "The company in Ireland for the manufacture of the Intel chip [Intel Ireland] has said, 'We would like to have Professor Zewail come here and give a talk.'" Before that I had received an honorary degree from Ireland, and they knew about my work. So he called and said, "People would like to have you there. Of course we will fly you business class. But"—listen to this, Heidi—"could you tell me when you want to go, so my travel agent can get a discount?" [Laughter] I just couldn't believe it, that he has multi-billions, but people like that don't want to waste. The other incident happened when I called him and was told by his office that he is in Hawaii. So I called him there because I wanted to ask him a question about something—I forgot now, what—and his wife picked up the phone.

ASPATURIAN: This is Betty.

ZEWAIL: So Betty picked up the phone: "Oh, yes"—she knows, because he told her, that I will be calling—she said, "but let me call Gordon to come and pick up the phone because he's on the roof fixing the [television] aerial." I mean, I'm on the phone! I am

in awe of what is happening with these people—great people, no pretension. He was extremely supportive with his words. He even talked science with me, because of course he has a PhD.

ASPATURIAN: Also chemistry, also Caltech.

ZEWAIL: In physical chemistry, in infrared spectroscopy. He talked about that and about his adviser, whom he liked very much. So you know, he had all kinds of great feelings about Caltech. But then, going back to the offer from Max Planck, he assured me, as chairman of the board, that—you know the atmosphere of Caltech—"Somehow we'll come up with what you need." And to be frank, I don't think at that point, it was just an issue of the money per se. Because there were many dimensions to consider on this, as I said—our children, for example. We feel that we are Americans, that we belong here. And I don't want the Germans to take credit so easily for all the work that I have done here. So, we had to decide then and, of course, we decided**.** Then, a few years later, I got the prize, and the problem came up again! Namely, the federal funding became even worse, and I didn't want to bargain that I could find a place to take me. Luckily, Gordon has given Caltech $600 million [2002].

ASPATURIAN: Right, I remember.

ZEWAIL: And so one day, to my luck—I don't know if I told you this story yet—a representative of the Moore Foundation and Gordon himself are coming to Caltech. Caltech arranged for lunch with them, and after lunch there was a presentation.

ASPATURIAN: Ah, yes, you did talk about this a little bit. [*See Session Six*] Go on.

ZEWAIL: So that was another thing about Gordon Moore that I found fantastic. I made a presentation of about fifteen or twenty minutes on what I'm dreaming about achieving, and then he said at the end, "I guess, Ahmed, the federal government wouldn't support this,"—meaning my vision for the long-term—but that he would put the money into it. Therefore, he was extremely supportive of my need for support, which of course went

through Caltech and the correct channels, and I received a major grant from the Moore Foundation. Another thing with Moore is that he wanted to understand the science, and if I had told him that I am trying, let's say, to extend the femto work, I don't think he would have been excited. He was always hunting for new possibilities.

ASPATURIAN: The next horizon.

ZEWAIL: Exactly. And things that he knows the federal government will not support.

ASPATURIAN: Just to step away from Gordon Moore for a moment, when I think back to how the Air Force of all agencies stepped up to support your original research when no one knew what would come of it [*Session Four*], what were your thoughts fifteen years later when the federal government was no longer in a position, or no longer had the interest, to support your work?

ZEWAIL: Yes. The federal government still supports my work. Both the NSF and the Air Force. The problem is that $100,000 in 1990 is worth half or one third of that amount in the year 2015, but with the federal government, there is no increase in support. So if somebody like me wants to build a machine for $2 million, how am I going to get that? To attract that kind of money, you are going to have to go to very special organizations and say that you are going to solve the problem of cancer, you are going to solve the problem of energy. Well, I don't do that, you see. And in fact, when we were writing the proposal for the Moore grant, David Baltimore was the president of Caltech, Ed Stolper was the provost, and David Tirrell [McCollum-Corcoran Professor of Chemistry and Chemical Engineering] was the chair of the division. I found it interesting that all three—I thanked them in my book—were more excited about what I am going to do for the future than the federal government was.

ASPATURIAN: Such a change in the climate and the outlook.

ZEWAIL: Yes, and unfortunately, or sadly, we don't have the same commitment that we used to. I just read an article yesterday on another dimension of this. The United States

used to be the No. 1 country in the world in giving international aid, helping people overseas, and so on. We now have moved to second or third. So things like that are not good for us. Fundamental research and basic research has to be the backbone of this country, but one reason we can do it is that people like Moore and Beckman are around to help us with our vision. And I want to tell you, this is almost purely American. In other words, you will not find this in Europe. You will not find this in the Middle East.

ASPATURIAN: The private philanthropies for science and research?

ZEWAIL: Yes. Yes.

ASPATURIAN: Well the roots at Caltech go back a long way if you've ever read *Millikan's School* by Judy [Judith R.] Goodstein [University Archivist emeritus]. It started with George Ellery Hale, a very wealthy man, and his private vision.

ZEWAIL: Exactly, exactly. So I think we are lucky to have this relationship with two of the giants of Caltech, and David Morrisroe, who came in the middle.

ASPATURIAN: You have worked with several Caltech presidents, starting with—

ZEWAIL: [Harold] Brown.

ASPATURIAN: I guess he was about to leave as you arrived. He went back to work for Jimmy Carter as the Secretary of Defense.

ZEWAIL: But Brown you can say hired me.

ASPATURIAN: Yes, that's right. And then he left.

ZEWAIL: And then he left. But I remember very well that when I was hired, they gave me fifteen or twenty minutes with him to shake hands. Later I got to know Brown on several occasions. One was when I was on the search committee to select a president.

ASPATURIAN: Oh, I don't think you told this story. Which president are we looking at?

ZEWAIL: We're looking at Tom Everhart. When I was on the committee, my job was to go and talk to Harold Brown as a member of this committee.

ASPATURIAN: This would have been around 1986, I think, or '85, because Everhart came in 1987.

ZEWAIL: Something like that. So I remember going to Palm Springs, the same place where we had the celebration for my Nobel Prize, and Harold sitting at the fireplace and I'm facing him. He has to be one of the smartest people.

ASPATURIAN: Everybody says this.

ZEWAIL: Yes. I asked him questions about Caltech, and the answers were coming—it's like he didn't think about it. Well, of course, he *thought* about it, but it comes with ease. He understood Caltech very well. He talked with me about what we really need and what is the uniqueness of Caltech, if you like. We interviewed lots of people, to ask them about what they think. But with Harold, I was just super-impressed.

ASPATURIAN: You've talked a little about Murph [Marvin L.] Goldberger and how he understood early on your vision of what you wanted to do. [*See Session Four*] Did you see much of him? Did you interact with him?

ZEWAIL: Oh, a lot, actually. Murph used to come to the Athenaeum Round Table quite a bit. Then we'd walk out from the Athenaeum together. Murph is a physicist and kept up with the field, so we talked quite a bit about physics. I remember two incidents with Murph that I felt showed how he's truly a good professor and president. One of them was when the Air Force told me, "We will give you the money for your laser machine but not now—in November," or something like that. When we were walking back from the Ath, I described to Murph what I wanted to do in a clear way, and I said, "the Air Force said that the money is coming later this year, but I need it now to fix the lab." He said,

"We'll do it. We will do it." Because he understood the significance of what I was talking about.

ASPATURIAN: Suppose he had said, "We won't do it." What would you have done?

ZEWAIL: Well, you will have to wait. Just have to wait. But that is what *should be* distinguishing Caltech from any other place on this planet. Namely that we can move.

ASPATURIAN: Do you think Caltech is still like that?

ZEWAIL: It's like that, but it has changed. There is definitely a change. You know, where before we would have one person like David Morrisroe, now there might be six, seven. You build up bureaucracy. When I came to Caltech I used to know essentially everybody, and I didn't need anything to communicate except the phone. I would call and say, "Hi, Heidi, could I see you?" But now if you want to do that, you have to leave a message and send an email. And now there are a number of people who don't even know about us because the bureaucracy has increased somewhat. I think the administration is trying hard to keep the atmosphere as it used to be. Tom [Thomas] Rosenbaum [Caltech president, 2014–] told me recently that one of the things he wants to do is for the staff to understand that they are serving the faculty. To try to avoid this bureaucracy.

ASPATURIAN: I will say, the staff used to understand that without being told. We were aware that we were working on behalf of the faculty.

ZEWAIL: Right, right. But you see it's a function of the finite size. It's extremely important. If you once had one vice president and now instead you have seven, it's a different story. And now also the federal government is imposing all kinds of forms and regulations that you have to follow in order to be in the so-called new world. I think I told you before that my first funding proposal was something like three or four pages. Today, it will be like thirty pages. Order of magnitude change. I recall that when the Nobel Prize came, a person from NSF visited Caltech and a group of us had lunch. I'm

supposed to say a few words, and I said, "There can be no doubt in my mind that if I submitted my first proposal on the femto to NSF today, it would be turned down. Because somebody is going to say, 'What is this, three, four pages? He's not respecting our intelligence; he's supposed to, you know, give a lot of details.'" We get now in the proposal section something called "relevance to society." How would I know what that relevance will be? But if I don't click it, if I don't put something there, I can't proceed. So what do I do—somebody like me? I have to hire somebody who will be specialized in this. I do the writing and everything, and he does the rest the right way. And so you get into this process.

ASPATURIAN: I see what you're saying.

ZEWAIL: Part of it is the imposition of the federal government, really. The other part is that Caltech has to protect itself, so you create a bureaucracy. I think I mentioned before that when I came here, you had one guy, Al Lindstrom, one guy and his assistant, Mary.

ASPATURIAN: Office of sponsored research?

ZEWAIL: Sponsored research. And that's it. I will call Al and say, "Al, I got this letter from NSF, and I don't know what to do with it." And he will say, "Don't worry about it. I'll call them." That's it. Today, it's a very different story, very different story. In the communications office [Caltech Office of Public Relations]—I'm just giving you examples to answer your question—there was Bob [Robert] Finn. Very good guy. He wrote the first press release about my work in 1987. He knocked on my door, and he said, "Dr. Zewail, your paper in *Science* is quite important, and I think we can really benefit Caltech by getting it out to the media." I said, "So what do you want to do?" He said, "I want to write a press release." And so that press release from Bob went to the *New York Times*, *LA Times*, the front pages. Isaac Asimov, the science fiction writer—he wrote a beautiful piece.

ASPATURIAN: So the press release went everywhere.

ZEWAIL: Everywhere. Front page of the *Los Angeles Times*, *New York Times*, the magazine, *Discover*, Isaac Asimov. It was just all over the map. And we got phone calls from everybody, and there was a guy, I forgot his name now. Gary? Very well-known.

ASPATURIAN: Gary Taubes?

ZEWAIL: Yeah! I think, he wrote for *Science* and *Discover*, and he came, and he wrote a nice piece about this. Here is the point: the communications department was very small. Yet, it had a huge impact. That is what Caltech should be.

ASPATURIAN: Stepping back to Goldberger, I think he had two provosts. The first was Robbie [Rochus] Vogt [Avery Distinguished Service Professor and Professor of Physics, Emeritus; Caltech provost, 1983–87]; did you work with him much?

ZEWAIL: Oh, yes, oh, yes. I know him very well, and there were all kinds of problems in administration. So, we had to form a committee and we have to find out what to do about the problems. I was also part of the committee that was formed when Tom Everhart had a problem with LIGO [Laser Interferometry Gravitational Wave Observatory, which went on to successfully detect gravitational waves in 2016. *–Ed.*].

ASPATURIAN: Oh, yes. For the record this involved Ron [Ronald W.] Drever, the project scientist, Robbie Vogt, and other LIGO physicists.

ZEWAIL: So he asked me also to be on the committee to see what we can do about it. But perhaps one of the most important committees I served on, and I think it was Tom Everhart who charged me with it, was where we produced what's now known as the Zewail Report.

ASPATURIAN: And this was in connection with what?

ZEWAIL: The question was, How does Caltech handle so-called "small" research—the type with the individual P.I.—and also big facilities? I told Tom, the only requirements I

will have as the committee chair is to have the time to do the job properly, and I also wanted to choose the members. So I choose Jerry [Gerald J.] Wasserburg [MacArthur Professor of Geology and Geophysics, Emeritus, d. 2016], David Goodstein, John Hopfield, and these are all guys—it's tough to deal with them, but on the other hand—

ASPATURIAN: They were all at the top of their game at the time.

ZEWAIL: Yes. And I wanted that because there is no reason to do it in a weak way. We produced a document that even today is offered to the new presidents. In fact, Tom Rosenbaum told me that he read it. So I think this was quite important.

ASPATURIAN: This was about how Caltech can balance its tradition of supporting the individual researcher with the move toward big science?

ZEWAIL: Exactly. For example, the clear example that we used to talk about in the discussions, at dinners and lunches and all that, is that, on the one hand, you have Ed [Edward B.] Lewis [Morgan Professor of Biology, Emeritus; 1995 Nobel laureate in physiology or medicine, d. 2004].

ASPATURIAN: Oh, I was going to say, he's the classic example of the individual PI.

ZEWAIL: Right, with a microscope and he's sitting and tabulating his data, and he doesn't need more than that. And then, on the other hand, you have LIGO or the Keck Telescope, you know. How do you handle it? How do you cultivate both and not one at the expense of the other? I think that was an important report that I did for Caltech with my colleagues. And that was during the Tom Everhart era.

ASPATURIAN: Why do you think he asked you head this committee? Did he see you as somehow having a foot in both worlds?

ZEWAIL: I think he saw something in the vision I have for Caltech.

ASPATURIAN: Were you in favor of hiring him to be president?

ZEWAIL: Yes. You know, hiring a president is like a pendulum; it swings. So we had a case before him with Goldberger, who was professorial and did not worry himself about finances, and so on. So we and the trustees wanted somebody who has experience there. And after that you say, "Gee, maybe we want a vision and fame and everything," so it swings back.

ASPATURIAN: To a David Baltimore. It sounds like your relationship with Tom Everhart was a good one.

ZEWAIL: Oh yes.

ASPATURIAN: I thought highly of him. He was very concerned about staff also. He did some very progressive things with regard to staff issues on campus.

ZEWAIL: He was straightforward, honest; clearly not playing fast and loose with things. I was impressed by his integrity.

ASPATURIAN: Some faculty have gone on record as saying they didn't think he was intellectually up to the level of the Caltech scientist. I thought that was an unfair appraisal.

ZEWAIL: I don't agree. And the reason I don't agree is this—because human brilliance shows in different ways. You could have some brilliance and have a glowing propaganda around you, or you could have full brilliance but you are the kind of person who doesn't go around broadcasting it. First of all Tom was a very accomplished engineer.

ASPATURIAN: So I understand.

ZEWAIL: As a matter of fact, in the field of microscopy there is a detector with his name. He was the first one to build this particular microscope in the United States. Tom was the

chairman of engineering at UC Berkeley; he went to [the University of] Illinois as president. He's a very accomplished guy, but he has his way of projecting things. He doesn't need to show you that he's brilliant. And maybe he doesn't have the obvious, apparent thing that people like to see, but that is not to say that he is not accomplished or that he is not a very good engineer.

ASPATURIAN: Paul Jennings [professor of civil engineering and applied mechanics, emeritus; Caltech provost, 1989-95; 2004-07] was one of his provosts. Did you work with him much?

ZEWAIL: I did. Like Tom, he is a man of integrity. If you really want something from Paul and he tells you, "I'll do it," he will do it. Paul is a very smart fellow, very smart fellow, and a very nice human being. I mean you can joke with him as a provost and all of that. As a matter of fact, I became also the chairman of a committee to find a provost at one point. This was when Steve [Steven E.] Koonin [Caltech provost, 1995–04] stepped down.

ASPATURIAN: Okay, that was under Baltimore.

ZEWAIL: So we had this problem of finding a new provost, and I remember vividly that we brought back Paul Jennings.

ASPATURIAN: For the second time, yes.

ZEWAIL: I was totally for this because we didn't want to take a chance on an interim provost while David decides what he wants to do. So we elected to bring back a man of integrity who knows what's going on until the president decides what he wants to do and selects the new provost. I think I was the chairman of this committee. But Paul didn't really want to do it because he has done it already.

ASPATURIAN: You persuaded him? What did you say?

ZEWAIL: Well, Caltech again, you play on their weakness for Caltech. "Caltech needs you; we are not in good shape right now and we have to straighten things out; this will be extremely important"—of course, with consultation with the president.

ASPATURIAN: Which brings us to Baltimore and his provost Steve Koonin.

ZEWAIL: Yes, you know, David is a good friend of mine. People say about him that he's arrogant, and this and that. I have to say, I didn't see it. Every lunch I had with David, I just enjoyed it immensely. Before we started today, you talked about Egyptian intellectualism. That's what I enjoy also with David. There is an intellectualism in him, a genuine interest in things from medicine to science to society to politics in Washington. When I sit with him, it's very enjoyable.

ASPATURIAN: You're on the same wavelength a lot of the time.

ZEWAIL: That's the point. We are, we are. Even on things related to the Nobel per se, we can talk about it and we are on the same wavelength. So I didn't see this arrogance. I think what he wanted to do was to look at the very big picture. And he wanted to leave the implementation of things to the people around him.

ASPATURIAN: More like a Goldberger in that regard?

ZEWAIL: More like a Goldberger but, you see, David knows the world much more than Goldberger.

ASPATURIAN: Less provincial you might say. And a different generation.

ZEWAIL: Exactly, exactly. And he knows, I mean, he *knows* Europe. He knows Asia. I think he was looking at the big picture, which some faculty have a difficulty with because they want somebody to whom they can give all the steps and instructions. And since he's a Nobel laureate, there's always travel, commitments, people. Of course, he was making us a name on the outside, but somebody had to do the work. Steve Koonin did the work,

and he's smart—very smart—but I think also he was ambitious perhaps to be the president of Caltech one day.

ASPATURIAN: He'd been educated here.

ZEWAIL: And Steve really did a lot of the work that needed to be done. But again, as you know, these things have to do with personalities. David understood that. He wants to finish the term without rocking the boat. I also believe that David cares *a lot* about Caltech. But in his own way—the way he wanted to enhance the biomedical aspect of research at Caltech.

ASPATURIAN: And [Jean-Lou] Chameau [president of Caltech, 2006–2013] succeeded Baltimore.

ZEWAIL: Yes. Now we have also as provost Ed Stolper. I would like to speak about him.

ASPATURIAN: Yes, let's do both.

ZEWAIL: Ed, he's a very good friend of mine. It's an incredible integrity. In fact, I tease him sometimes by saying he is an orthodox rabbi in that if everything is not done correctly and properly—

ASPATURIAN: Ah, according to the Law.

ZEWAIL: According to the law and the Constitution; otherwise he is not pleased. There's also another thing about Ed, and I don't know how he does it, but he knows everything that goes on at Caltech. Everything that goes at Caltech, Ed knows. When he was a chair of his division [Division of Geological and Planetary Sciences], he did marvelous things. He hired young people, he built the department. But when I have lunch with Ed and he talks, he can talk from physics to geology to chemistry to biology, and he knows individual names and what they do and what our problems are, and all of that stuff. But you can't twist his arm unless you have a good case. You really have to have a good

case. It has to have logic, and if you don't have that, you're going to have a hard time with Ed. So I think we are really truly lucky—and I say this for the record—truly lucky to have Ed Stolper as a provost for so many years now. Incredible devotion to Caltech, giving all of us the atmosphere he can come up with. And, let's not forget this: In his field, he's a first-rate scientist.

ASPATURIAN: Yes, he was elected to the National Academy of Sciences at a very young age. I don't think he was forty.

ZEWAIL: Absolutely. And still today, he gets invited to England and France and all of these places to give lectures and all of that. I think if there is—what do we call it—a prototype or epitome of a model provost, you can find such a provost at Caltech, and if you followed that model elsewhere, those institutions would do great. Now, some people might disagree with Ed, but I always say that should not be personal. He's really a strong believer in what he's doing and you have to convince him that he's right or wrong, you see; and I trust him.

ASPATURIAN: One of those who disagreed strongly with Ed Stolper at times was your good friend Tom Tombrello, as you probably know.

ZEWAIL: Yes. And that's sad actually because in the beginning, they were really working together. Basically their ways were similar, but then as I told you earlier [*Session Five*], Tom understood Caltech inside out; his life was for Caltech, but his approach used to offend people, whether it's a president or provost or this or that. Because, you know, he will call them names, tell them they don't have what it takes, and that kind of thing. You can't do that. You can't do that. On that high level, you have to approach this differently, while you can still be strong and be against what you don't believe in. So I think because of that there were some clashes.

ASPATURIAN: Let us talk a little about Dr. Chameau, and his career at Caltech and beyond.

ZEWAIL: Jean-Lou Chameau, I got to know him quite a bit. Also socially—my wife and I—because he used to call on us when major fundraising is coming. But I won't forget the one thing that he did for me personally. And this is really Caltech at its best. In January of 2011, I immediately went to Egypt with the beginning of the revolution. I wrote an op-ed in the *New York Times*, which I know he read, asking Mr. Mubarak to step down, and at the end I said, "Mr. Mubarak, it's time to step down." And then I did a televised ten-minute speech that was broadcast on *Al Jazeera* and everywhere in Egypt saying, "Mr. Mubarak, you really have to step down." I was now in the camp against him, so going to Egypt was dangerous. I actually tried to get a plane, and I could not find any that are going to Egypt except the United Emirates airline. So I had to take the Emirates to Dubai and then fly from Dubai to Cairo. I will never forget this. On the road from the airport to the hotel on Tahrir Square, people are on the right and left, and they stop the car and then they see me, "Oh, Dr. Zewail, come! Welcome!" So Jean-Lou saw that within about five days in Egypt I'm immersed totally into it. So he gives me a call at the hotel and said, "We are willing to hire, from America, guards to protect you until you come back to Caltech." And I don't think I will ever forget that. Here is the president of Caltech worrying about my life and physical safety, and Caltech is willing to do this. And in fact he made the point, "Don't worry about finances; we'll take care of that."

ASPATURIAN: Did they in fact hire somebody?

ZEWAIL: No, I told him that I have actually a guard there, but if I need more, I will let him know. And then when I came back he asked me to speak about the Egyptian revolution at a lunch for the trustees.

ASPATURIAN: How much time had elapsed? How long were you in Egypt?

ZEWAIL: It's probably two weeks. So he asked me to speak at the lunch, and he also asked me to give the commencement address for Caltech. Really the reason I'm mentioning this story is because Jean-Lou understood and was concerned about the dimension of world peace and the so-called Arab Spring; he was following all of this

stuff. And he wants to make sure that I am safe and well, and that I can tell the Caltech community about my experience.

ASPATURIAN: If I can inject a personal note here. A friend emailed me at some point and said, "They're discussing the commencement speaker again," and I emailed back—and I have this email—and said, "They're probably going to ask Ahmed Zewail to give the address."

ZEWAIL: [Laughter] You're smart.

ASPATURIAN: Well, because of what you were doing at that time in Egypt. It seemed like a natural choice.

ZEWAIL: They did ask me; and at commencement, the chairman of the board of trustees, I'm trying to remember—

ASPATURIAN: Kent Kresa [chair, Caltech Board of Trustees, 2005–2012; trustee chair emeritus]?

ZEWAIL: Kent Kresa. He introduced me as having received the Pulitzer Prize [laughter], but he corrected himself. So this is really Jean-Lou. I think also it's perhaps that Jean-Lou thought that Caltech should be moving in directions other than the traditional ones. I think there was resistance.

ASPATURIAN: Do you think the resistance was justified?

ZEWAIL: Well, you know, we are conservative at Caltech. We didn't want to build an army center [the Arroyo Center] here. We didn't want Lee Hood to have a huge biomedical establishment. That's why he left. We tend to be conservative in this. Now, is that good or bad? Well, in general, I like to feel that when you are conservative and things are going extremely well, if you want to make a change, make it in an incremental way. Because if you make an abrupt change, you get a lot of resistance and also it might

fail because a lot of people will be against you. But I think you can do it. I think you can do it. David Baltimore's interest in having translational medicine here is an example. Now we didn't have that before, or we did not think of it, but you know, slowly but surely, he brought along collaborative programs with UCLA and UC San Diego. You can get such changes going. But if you come and you say, "I'm going to build a whole new building to do this with companies for the faculty," for example—

ASPATURIAN: You will encounter a lot of resistance. What do you think of Chameau's decision to become the president of KAUST [King Abdullah University of Science and Technology in Saudi Arabia]?

ZEWAIL: Well, you know, I talked to him about this, and you also hear two theories. I think there is one theory that he felt he had done enough for Caltech, and he would like to help this part of the world, going there. There's another theory saying that Jean-Lou is paid very well now and this might help in the after-Saudi-Arabia time, so—. I think really that he is the best to judge this. And you know, you never know with these decisions. It's like what I told you about the Max Planck offer to me. There's sometimes a gut feeling, and you take the decision on that basis. Maybe he even wanted to be closer to France. It could be as simple as that. So I really cannot judge it.

ASPATURIAN: You've mentioned a couple of Caltech committees that you were instrumentally involved in. Were there others that we should talk about?

ZEWAIL: Well, of course I have also done my homework for the division.

ASPATURIAN: Chemistry?

ZEWAIL: Yes, chemistry and chemical engineering. I was the chairman of the committee that hired [David A.] Tirrell, for example. I served for years and years on the staffing committee for bringing in new faculty. I feel like it's not that I have to do it, but that I am part of the fabric of Caltech and therefore it's a pleasure to do with all the time that I have, whatever it takes.

ASPATURIAN: Speaking of chemistry and the division, what do you think of the directions it is pursuing now, and do you think they are the right ones?

ZEWAIL: Chemistry and chemical engineering is really very healthy, even in comparison with other divisions.

ASPATURIAN: Well, you also have an appointment in physics.

ZEWAIL: Yes. In chemistry, we are quote-unquote homogeneous, meaning that when we hire somebody, we are all involved. There's also a very nice feeling of a supportive attitude from the faculty there, so you know this subgroup is not going to block that subgroup in order to get an appointment through. We don't do things like that. Chemistry is healthy. The direction is very good. I mean if you look, it's the only division that has three Nobel Laureates. So, no, chemistry and chemical engineering is quite strong.

ASPATURIAN: Have you ever gotten the sense, with your diplomatic commitments, that there is an underlying attitude of "Dr. Zewail, come back to Caltech and spend more time contributing to the life of the community"? Or has the campus been very supportive?

ZEWAIL: Very supportive. To the point that our provost, Ed Stolper, says, "You know, when I try to choose a statesman, I will choose you. Because you not only serve your community in chemistry but you are also trying to help the world." No, they are very supportive. When I got involved in this revolution [Egyptian revolution of 2011], they were fantastic.

ASPATURIAN: How did you decide what you were going to say in your 2011 commencement address [http://www.americanrhetoric.com/speeches/ahmedzewailcaltechcommencement.htm]?

ZEWAIL: Well, good question, actually because—I don't know if you know this and I don't know how they do it—but my commencement address came out on the internet as

one of the best, along with speeches from John F. Kennedy and a few others [National Public Radio website "The Best Commencement Speeches Ever": http://apps.npr.org/commencement/].

ASPATURIAN: Really, and who made this determination?

ZEWAIL: An organization that is concerned with all the commencements that have taken place from the year so and so to the year so and so [1744 to the present, per the website].

So what was I thinking about when I wrote it? I was thinking about helping our students understand the unique aspects of Caltech. That's No. 1. You know it's like your children. They live with you, and they think that's the norm of things. But the reality is that if Caltech students were to be at UCLA or UC Berkeley, they would get a completely different treatment there. So I wanted to give them first of all a sense of how unique this place is. Two, to talk about where the world is going with science. Why science is important and where it's going. And so I give them a few examples, whether it's from astronomy or nanotechnology or medicine. Three, how revolutions in science are made. I wanted them to understand it is not an incremental thing when you go out on your own: You do research, you publish a paper, and you think you made a contribution that's very important—no. *You have to change the way we think.* And, finally, I also wanted to talk about revolutions in society, and I choose the Egyptian revolution and my role in terms of the Science and Technology City [now Zewail City]. And so that's how it went. And I think the title was "Revolutions in Science and Society." That was precisely the point that I had in mind.

ASPATURIAN: Did you get feedback from the graduating class about your remarks? What did they say to you?

ZEWAIL: Oh, yeah, people were really—well, it's hard to tell you these things about myself, but you know they say they are super-impressed; this is one of the best. You get to hear these kinds of comments. But I had a mission of just wanting to convey something specific to these young people and not to be too lengthy. Sometimes they will go to sleep, and I wanted to make sure they stay awake.

ASPATURIAN: We've talked a lot about Caltech's successes and its positive qualities and that impact on your life and career. Have there been aspects where you would like to see things move in a different direction?

ZEWAIL: Well, you know, when I gave the Nobel speech in the Athenaeum, I talked about the three aspects of Caltech. Sky is the limit, the freedom I had as a young person not to be told what to do, and the unique environment around me.

ASPATURIAN: Supportive community; I remember reading about this.

ZEWAIL: So these were the three, and I hope that these will be the three that Caltech continues. Because I don't want to see that we lose this in any way. There is a pressure. There is bureaucracy creeping. But I really do hope, and maybe I told you before, it's almost impossible for a young assistant professor to come to anyplace and do the work equal to a Nobel in eight years or something like this. I hope we can continue to be that place.

ASPATURIAN: And in a completely new field, too. I think that's worth pointing out.

ZEWAIL: And actually there was no background for it at Caltech. In other words, I'm doing lasers, and there wasn't really anything like this. If I had decided to continue with Pauling's X-ray research, for example, it would have been understandable, but we had to create the entire infrastructure. So that's what I love about Caltech. What I am concerned about—what I just hope—is that we don't lose this. I want us to be hiring the very best people—staff and faculty—but also not to let the bureaucracy control our lives.

ASPATURIAN: Do you think the pendulum has swung a bit too far that way?

ZEWAIL: Well, just to be fair to Caltech, the society as whole is moving in a different direction, if you look at all of these demonstrations now going on in American universities, at Yale and at many others.

ASPATURIAN: Claremont.

ZEWAIL: Occidental too, I think. [Reference is to student demonstrations over diversity issues that occurred at a number of American universities in the second half of 2015. – *Ed.*] So you have to take this component into consideration. But I think Caltech is smart enough, or the people of Caltech are smart enough, and we are small enough that we should not be going too deep into any of this.

ASPATURIAN: Anything else you would like to put in this segment about the Institute, your experiences with it?

ZEWAIL: I think you really covered everything beautifully. Perhaps at the very end, is the influence of the Athenaeum Round Table on me. This was so unique to Caltech—a chemist, an economist, an astronomer, a finance person—it just had a fantastic influence.

ASPATURIAN: An interdisciplinary microcosm. And food, too.

ZEWAIL: And it's one hour where there are these intellectual exchanges, and I think it's unique to Caltech, and I benefited a lot from it.

ASPATURIAN: Well, you said ninety minutes and I think we're there.

ZEWAIL: That's perfect.