CHEMICAL HERITAGE FOUNDATION

NORMAN N. LI

Transcript of an Interview
Conducted by

James G. Traynham

at

Mount Prospect, Illinois

on

5 May 2000

(With Subsequent Corrections and Additions)

ACKNOWLEDGEMENT

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Norman N. Li, interview by James G. Traynham at Mount Prospect, Illinois, 5 May 2000 (Philadelphia: Chemical Heritage Foundation, Oral History Transcript # 0195).

Chemical Heritage Foundation
Oral History Program
315 Chestnut Street
Philadelphia, Pennsylvania 19106

NORMAN N. LI

1933	Born in Shanghai, China, on 14 January

Education

1954	B.A., chemical engineering, National Taiwan University, Taipei
1957	M.S., chemical engineering, Wayne State University
1963	Ph.D., chemical engineering, Stevens Institute of Technology

Professional Experience

1963-1981	Exxon Research and Engineering Co., Linden, NJ Senior Research Scientist
1981-1988	UOP Co., Des Plains, IL Director of Separation Science and Technology
1988-1995	Allied Signal Co., Des Plains, IL Director of Research and Technology
1995-present	NL Chemical Technology Inc., Arlington Heights, IL Chief Executive Officer

Honors

1980	Chairman, Industrial and Engineering Chemistry Division, American Chemical Society
1988	Alpha Chi Sigma Award for Chemical Engineering Research, American Institute of Chemical Engineers
1988	Separation Science and Technology Award, American Chemical Society
1989	Fellow, American Institute of Chemical Engineers
1990	Member, National Academy of Engineering
1992	Director, American Institute of Chemical Engineers
1995	Special Symposium in Honor of Dr. N. N. Li, American Institute of Chemical Engineers
1995	Ernest W. Thiel Award, American Institute of Chemical Engineers
1996	Member, Acedemis Sinica
1998	Member, Chinese Academy of Sciences

2000 Perkin Medal, Society of Chemical Industry, American Section
2000 Chemical Engineering Practice Award, American Institute of Chemical Engineers
2000 Special Symposium in Honor of Dr. N. N. Li, American Institute of Chemical Engineers
2001 Fujimura Award for Lifetime Achievement in International Technology Cooperation and Development, American Institute of Chemical Engineers and World Congress of Chemical Engineering, Melbourne, Australia

ABSTRACT

Norman Li begins the interview with a description of his family and childhood years in Fuzhou, China. After World War II, Li's family moved to Taiwan, where Li completed high school. Li then attended National Taiwan University, where he majored in chemical engineering, receiving his B.A. in 1954. Li's father encouraged him to further his education in the United States. Li attended Wayne State University, where he benefited from the care, support, and assurance of Professor Harold Donnelly. He received his M.S. in chemical engineering in 1957, and then attended Stevens Institute of Technology, receiving his Ph.D. in 1963. Li accepted a position in the Process Division of Exxon Research and Engineering Company. Early in his career at Exxon, Li began thinking about liquid-membrane technology and applications. While with Exxon, Li received a combined total of forty-four patents on either hydrocarbon separations or facilitated transport. Li was approached by Mary Good about a new career opportunity at UOP Co. After much deliberation, Li decided to make the move from research to research administration, becoming Director of Separation Science and Technology at UOP in 1981. As soon as he arrived at UOP, Li wrote a proposal that established a liquid-membrane research program. Li left UOP in 1988, joining Mary Good at Allied Signal Co. In 1995, Li decided to "retire" from Allied Signal and establish his own consulting firm, NL Chemical Technology, Inc. Li concludes the interview with a discussion of the future of chemical R&D, reflections on winning the Perkin Medal, and thoughts on his family.

INTERVIEWER

James G. Traynham is a Professor of Chemistry at Louisiana State University, Baton Rouge. He holds a Ph.D. in organic chemistry from Northwestern University. He joined Louisiana State University in 1963 and served as chemistry department chairperson from 1968 to 1973. He was chairman of the American Chemical Society's Division of the History of Chemistry in 1988 and is currently councilor of the Baton Rouge section of the American Chemical Society. He was a member of the American Chemical Society's Joint-Board Council on Chemistry and Public Affairs, as well as a member of the Society's Committees on Science, Chemical Education, and Organic Chemistry Nomenclature. He has written over ninety publications, including a book on organic nomenclature and a book on the history of organic chemistry.

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INTERVIEWER: James G. Traynham

LOCATION: Mount Prospect, Illinois

DATE: 5 May 2000

TRAYNHAM: Doctor Li, I know from some things I've read that you were born January 14, 1933 in Shanghai, China. Can you tell me something about your parents and your early childhood there?

LI: Yes. You read that my mother actually died two weeks after giving birth to me. She had this so-called "afterbirth fever." Unfortunately, at that time there was no penicillin. Today this wouldn't be a problem. With penicillin I think the patient could be cured. But at that time, it was deadly, so she died. I must say that has been my lifelong great regret and sorrow.

TRAYNHAM: What was your father's occupation in Shanghai?

LI: My father was a writer. He studied in France. In his time, going to Europe to pursue advanced study was kind of the fashionable thing to do in China. So he went to France. He stayed there for seven years. He actually met my mother there, and they married. Then they returned to their homeland, China. They wanted to contribute to China, but as I said, unfortunately, my mother died. My father continued his work. He became a very well-known writer. Not only did he write a lot of articles, novels, but he also translated well-known French literature into Chinese so that people there can read them.

TRAYNHAM: Did you have any siblings or were you the only child?

LI: I have a younger brother and a younger sister. They are half-brother and half-sister. My father told me himself that he wanted to take care of me. He wasn't sure if he'd get married soon. The woman, whoever he married, of course, would love him, but he wasn't sure the woman would equally have love for his child. So he actually waited for eight years, and then he remarried. It turned out my stepmother was a very loving woman, a very devoted Christian. She lives with my stepsister now in Atlanta.

TRAYNHAM: During those eight years before your father married again, did he have any help in taking care of you as an infant and young child?

LI: Yes, my grandmother helped a lot. She moved in to live with us for a few years, and then my father, for maybe up to two years, had me stay with my uncle because he was so busy with his work. But by and large, he really was the one who took care of me. So that actually developed a very, very close, loving relationship between my father and me. I also had a tremendous trust in my father's wisdom and judgments.

TRAYNHAM: Well, it was certainly a tragic experience for you to be without your mother during those early years. What was your school experience as a child?

LI: I was doing well, but I was a very shy student. I don't know why. Maybe that's part of my personality. Maybe partly because I didn't have a mother. I didn't want to participate in a lot of extra-curricular activities because of being shy.

TRAYNHAM: I note from some of the biographical information that's available that you attended National Taiwan University for your undergraduate education at the college level. When did the family make the move from Shanghai to Taiwan?

LI: Right after the Second World War, actually from Fuzhou in the Province of Fujian. When the Japanese were evacuating from Taiwan back to Japan and the Chinese government was moving into Taiwan, my father went with the first group of people from Chinese mainland to Taiwan. So we went to Taiwan very early.

TRAYNHAM: So that was before the Communist takeover?

LI: That's right. Indeed.

TRAYNHAM: Did your father go to continue his writing career in Taiwan or did he have other business to do there?

LI: No. He continued his writing then. He was a professor of French literature at the National Taiwan University. And he was in that position until the day he died, which was in 1972.

TRAYNHAM: The lapse of years between your birth and the years immediately following World War II makes it sound as though you were still a teenager at the time you made the move, so you must have attended high school in Taipei?

LI: Yes, I attended the high school in Taipei.

TRAYNHAM: And then went to the National Taiwan University?

LI: That's right. Yes.

TRAYNHAM: Did you have to take any entrance exams to qualify for the university?

LI: Oh, yes. Absolutely. You submitted your choices of universities. National Taiwan University was always the first choice for good students, and I was one of them, so I naturally put down National Taiwan University.

TRAYNHAM: Had your interest in an engineering career developed while you were in high school, or while you were at the university?

LI: You bring up an interesting point. [laughter] I mentioned that during my Perkin Medal speech. I was torn in between. I actually wanted to become a writer just like my father, but for several reasons, I changed my mind and became a chemical engineer. Reason number one: my father simply told me, "If you are a writer in China [at that time], most likely you'll be starving." And that was pretty powerful persuasion. [laughter]

TRAYNHAM: Yes, it's an unexpected warning from your father, since he apparently was a successful writer.

LI: Yes, Jim, you're absolutely right. If you are successful, even as successful as he was, he still had a hard time earning enough money for the family. I think in general, at that time in China, including Taiwan, people in the liberal arts field really did have a hard time to earn a good living. So that's the number-one reason. Number two: I found out that in high school I was doing equally well between chemistry and the liberal-arts courses. So I really, indeed, could choose either one. The third reason was that, as I told you, my mother died because of me, so that really made me feel deeply that maybe I should study science—because of the lack of science she died, lack of good medicine.

TRAYNHAM: But you were not persuaded to go into medicine. You chose the engineering path. Can you identify any particular influences on that choice?

LI: Yes. I have to admit, that was partially influenced by the society at that time. At that time, engineering was considered to be the really top profession to have. And since I was doing well in chemistry—I didn't know too much about medicine—I said, "Okay, chemical engineering, that seems good." So I chose chemical engineering.

TRAYNHAM: So you went to the university already knowing you were going to study chemical engineering.

LI: Yes.

TRAYNHAM: Did you have any particular professors at the university that had significant influence on your studies?

LI: Come to think of it, really not.

TRAYNHAM: You were just already so sure of what you wanted to do that you were ahead of the game, so to speak.

LI: Yes. You know, it's such a phenomenon that I must say this. Because so many students tried to get into National Taiwan University as their first choice, those who got in, they are of course the best students. So despite the professors, they were doing well on their own. That's the way I observed it, including myself.

TRAYNHAM: Then you graduated from National Taiwan University with your degree in chemical engineering.

LI: Yes.

TRAYNHAM: What was your choice at that time?

LI: Well, I did say engineering was the top profession at that time, but Taiwan at that time was already isolated from the Chinese mainland because of the civil war, and Taiwan itself is a very small, tiny place. So it turned out that whether you are a chemical engineer or not doesn't matter. It was very difficult to find jobs. So I decided I just needed to advance my study and that was the time I decided to seek opportunity to study in this country.

TRAYNHAM: Was there any particular individual that guided your choice to come to the United States, or did more or less that come out of your own thinking about the possibilities?

LI: Both. My father encouraged me and I myself wanted to come to United States. You see, as I mentioned, in my father's time, people thought about going to Europe as their first choice, but in my time, going to the USA was the first choice.

TRAYNHAM: What year was it that you came to the United States?

LI: 1955.

TRAYNHAM: You came to which university?

LI: The name is Wayne State University. But I must tell you the story.

TRAYNHAM: Yes. Please do.

LI: You know that my father, of course, was not able to send me to United States, so it would be entirely up to whether I could get a scholarship to come. And at that time, almost all the students who graduated from the engineering college applied to the schools here in the United States. Therefore, the competition was very keen. Usually, we just ended up getting an admission but not a scholarship. But I remember I wrote a long letter and sent it out to a few schools here, and the late Professor Harold Donnelly at Wayne State later told me that he was quite moved when he read my letter. So he arranged a scholarship. As I mentioned to you, Jim, last night over dinner, what I got back was a letter saying, "I have arranged a full scholarship for you," which was one thousand two hundred dollars per year. That was very adequate for me to support myself at that time. I was elated. So that's how I got to the United States.

TRAYNHAM: When you came to the United States, did you already have a command of English language, or did that develop after you got here?

LI: I believe I had quite good command of English, not only because I learned it in school, but also I was quite active in a Christian church. The name I still remember. It was called The Youths to Christ. And I also remember the minister; his name was [Bob] Sparks. He was an American. So I was very involved with Mr. Sparks and his associates, and that really helped my English quite a bit. I also took private lessons from two American nuns. They were English teachers at the National Taiwan University.

TRAYNHAM: What particular highlights do you recall from your graduate studies at Wayne State University?

LI: I honestly felt I was very fortunate that I had met the late Professor Donnelly. He was indeed a person who cared very much about his students. He had tremendous influence on me. I remember the first summer I spent in this country, he just stopped by in my lab before the summer. He said, “Norman, I figure you need a summer job.” I said, “Yes. I’ve been thinking about that.” He said, “Well, in Detroit there is a company called Parke-Davis [now part of Pfizer, Inc.], a famous pharmaceutical company. I know some people there. Why don’t we try to get you a job there?” Of course, I was very happy to hear that. I remember he personally drove me—because I didn’t have a car—to Parke-Davis for the interview and, subsequently, I got a job there. So he really showed his care—not only his care, but also his belief in me. I’ll give you one example. He said, “There is a course you could take, which is called Plant Design.” Then he said, “If you’re going to work at Parke-Davis, maybe you should also take this course. From what I understand you’ll be involved in that at Parke-Davis, and that could be part of this course. You can write a report on that.” I said, “Great.” Later on, after the summer, I came back. I wrote a big, thick report. My supervisor at Parke-Davis read it, thought it was great, released it, and I presented the report to Professor Donnelly. You know what happened? He took the report; he never read it. He said, “I’ll give you an ‘A’ because I know you did a good job. I knew you would.”

TRAYNHAM: That was quite a bit of confidence. At least at that point, you had your opportunity to return to your first love and become a writer. You wrote the long report.

LI: Yes, and I should add that I have never forgotten his confidence in me.

TRAYNHAM: You received a master’s degree, I believe, from Wayne State University.

LI: Right. Yes.

TRAYNHAM: What choices did you then make?

LI: I was really facing several choices. I honestly was very eager to get a full-time job because I was very eager to repay what my father did for me in the sense that I liked to send money back to help my family there. As a matter of fact, I got a very nice offer from Goodyear Tire and Rubber Company in Akron, Ohio. But then my father encouraged me to continue to study. He said, “Although the economic situation is not so good and I can’t earn much money; I want you to continue your study.” The reason I ended up at Stevens Institute of Technology in Hoboken, New Jersey, where I got my doctorate degree in chemical engineering is actually financial. They gave me not the usual graduate assistantship, which is what I got from other universities. They actually offered me an instructorship. I still remember the salary at that time was seven thousand dollars. To me that was a windfall! [laughter] So that’s why I became an instructor at Stevens, meanwhile doing my graduate work. So there I finished my Ph.D. and one thing led to the other. Stevens is very close to Exxon Research and Engineering Company, so before I finished my Ph.D., I went to Exxon for interview and Exxon immediately made me an offer. So after I graduated, I joined Exxon.

TRAYNHAM: You didn’t consider any other company at that time?

LI: I did. It was a very interesting story. I interviewed only one other company, DuPont [E. I. DuPont de Nemours and Co., Inc.]. At that time, Jim, you may remember, DuPont came out with some kind of artificial leather, which was used to make shoes.

TRAYNHAM: Corfam, I think.

LI: Corfam. That’s it, exactly. They had a big laboratory and they wanted me to join them. They made me an offer, and the offer was exactly the same as the offer I got from Exxon, to the penny. Even to this day, I never understand. It’s just such a coincidence. Exxon wanted me to join their Process Division and the work really appealed to me, so I chose Exxon.

TRAYNHAM: Well, tell me about your early career at Exxon. You joined the Process Division and what kind of assignment did you have?

LI: I really think I was very fortunate. I was able to kind of, if you will, cut my teeth, as a young, Ph.D. chemical engineer in a big company. I learned a lot of things. My first assignment was on lube-oil processing, specifically on de-waxing, taking the wax out of lube oil. It is really a very nice chemical engineering process that I contributed. I got some patents out of this work, and I learned tremendously. Later on, I perceived the idea of liquid membranes.

TRAYNHAM: How early in your career did the liquid-membrane solution come to your mind?

LI: That was around 1965.

TRAYNHAM: So it was a couple of years after you started work. Let's back up just two years, to the beginning of your employment at Exxon in 1963. You had quite a full year in the sense of important events. You got your doctoral degree from Stevens. You began your employment with Exxon. I believe you also got married, and you became a U.S. citizen, all in one year!

LI: I forget which year I became U.S. citizen. [laughter] I could check [it was 1969].

TRAYNHAM Well, your biographical sketch indicates 1963, and I noted that a lot happened that one year.

LI: Of course, I did get married with a very loving lady in 1963, after we got to know each other for three years. [laughter] My wife just finished her B.S. degree.

TRAYNHAM: Also at Stevens?

LI: No, at Hunter College in New York. So it was a very good year that we got married. We both finished school, and so that was a very good timing.

TRAYNHAM: Well, back to Exxon. You had been employed two years, and this very important technology of liquid membranes came to your idea and attention. Describe how that got started.

LI: All right. That was a chance observation in the lab. I was measuring interfacial tension between two phases. That's where you have the interface. The water phase is down below, and the oil phase is on top in a dish. We used a method called the Du Noüy-ring method. Briefly describing it: you dip the ring below the interface and then you use a gadget to slowly raise the ring. When the ring goes through the interface, it has to break this interfacial tension and that force is recorded as interfacial tension. So when the ring breaks through the interface, and thereby getting from the water phase to the oil phase, I noticed the ring actually hooked up some kind of a liquid film at this interface. My lab technician said that every time he did the experiment, he got very different numbers. So I actually stood by him, I remember, and tried to watch exactly what happened. Then I saw this very, very thin film that was hooked up by the ring. I didn't know what that thing was. So I started to analyze the water phase. It turned out the water phase had some kind of surfactant, so it dawned on me that the surfactant formed this interfacial film and the ring simply hooked it up. That was the very beginning discovery of the liquid membrane. I became very curious about this phenomenon.

But also, as I said in the Perkin Award acceptance speech, I believe people always say in a romantic way, this discovery was done in a serendipitous way. Yes, maybe so. At that time my assignment was changed from the de-waxing process to gas separation by polymeric membranes. So I was working with membranes already, except it was solid polymeric membranes. With all the membrane knowledge that I got, based on that, maybe consciously or unconsciously, I thought about liquid membranes from the point of view of separation. And I also tried to compare: if I got a liquid membrane, how would that perform in separations? What kind of advantage do I have as compared to solid membrane? So although the observation maybe was a chance observation, a serendipity discovery, my mind was prepared, so to speak, for the invention.

TRAYNHAM: You inferred that as you saw this adhering material to the ring coming through the interface, it was surfactant material in the water. Had that been deliberately added to the water, or were you just dealing with impure water?

LI: I was dealing with impure water.

TRAYNHAM: So that if you'd had pure water you probably would have missed it altogether?

LI: That's right. Yes. Exactly! [laughter]

TRAYNHAM: I recall that one hundred years before, William Henry Perkin, for whom your medal is named, discovered the first synthetic dye by the chance contamination of the aniline he was using. Had he been using pure aniline, he would not have gotten the purple dye that he managed to get. So I've often wondered how many interesting developments we may be missing because we now have the advantage of using very pure starting materials!

LI: That's right! Good comment.

TRAYNHAM: It seemed to be carried through in your remarkable observation.

LI: Thank you.

TRAYNHAM: Well, from that observation of this very thin membrane appearing at the interface between the water and oil layers in your experiment, how did you go on to develop the whole concept of liquid membranes and their utilization?

LI: Well, first of all, at that time I was working with solid polymeric membranes, and my major problem at that time was the so-called "pinhole" problem. A solid polymeric membrane usually cannot be made in a perfect way without any pinholes. If you've got some pinholes there, imagine you have gas on one side under pressure and try to get some molecules to diffuse across the film, the gas molecules just all go through the pinholes and you don't have any separation. So that problem bothered me. When I saw the liquid membrane, I was very, very excited. I said, "I have no pinholes." You know why? Because I realized that surfactant molecules spread naturally, being in a liquid membrane, according to their surface tension. So it's a perfect film. It has no pinholes. It can be broken, but it has no pinholes, okay? [laughter] That intrigued me.

So I kept on thinking, "Oh, maybe I can use that for separation—a membrane without pinholes. Also the other idea that intrigued me was that this membrane could be formed *in situ*. You don't have to go through a big factory to blow molding or to extrude the polymer film. I can form a surfactant film at an interface, *in situ*. That kind of also intrigued me. So I went ahead; I wanted to develop that as a separation film. Now, I must say this: I was very fortunate. I had what I called an enlightened management. I also mentioned this in my Perkin speech, it doesn't matter—big company or small company—you need an enlightened manager, and I had one. His name is Don Baeder. He was the Vice President of Research at that time. He said, "Norman, you can have time to explore this." I know, normally, your boss would tell you, "Do the assignment I give you, because that's what I want to get done. I don't want you to take a detour." But here I was taking a detour. I wanted to do something new, totally on my own, on company's time and resources. So Don Baeder really took a chance and said, "Fine, Norman. You can do it. Go ahead." Initially, I was part time. Later on, when things got to be very, very interesting, he said, "Okay. Full time."

TRAYNHAM: How long a period lapsed during that part-time activity?

LI: Maybe three years.

TRAYNHAM: So it was a moderately long gestation period before the real industrial potential was becoming apparent?

LI: That's right.

TRAYNHAM: During that time you were doing experiments on the development of liquid membranes and just seeing if they would function?

LI: Yes. Jim, I think it's a very, very interesting invention story, if you will.

TRAYNHAM: Well, please tell us about it.

LI: All right. Working in Exxon, of course, the first thought I had was to use a membrane to separate hydrocarbons. When I mentioned I was doing gas separation, those gases were hydrocarbon gases like ethane, propane, butane, and so on. But for liquid membrane, I was thinking about heptane and toluene, those liquid-type of hydrocarbons. Here I learned something that has been a benefit to me throughout the rest of my research life, which is that you actually learn a lot in developing one invention. This is just like climbing a mountain. You get to the top of the mountain and then you begin to see there are other mountains beyond. If you don't climb on the top of the first mountain, you never see other mountains beyond. The first mountain in the liquid-membrane case is the hydrocarbon separation. When I did enough of that, I realized the benefits were there but not sufficiently so to dislodge existing processes, i.e., to build new plants to do hydrocarbon separations. However, I learned enough to find there's another mountain, which to me, I think, could be the part of the reason for my Perkin Award—that is for metals separation, using the so-called facilitated-transport mechanism.

The facilitated-transport mechanism exists in nature, in biological cell membranes, for millions of years. People talk about it, but no one knew how to mimic that in a synthetic membrane. The whole idea is, you put a chemical reagent in a membrane phase. You have complexation reaction. You complex the metal ion on one side of the membrane. Then you move the complex to the other side where you do the de-complexation. In this way the metal ion gets to the other side. Then the freed complexing agent diffuses back to the other side, starting complexation again, so you do this cyclically. But people couldn't do that. The reason was, in a solid polymeric membrane, the diffusion is too slow. Only when I formed the liquid membrane was I able to join the two things, i.e., I can put facilitated transport mechanism in a liquid-membrane system. As you know, the diffusion coefficient in solids compared to that in a liquid are just so different. The diffusion coefficients are 10^{-9} and 10^{-5}, respectively. So I believe, really, my major contribution is the second mountain where, if you will, I had another major invention, which was incorporating the facilitative-transport mechanism in a liquid-membrane system so that it can pick up ions, like copper ion, on one side of the liquid membrane, moving it across the membrane to the other side. I think that opened up a lot of possibilities.

We nearly got two processes commercialized at that time, but unfortunately, both did not go because of the economics, not because of the technology. One was the uranium extraction. We actually went to Florida and worked in a phosphate plant. It's nature's way—when you dig up the phosphate ore, you can find uranium in the ore. We were trying to extract uranium using liquid membrane. Uranium concentration was very low, like 200 ppm. However, we were able to extract uranium from the phosphate solution and to concentrate it. We demonstrated the process in a pilot plant. The only reason that process was not commercialized was, unfortunately, due to the Three Mile Island incident. As the chief scientist, I was the one who actually recommend to Don Baeder, "Let's stop this." Because we no longer had the economical driving force. The "yellow cake" for uranium used to be sold at thirty dollars per pound, but after Three Mile Island incident, it dropped down to ten dollars. We lost the economic driving force. No point to go on.

The other unfortunate case was the copper. Copper was a nice application for liquid membrane, except we hit an economic depression era around that time. People did not build new houses anymore. For the first time I realized the major consumption of copper is in new houses. They use a lot of tubings. This never dawned on me until I got hit with it. [laughter] When they didn't build new houses, copper consumption went way down. There's no market, and we dropped that application. But I'm glad that as recently as last year, two plants were built in Baltimore Harbor, it was publicly announced, using my liquid-membrane system with modification, to take out chromium from groundwater. So again, this is a case of metal ion in water phase; we get it to move across the membrane by facilitative-transport mechanism, and concentrate it greatly.

Jim, you know, this is the power of the facilitative-transport mechanism. Let's use this actual commercial case to illustrate this. The chromium concentration in groundwater was about 150 ppm; it was concentrated to 20 percent and that concentrate could be sold. So not only do you clean up water, you also have this value-added product, if you will. Both plants are now on stream. I'm very happy to see that.

TRAYNHAM: I'm sure you are. Was this process you discovered, developed, the first application of facilitative-transport process? You mentioned that it was known to be present in nature but had not been duplicated from the lab, that this was the first duplication in the lab?

LI: Yes. As far as I understand. As far as I know, in an industrial lab. Maybe in some kind of bio-science lab. I do not know.

TRAYNHAM: Well, this transport of metals across the liquid membrane was the second mountain that you referred to.

LI: Yes.

TRAYNHAM: Was there a third mountain then?

LI: Yes, indeed. [laughter] You ask good questions, Jim. But before I answer that question, I think we ought to first point out the novelty of incorporating the facilitative transport mechanism in a synthetic membrane, if you will, by the fact that we are able to get a lot of U.S. patents. My total U.S. patents number was forty-four. I did not count how many are for liquid membranes, and I did not count how many are for the facilitated transport. But there are quite a few about this innovation.

TRAYNHAM: Were all of those during your Exxon years?

LI: Yes. They are. Exxon did a good job in covering everything, making sure nobody can invade into this area. So my first batch of U.S. patents was on hydrocarbon separations; the second batch was on the facilitated transport. Now that leads me to answer your question about a third mountain. Having climbed the "second mountain," I saw that liquid membrane could be used as encapsulation—not only for separation but for encapsulating liquids. We subsequently developed a commercial application in Exxon. It was a very interesting application. When you drill an oil well, you may hit some explosive gases, and when that happens, it might have an explosion. If an explosion happens, of course, you lose the equipment; you may even lose life. So what we did was we tried to form some kind of a seal down below in the drilled well.

[END OF TAPE, SIDE 1]

LI: So when I thought about using liquid membrane to encapsulate something, I looked for applications. Working at Exxon, I had the advantage of talking to oil-drilling people and they told me, "Norman, we need something that forms a seal down in the well, several hundred thousand-feet deep." I said, "Oh, my God! How do we do that?" Then I got to thinking about it. Can liquid membranes do it? But first I asked them, "What kind of seal do you want?" They said, "Some kind of clay, maybe." I said, "Okay." But they told me, of course, you couldn't pump this kind of gooey, sticky stuff down the drilling pipe. You know, you just cannot pump it. Besides, the well is usually several thousand-feet deep. So I said, "Okay. Give me a clay that I should try." They said, "Bentonite." I said, "Okay." I went to the lab, and I remember I put bentonite in water, and right away, when bentonite mixed with water, I formed this putty, this sticky mud. So I began to understand that it could seal the explosive gas, but no way could you can pump this sticky mud down the well. So I said, "Let me try it in a different way." I encapsulated bentonite with a liquid membrane and then slurried that with water, so water was the outside phase, and bentonite was inside the liquid-membrane capsule.

TRAYNHAM: Just as a solid?

LI: Just as a solid. I can make that liquid membrane very strong. It will not break. And as long as you keep bentonite separate from water, they both can be pumped together as a fluid suspension. Now, how to get the liquid membrane to break later to form a seal—that takes some other inventions. That's why, by the way, I always think a single invention usually will not bring one all the way to commercialization. You need several inventions. I talked to my chemist colleagues. I got hold of some surfactants that I used to form the liquid membrane. Those surfactants get double bonds, which can be cleaved under temperature. So I was thinking to utilize the increase of temperature down several thousand-feet deep inside a well. There's a temperature profile from above the ground to several thousand-feet deep. I therefore know, roughly, what kind of temperature increase is down there, and I got the proper surfactant, which had molecular-chain cleavage at that kind of high temperature. Therefore, the membrane was basically weakened. That, coupled with this whole slurry, pumped through the drilling nozzle bit under high pressure, the membrane can be broken. The weakened membrane can be broken by sheer force, and you form the plug right there at the place you want it. So I was very proud of that invention. I never even thought about this several years back. But that's the third mountain—you can use liquid membrane to do encapsulation.

From there I devised another thing, which I really wanted to commercialize, but unfortunately, Exxon said it's not within their core business. The other invention I had was the artificial kidney. For kidney patients, when their kidneys do not function, of course toxins build up in the blood, and that's why they have to go to hospital for dialysis. So I thought about it, and then being a chemical engineer, I thought about mass transfer of these toxins. The toxins are in the blood—where do you pick them up? It turns out to be in the intestines. Because in the intestines around the wall you have many minute blood vessels, their total surface area is very large. That's where you get the mass transfer of the toxins from the blood into the intestines. So I said, "Oh, okay, I'll just pick out a major toxin, which is urea, to study." The other good thing about working in a large company is, you have bioscientists and chemists and all the people with different experience and background. So I talked to a bioscientist. "Give me something I can use to react with urea." He said, "Well, I'll give you the enzyme urease, which would decompose urea." So I said, "That's very good. But how am I going to protect urease going through the stomach?" That's when I thought: "Well, why don't I couple the two. Encapsulate urease so that it would not be digested in the stomach and can be put in the intestine. And then the urea would diffuse into the capsules and be reacted by this enzyme." But then I realized that when urease decomposes urea, it forms ammonia. Ammonia would diffuse back out into the intestine. That would not help the patient at all. [laughter] You remove his urea, but you give ammonia to him. So I simply had another type of liquid-membrane capsules. I encapsulated citric acid. When ammonia was created, it was neutralized by the citric acid. So I ended up making a milkshake, if you will, that has two different capsules. One type of capsule gets urease enzyme, the other type of capsules get citric acid.

TRAYNHAM: So for it to operate, the ammonia has to diffuse out of one capsule and enter another capsule.

LI: That's right. But if you have sufficient concentration gradient, you can do that. As a matter of fact, I decided to work collaboratively with Professor H. W. Wallace at the medical school at the University of Pennsylvania. He actually did *in vivo* experiments with dogs and the results were very good. In this research, there were two interesting small stories. One was that I wanted to get fresh blood. I actually found a slaughterhouse near our laboratory. I found out the way they killed animals, which was the kosher way. We preferred this way, because the animal is killed by cutting the throat and the blood is drained immediately. So I went to the kosher slaughterhouse and talked to a rabbi. He was very helpful. He said, "This is for a good cause so I'll do everything I can to help you!" So I got lots of blood for our artificial kidney experiments.

The other story is that CBS in New York got wind of it. They had a *Science* program. I still remember the person in charge of the program was Mr. Crawford. I think he is well known in television. So Mr. Crawford called me. He wanted to interview me and I said, "Fine. Come over to my lab." So he came and actually they aired the interview in New York, on the CBS evening *Science* program. But instead of being elated to become famous on TV, I was saddened because after they aired that interview, I got a lot of phone calls from kidney patients, telling me they wanted to be my guinea pigs. They wanted to experiment with anything new. They were in a desperate situation. That was really sad for me to realize that kidney patients were in such an unhappy state. I asked them, "Why do you want to try this, as I'm still years away? Why are you so anxious? Why can't you just do your dialysis in the hospital?" They said, "Dr. Li, do you realize that I go to the hospital three times a week? I have no life. I cannot travel. I want to take your medicine so I can travel." That was really the whole idea. But the ending was not too happy because, as I said, Exxon believed they should not get into the pharmaceutical or drug business, so that work eventually didn't go anywhere. I think after I left Exxon they licensed it to another company and I lost track of it. I don't know what happened. I believed I could be the driving force behind that, if I could follow that project. But once I left Exxon, they licensed it to somebody else and maybe that was the end of it.

Anyway, there was the third mountain: encapsulation, which had a lot of potentials. Unfortunately, some potentials did not relate to Exxon's core business. For instance, there's another big potential about encapsulating pesticides, and insecticides, but that's the agriculture business, which Exxon wasn't going to get into. It was kind of unfortunate.

TRAYNHAM: Has anyone else picked up on that possibility?

LI: No. But you see, Jim, you really need somebody to push. You need the inventor who has a strong desire to see that his invention is being used, somebody who's the primary driving force. I'll give you one more example. I'm still fascinated about encapsulating insecticides together with sex-attractants like pheromones. People did that. I'm not the first one who thought about it. But they used solid capsules. That, to me, was not effective. The solid capsules don't stick to the leaves. They would just eventually drop to the ground. But when you use liquid membrane, they stick to the leaves because they are liquid. It would be so much more effective, so much more. And I would really love to see that kind of application being commercialized. I think maybe with time, somebody can eventually commercialize that.

TRAYNHAM: Is there any more to your Exxon story that we should include?

LI: That was it. Those were the highlights. Of course, we do have other things to talk about. I did a lot of, as I say, the refining processes. But my highlight at Exxon was the liquid membrane, and as I have pointed out, I think the major contribution there is the coupling of facilitated transport with the liquid membrane.

TRAYNHAM: Is that still being used by Exxon?

LI: Exxon patents now have expired. That's why Commodore Company built the two plants in Baltimore Harbor in 1999. They didn't have to obtain a license; it's free for everybody to use.

TRAYNHAM: Well, then you made a change in your employer?

LI: Yes. That was very interesting. Dr. Mary L. Good, at that time, moved to UOP, Co. here in Chicago, and she became Vice President of Research. Under her there was a Director of Separation Science and Technology. That gentleman retired, and so I understand they interviewed quite a few people, and Mary was not too happy, I guess, with the candidates. So out of the blue, she called me. She said some people had recommended my name to her. She had heard about my name, however, she didn't know me at that time—only through my reputation. She wanted me to come for an interview. At that time, because of the liquid-membranes research and my early work on the de-waxing process, which resulted in patents, I was doing very well in Exxon—I never thought I would move. I was pretty high up in the R&D organization as a scientist. I didn't get into management. Exxon does have the ladder system. One the technical side, you can be very handsomely paid, have a high position, recognition, but no administrative responsibilities. I was on the technical side and I really enjoyed the freedom as a senior scientist. So I was very happy doing my research. But here Dr. Mary Good called me, saying, "We want you to be interviewed as a director." So I said, "Wow, that's quite a change from a laboratory researcher to a research administrator." That was really a one-hundred-eighty-degree change. I didn't know whether I wanted to make that change. So initially, I didn't even want to go for an interview. I didn't want to waste her time and my time. But she persisted with a few more phone calls, and finally, I think she said something like, "What do you have to lose? You come here, you get to see things, talk to us. All just in one day's time." Finally I said, "Yes." Jim, just like you said about well-meaning people. She is one of them. Besides, it was just one day's time. So I said, "Fine. Let's do it." I came for the interview, and I still remember the way Mary Good did the interview. At the end of the day, she had all the other directors with her in one room to see me. So it was like doing a Ph.D. oral. [laughter] She was the one asking me questions. So I was standing there answering those questions. I remember she asked me about liquid membranes, and so I answered a lot about this question. I think after the interview she was happy. She made an offer to me. But, Jim, you probably can see that my wife and I are very close. Therefore, immediately, I realized several things I had to resolve with myself and with her. First, I needed to make up my mind: "Am I going to be a researcher for life, or am I going to change the career to become a manager?" That was one thing. Secondly, my wife by that time had already gotten her Ph.D. in statistics. She also worked for Exxon. I was with Exxon Corporate Research, and she was with Exxon Chemical. She was doing very well. As a matter of fact, they actually told her they earmarked her to go up—she had great future with Exxon and she could have become a director in Exxon, quickly. They had great hope in her. Especially of course, they really wanted to nurture, cultivate, if you will, a woman manager. Once they saw she had the capability to manage, they really wanted her to go that route. So she had a great future with Exxon. If I relocated, what would happen to her, her career, and all that? I had to really face that question as well.

I decided that I wanted the change immediately. I happened to like not only Mary Good, but her directors as well, and I thought I would enjoy working with them as one of them. But I wanted my wife to meet them, too, to help me make the final decision, as I always trust her judgments. I thought that if I talked to my wife about the job, "Mary has five directors, and they are all nice guys, et cetera," she would have no idea as to exactly what I'm talking about. So I did something I think very few people ever did. I called Mary Good and I requested another interview. That of course was considered normal, because people do request another interview, or sometimes the company wants another interview. But the strange thing of my request was that I wanted to use the same schedule. In other words, I wanted to see the same people, everybody the same. I don't know whether they suspected anything, but that's the way I told her. I said, "I'll bring my wife, go through the same schedule one more time."

TRAYNHAM: Did you request that your wife be in the interview also?

LI: Yes.

TRAYNHAM: She was to go with you?

LI: Yes. In my first interview, I got to see the individual directors, then at the end I saw the group. As I mentioned to you, Mary Good chaired a group meeting with me. So I requested the whole thing, except the final group meeting, because I didn't think my wife needed to see that. But I did want her to see the individual directors. So we did the second interview and we talked with them, every single one of them, one more time, only this time my wife was there with me. We talked not only about the science, the program, the administrative stuff, but also about living in Chicago, and the kids going to school. When my wife came back, she agreed that if it was under Mary Good, it would be a good environment for me to work.

So that kind of began to further strengthen my idea that maybe I could change my career. But I didn't solve the second problem yet. The second problem was, "What happens to her? I don't want to have an unhappy wife sitting at home." Again, Jim, you can see my wife and I are very close. I cannot be selfish and just say, "I want to go. You just follow me." No, I'm not that type. I'm the opposite. So I told Mary, "No, I probably won't come." Just like in your case, you know, with the Chemical Heritage Foundation. Mary said she understood, but then she said, "You know something? UOP doesn't have a single person who has the statistics background and experience as your wife does. UOP Company is a chemical engineering company. Such a process company should use statistics, and they don't have a person to head the effort." She then said, "Let me work on that." In the end, they created a position for her as the manager of their data analysis, the computer and statistics, things like that. And they did an interview with my wife. This time it was not under Mary Good. It was under another vice president. His name was Frank Adams. They interviewed my wife, and they made offer to her. But I sat on Mary's offer for about a year. Toward the end of a year's time, I remember Mary called me in New Jersey and she said, "Norman, I cannot wait. I made this offer to you so long ago. I really need you to be here." So finally we decided to accept the offers. The whole family moved, uprooted, if you will, because we'd been in New Jersey for a ling time. I worked for Exxon for eighteen years. That was indeed a very long time! Our two kids, they really didn't want to move. They had a lot of friends down there. But anyway, my family moved. My daughter, fortunately, played piano and she was very smart, in that as soon as she joined the high school here, called Hersey High School, she joined their band, played the piano in the band, and right away she made a lot of good friends. I think that was very smart. My son was much younger, so for him it wasn't as important to leave friends as my daughter felt. She really left quite a few good friends in New Jersey.

TRAYNHAM: She was in high school at the time?

LI: Yes, I think so. So, we settled down in Chicago. But, I'll tell you, I don't regret the move. I think Chicago, overall speaking, is a nicer place than the part of New Jersey close to New York City. I think Midwest people are more leisurely, if you will, and that part of New Jersey is just like New York City. There's what I call the "subway mentality." [laughter] They would push their way through the crowd and rush somewhere, you know. Always rush, rush, rush. Also, I remember a very well known professor, his name is Professor Edwin Lightfoot at the

University of Wisconsin. He is a very good friend of mine. I invited Professor Lightfoot to give a lecture at Exxon and he subsequently told me, “Norman, do you realize there’s a cancer belt in New Jersey? In that area, people have a high potential of acquiring cancer.” Because, I guess, of industrial pollution, whatever. And we lived in that cancer belt. But moving to Chicago, as you know, it’s the Windy City, the air is always fresh. We just enjoy it. We enjoyed this move.

TRAYNHAM: When you moved, did you set up residence in the suburbs as you now live, outside the city itself, or did you actually live in Chicago?

LI: No, we never lived in Chicago. We lived outside. We kind of enjoyed both worlds. We like the quietness outside of city, but we go into the city for the culture things: museums, the symphony, and so on.

TRAYNHAM: Well, what was your beginning assignment and activity with UOP once you made the move from Exxon? You were now in a new role as manager. You had experienced enlightened management, and I trust that you were an enlightened manager when you came to UOP, but what did you do?

LI: Well, I was taking care of the separation programs for UOP, and UOP’s company has two major business areas. One is catalysis. They studied a lot of catalytical reactions. Based on those reactions, they have manufacturing processes. So they do a lot of licensing in the catalysis area. The other area is separations, and they have the so-called Sorbex technology, which is a liquid-phase absorption. They have many commercial applications. One big, money-making process is called Parex, where they use absorption to preferentially absorb para xylene, over the other two isomers, because para xylene is used to make, eventually, polyester. These are the two major business areas. Therefore, the separations program is very important for UOP, and I was in charge of that program. One of UOP’s ways of doing things is that they would send marketing people to visit different companies, like DuPont, find out what they need in terms of separations, and then they would come back to me saying, “Okay, if you can do this kind of separations, maybe we can sell that later on.” So we got a lot of good feedback and we did a lot of exploratory work. Then if exploratory work turns out to be successful, we’ll move to pilot plant studies. Once we finish the pilot plant work, the process will be ready to be licensed. UOP is a company that’s strictly doing business by licensing technology. So technology is very important for them.

TRAYNHAM: Were you able to bring your interest in and experience with liquid membranes to your UOP responsibilities, or was that left behind at Exxon?

LI: That was left behind in Exxon. I should tell you one thing of which I feel very proud. Maybe in a small way I contributed to the U.S. Apollo Program, Moon Landing Program. Excuse me for taking a side trip here. When I was with Exxon, I got a phone call. They wanted me to be their consultant on the U.S. Moon Landing Program, the Apollo Program, because they used polymers to make so-called fuel bags. They put the liquid fuel inside a polymeric bag and then by changing the pressure outside the bag, they would squeeze out the fuel. They told me this was a very precise way you could inject the fuel, by just using a flexible container, if you will, and you control the injection rate by controlling the surrounding air pressure. They wanted me as a consultant to study the diffusion rate of fuels through the polymers. So I was very proud. I contributed, maybe in a small way, to the Apollo Program.

When I left Exxon, there was no point in continuing my work on liquid membranes. Exxon did such a fantastically good job in getting all the patents. They monopolized the whole field. However, as illustrated by my consulting work for the Apollo program, I never truly left the solid-polymeric-membrane field. It was very interesting, at that time, when I took over the job, I noticed there was no membrane program in my department, only an adsorption program. So I wanted to start a membrane program. But UOP was not familiar with membranes, and I foresaw that I would have trouble getting money to support a new program on membranes. As I remember, I told Mary Good, "I am going to write a proposal for the Department of Energy [DOE] and see what happens." Actually, the idea about writing a proposal for DOE came to me when I was at Exxon, just about to leave. As soon as I got to UOP, I sat down in my office. I just started to write. Of course, during the day I had to manage a lot of things. But I spent the first four weekends writing the proposal. There it was—an unsolicited proposal. I just had a strong drive. I wanted to get a membrane program in this new place. I put down some ideas I had—three or four ideas—into an unsolicited program and sent it out, just like that. Then the news came. DOE saw it. They told me that they liked it. They gave me 1.2 million dollars for the next three years. That was in 1981. So, 1.2 million dollars for three years was very good money to get something started.

TRAYNHAM: Oh, yes.

LI: I was elated. But it shows you that sometimes you have to—I don't know how to say it—you just have to have faith in yourself to drive it, because nobody encouraged me to do that. And the odds were unknown. I, as a new director, personally wrote this proposal. If it didn't get funds, you can just imagine, maybe people would laugh at me or something. But I didn't care. I wrote it, and it was not even a solicited program. I just sent it in based on my own ideas. That's how UOP got started on its membrane program.

TRAYNHAM: If it were not liquid membranes that you had pioneered at Exxon, what was the nature of the membranes at UOP that you were concerned with?

LI: Well, as I mentioned, I got three or four ideas in that proposal. One idea was to use solid polymeric membrane for natural gas separation, to separate out H_2S and CO_2 and only have the methane left. That was one sub-program. The other program was to use membranes to separate solvent from heavy lube oil. This is going back to my experience with the de-waxing process. You hit the heavy lube oil with a light solvent, like pentane, then separate the wax from the lighter phase. Now there was this very light component, solvent, mixed with a very high-molecular-weight lube oil. When you try to recover the light component, the conventional way is by distillation, but I proposed to do it by membranes for lower energy consumption. So those are the things I got started.

And then I got involved with reverse-osmosis membrane, because UOP had a company in San Diego. It's called Fluid Systems. Their business is in making reverse-osmosis membrane. Since UOP was its parent company, we did a lot of work to support them. So I was getting into reverse-osmosis membrane at that time.

TRAYNHAM: For the record, briefly, tell us what reverse osmosis entails? What does it mean?

LI: All right. In nature, if you take pure water, put that on one side of a semi-permeable membrane, and on the other side you put seawater—seawater typically has a salt concentration about 3.5 percent—if you set up something like that, water on one side, seawater on the other side of a semi-permeable membrane, the natural way is for pure water to diffuse across the membrane to the seawater side, and that tendency is characterized by the so-called "osmotic pressure." It's this osmotic pressure that drives pure water to the seawater side. It's proportional to the concentration of the salt. In other words, seawater has 3.5 percent salt. If you change that to brackish water, which has only 1 percent or less than 1 percent of salt, then the tendency for water to diffuse to the other side would be less. This is called osmotic diffusion. Now, think about it. If you put pressure on the seawater side, with that pressure, you are kind of forcing the water to go the reverse way. Instead of losing your pure water to the seawater side, you want the water from the seawater side to diffuse to the pure water side. This is what the reverse-osmosis membrane process is all about. So you take seawater, for instance, and subject it to high pressures because of its high salt content, to maybe 800 pounds to 1,000 pounds. You are able to produce potable water by using reverse-osmosis membrane. Reverse-osmosis membrane can be used for not only desalination purpose, but also purifying industrial waste water.

TRAYNHAM: What was the nature of the membranes that permitted this reverse osmosis to operate?

LI: You ask a very good question. The membranes have tremendous selectivity for water, but to this day, I don't think we fully understand why. When you have sodium chloride, say, dissolved in water, you have sodium ion and chlorine ion and the water molecules, being polar, form solvated molecular clusters, as we know. But when water diffuses through the membrane, it's only water. It's not carrying salt going through it. A very, very small amount of sodium chloride can be found on the other side of the membrane due to diffusion based on the salt concentration gradient, but it's not like a major carrying over. No. The whole detailed mechanism of why just pure water is going through this particular membrane is not known. There are several types of membranes you can use. Why do these few types of polymers allow pure water to go through? I don't think we have a complete understanding yet.

TRAYNHAM: Was this utilization of the idea of reverse osmosis original with you and UOP, or was it a specific application of previously existing technology?

LI: The very early mention was made maybe sixty years ago. UOP certainly was not the inventor. The real practical applications may be as old as thirty years.

TRAYNHAM: But you developed new membranes to accomplish this? Is that the idea?

LI: Yes, the whole idea was to develop new membranes, and the membranes with various chemical resistance. For instance, in the United States, the municipalities purified their water by chlorinating water. The residual chlorine in the water would cause damage on membranes. So we did a lot of work of developing polymers that resist the chlorine attack.

TRAYNHAM: What other developments occurred in your management at UOP? You indicated that was the initial undertaking that you did.

LI: Well, yes. The main thing was still adsorption. That technology I should mention a little bit. It was called Sorbex. The whole idea was, when you do the liquid phase adsorption, you have a certain adsorbent that absorbs certain material, but then you have to add a desorbent later on to desorb the material that has been adsorbed. The whole thing has to be carried out in a liquid phase. UOP had a very, very bright chemical engineer. His name was Don Broughton, who died maybe ten years ago. He was very bright, and smart enough to figure out on paper the simulated moving-bed theory. In general, we need a counter-current flow process. In other words, in an adsorption column, the solids flow one way, the liquid flows the other way. That would give the best, most economical system. But in reality we cannot get all the solids to flow. They are heavy. So Broughton said, "Instead of having solids flow, I am going to change the inlet and outlet positions of all those streams with time. If I have a time clock that can make the changes of positions with time." Say all the positions are moving up one notch that simulate the solids going down one notch—it's just like two trains, you know. One train moves, and if you're sitting in the other train, which is not moving, but you feel you are moving oppositely.

Same idea. And he proved it mathematically that this so-called simulated moving bed would give the same economical advantage as the real moving bed. That was the basis for UOP's invention of the Sorbex system. This so-called simulated moving bed, to me, is a very amazing invention. It's like a gold mine. The core technology is the foundation. From there, you keep on coming up with different applications. I mentioned Parex, to separate para xylene from xylene isomers. There are many other applications. So our job at that time was to develop new applications.

For instance, one application I worked on—this one we happened not to be able to commercialize—was with fish oil. In the fish oil, as we know, there's a compound called omega –3 fatty acid, which is very valuable for depressing high blood pressure. I remember we worked on that separation using adsorption. So we tried different applications. We tried to develop new applications based on the Sorbex fundamental invention. That was the main job of the separations department.

But I should mention something here: when I first came, I found that I really needed to reorganize the department. That took me quite a bit of time. Reorganizing actually meant letting some people go and hiring some new people.

[END OF TAPE, SIDE 2]

LI: The reason I can work very well with Mary Good is I find that a lot of times, we think the same way. I happened to think it's important to find bright young people, but not necessarily the people with the skill and experience that fit into our projects. I believe strongly that if I can find a young Ph.D., for instance, who is very bright, then by his Ph.D. training he should be able to learn things quickly. Mary also believes in that. So we were able to hire quite a few bright young people to join the department. But that took quite a bit of my time, and I can be honest in telling you that I also met a lot of resistance within the existing staff. Of course, they felt uncertain about their future and so on. But my purpose was simply to make the separation department much more efficient and competitive.

TRAYNHAM: Did you do much of the recruiting visits yourself or did you have others who did that?

LI: I didn't have to make the plant trips to other companies, but I had people coming in and then I always participated in the interviews.

TRAYNHAM: Were most of your new hires fresh out of university education, or were they brought over from other companies where they had been employed?

LI: We had both, but I think most were new Ph.D.'s. A few came from other companies. So, yes, I think Mary was right. She believed it was one of my major contributions as a manager to bring in very bright young people to join the old-timers.

TRAYNHAM: Did you have any pangs of discontent over the fact that these young people you were bringing in were the ones who were doing the actual bench work, which you used to do, and you were now recruiting and managing their work? Did you have any feelings of missing the direct involvement in the bench chemical engineering yourself?

LI: Yes, I did. Except I realized, maybe I was in even a better position because I could offer them my ideas and have them try my ideas, if they believed my ideas sounded promising. So instead of doing it myself, which would be slower, I now could have more people working, perhaps, on my ideas.

TRAYNHAM: So you were beginning to find some enjoyment in being a manager?

LI: Yes. I was kind of a very involved manager, if you will, and I subscribed to what Mary said about an open-door policy. In other words, my door was literally always open. Anybody could just stop by. Didn't need to make any appointment with me, although I had a secretary. So I believe I was very close to my researchers.

TRAYNHAM: You made a change of employer again after the UOP experience, I believe. What led to that change?

LI: Yes. That was a difficult change, you know. I realized a lot of times you cannot think purely based on the work. People are another important element. When I faced the change of either staying with UOP or go to Allied Signal, where Mary was going, I decided to follow her. Although technically, I don't think it was a good choice simply because at Allied Signal, separation is not nearly as important as at UOP, and separation is my specialty. I have mentioned separation is one of the two large businesses for UOP. Allied Signal is much bigger, with a lot of things going on, but even chemical engineering is not a major part of Allied Signal. But I think here the people-factor became important. I really feel that Mary Good is what I call an enlightened manager, and I followed her to Allied Signal.

TRAYNHAM: Did you know who would be replacing her at UOP before you made your choice to move with her?

LI: No. At that time, I was mainly concerned about whether I could have someone above me that I respected and received support from, which I was confident that I could get that from Mary Good. But actually, it turned out to be also a good move from a technical point of view because, although Allied Signal did not do that much separations work, I did end up doing a lot of catalysis work, which was a new experience for me. For instance, Allied Signal is big in making the refrigerants. By the way, DuPont's trade name is freon®. Allied Signal and DuPont are two major competitors. In making the refrigerants, you need to have good catalyst. Especially later on, when we tried to produce the so-called "ozone friendly" refrigerants. That meant a whole new process with a new catalyst. We did it in my laboratory—my job title was changed too. It was no longer Director of Separations Research, but rather Director of Research and Technology. You can see from that title, my responsibility increased tremendously. So not only did I have the separation programs, I also had quite a few catalysis programs. Allied also is big in automotive catalysts, so we did a lot of work on automotive catalysts. Allied is also very big in making nylon fibers, and nylon fibers are used to make carpets. Again, Allied and DuPont are the two major suppliers of nylon fibers. So we did a lot of work on things relating to extrusion and to fiber surface properties.

One major project at that time was how to change the chemistry of the fiber so that the fiber becomes stain-resistant. You can pour coffee to your carpet and it will not stain. You can wipe it off. We did a lot of research on those kinds of things. So in hindsight, my going to Allied Signal got me into some separation research, but more into catalysis and polymer chemistry. So I consider that as a good move. I must say, that was not a determining reason for me to move in the beginning because I did not know I would get into those areas. The reason, as I mentioned, was because Mary Good was there, she invited me to go, so I decided to go.

TRAYNHAM: But her career at Allied Signal was cut short by her becoming Assistant Secretary of Commerce. Where did that leave you at Allied Signal?

LI: Well, as I mentioned, the people-factor is important, indeed. After she left, the person who took over was, frankly, a disaster. A disaster to the degree that upper manager in Allied decided to abolish corporate research altogether. I guess her successor didn't show the benefits of corporate research, or couldn't convince the upper management that they should continue to support corporate research with that kind of huge funding. So the policy was completely changed. They abolished corporate research. They laid off some scientists, and sent the rest of the scientists to different divisions to get them to work on the division-sponsored, very-applied research. So Allied then decided to quit from the long-range research. To me, I think it's a loss to the company.

TRAYNHAM: So it was a contrast to the management you had experienced up to that time?

LI: Yes, that's right.

TRAYNHAM: Unenlightened management, I guess you would call it.

LI: That's right. That led me to decide that it was time for me to leave Allied.

TRAYNHAM: So at that time, you had had how long a career as an industrial employee? Eighteen years with Exxon, and then how long with the others?

LI: Fourteen with UOP and Allied combined. So thirty-two years.

TRAYNHAM: That, for most people, would be a full career.

LI: Yes. But then I thought, health-wise, I was fine and, therefore, should continue to work. My wife was doing great in UOP. The interesting thing is, UOP is a kind of old-fashioned company, if I can put it that way. In old days, they calculated everything with slide rules, so to speak, and then when they got into computers, they didn't pay too much attention to the software. The engineers were taking a lot of data, but they didn't have a good scientific way of analyzing the data. They didn't really use the statistics in analyzing the data. I happen to believe, and also have learned quite a bit from my wife, that a lot of information is there in the data. You cannot just eyeball them. You really have to work on them to extract the maximum information out. I think UOP really learned from my wife because of her statistics background. So UOP started to apply statistics to design of their experiments and to data analysis. Design of experiments means that instead of rushing to lab and cranking out one thousand experiments, you carefully design by using statistics. Instead of a thousand, you make, say, ninety-five or something, a much smaller number of experiments. Once you get those experiments done, you analyze them very carefully. This is why my wife's work is very important at UOP, and instead of thinking like a person would normally think after working for thirty-two years—retiring and lying on a beach, enjoying himself—I decided to have this consulting company. So I took early retirement and—well I don't know how "early" this means—I was actually sixty-two years old in 1995. But anyway, I decided to retire from Allied Signal and start this consulting company. I decided to have some fun and not worry about all those bureaucratic things in a large corporation. So that's where I am.

TRAYNHAM: The change from UOP to Allied Signal did not require you to change your residence, I believe.

LI: No. I've been staying in the same house for fourteen years.

TRAYNHAM: The commuting route was a little different, but other than that, it was not a change of place.

LI: That's true.

TRAYNHAM: So you didn't face the same problem you faced moving from New Jersey, as to what would your wife do. She just continued in her employment with UOP.

LI: That's right.

TRAYNHAM: She continues to do that?

LI: Yes, and she has, of course, advanced in her career. As I mentioned to you last night during dinner, she's now the Director for the Statistics Science Center and the director of UOP's quality management program. She's doing exciting things.

TRAYNHAM: You retired from Allied Signal at age sixty-two and started your own consulting business. That's where we are now. What's the nature of the consulting business you carry on?

LI: Well, I do so-called individual consulting. In other words, a company would invite me to go there—just like when I was in Allied Signal, I invited professors to come to consult. But also we do project consultation. That is, somebody, a company, wants to ask us, for instance, to set up a membrane plant from the beginning to the end. So we have to do everything. Of course, we don't actually do everything. We don't have enough people to do that. But we will take care of the entire project. So that's why it's called consultation by the project. If the machines in the project have to be made, then we will contract machine companies and so on. We do all that kind of thing.

TRAYNHAM: Do you find that all or most of your consulting business comes by companies coming to you to request your services, or do you advertise your availability for certain specializations?

LI: We have a web page, but other than that, we don't send out brochures or anything. As a matter of fact, we don't even have a brochure. I don't intend to make this company grow into thousands of people. If that were the case, I might as well have stayed at Allied Signal. I think it should be small so we can be agile, we can do the things we want. We don't have to worry so much about overhead and cash flow. We can select the programs. In my situation, I can afford to select the programs that I feel happy with because they have a direct impact on people.

I'll give you one example. When I was in Beijing, China, there was this university called the Beijing University of Chemical Technology, where I visited. The President took me for a tour. The president was a woman and she said, "We have more than twenty thousand students here, and once they leave the dormitory, come into the classrooms, they don't have water to drink. They either have to buy bottled water, or Coca-Cola. But they cannot drink the water from the faucet. We used to have a huge boiler. We tried to boil the water for them, but we don't have the money anymore. We cannot supply twenty thousand students with drinking water."

TRAYNHAM: Is that the case all over Beijing?

LI: I believe that's the case all over China, not only in the universities, but also train stations, et cetera. You go to the Beijing train station and you see so many people but the water there—you'd better not drink it. So I said to myself, "If you could use membranes to purify water, it would directly impact people." Another example: I mentioned artificial kidney. One project we have is the artificial kidney. This is with the conventional dialysis technology, but we try to modify the membranes so that it would be a better membrane. We work together with a German company. This is also based on my early, sad experience that I mentioned with kidney patients. They really need some good ways to help them. So I think, at my stage, I don't worry about money and stocks, you know, all these kind of things. I simply try to do a few good projects.

TRAYNHAM: I'm sure you find it rewarding to have that undirected type of career opportunity.

LI: Yes.

TRAYNHAM: Well, you've had experience with at least two extremes of research and career management, and happy experiences with both Exxon and UOP and the early days at Allied Signal, and then followed by what was a less-happy research mode. You have made reference several times along the way to the importance of people in your evaluation of your career situation. What was your experience with industrial teamwork in terms of getting research done? Was your experience more of an individual project, or was it a team research project that carried through most of the time?

LI: Well, in my early days, it was more individual research, but later on I really subscribed to the new thinking, if you will, of doing things with a team—as a matter of fact, a multi-functional team. I learned one thing, which is very interesting and actually I learned it back in Exxon, except it wasn't used very commonly. But I learned that very quickly. It's a skill. It's a way to solve problem by using teams. It's very interesting. If I hit a research problem, and I talked to my colleagues, we thought about something we applied, but we still couldn't solve the problem. One last way was to call a meeting, inviting people who had no background and experience about this project. As a matter of fact, you want to invite somebody who may be a physicist, or a mathematician. In other words, if you are working on a chemistry problem, then invite somebody far away from chemistry. You get a team like that, and amazing thing usually happens. At a team meeting, you pose this problem to the team, and one rule I always have is: you cannot laugh or put down somebody's ideas. You have to respect people's ideas, no matter how ridiculous they seem. Do they come up with ideas! The amazing thing is that sometimes their ideas will come out really helpful in solving the problem.

I remember my own experience—that is why I believe in this approach. I was trying to solve a problem with a surface-related problem. Exxon invited a professor to be my consultant, which reminds me of what I am doing today, myself. The professor spent one day with me. I remember he wrote all the theories on my blackboard. He tried to tell me my problem couldn't be solved because it was governed by certain theories. But I solved the problem in the end—I was very proud. As a matter of fact, I got one U.S. patent to prove that. I remember I didn't give up on my initial ideas. I agreed with him on the theories, but I was not intimidated by them. I was maybe ignorant enough that I decided to attack this problem based on my own ideas. So I learned in early times that you get a group of people with different backgrounds as an idea-generating team. This would be good. Now with this Six Sigma and Quality Management approach, we tend to have a multi-functional team. In other words, we have researchers, we have marketing people, and all that, joining as a dedicated team for a certain project. I certainly agree with that, too. But I do feel there should be some important element here. I feel that good judgment has to be there, because when you talk about team, you most likely talk about empowerment. You empower the team, let the team members to do things. Invariably, good judgment becomes very important. Otherwise, they may be led astray doing something unimportant, wasting time. I think that's one important element. There is another important element, which is: people have to be energized. You form a team and by the team's interaction, they should be energized. If they feel like it's just a routine thing, they just go to the team meeting and put up with it. That would be very bad. So on one hand, I very much subscribe to the team approach; on the other hand, I think one has to be very careful in organizing the team, and sometimes, as a manager, you still cannot relinquish your managerial responsibility. You still have to exercise leadership.

TRAYNHAM: Well, out of your extensive experience, how would you summarize your view of what constitutes scientific innovation?

LI: Jim, you see, I'm an industrial scientist. All my career has been with industry. Therefore, my view could be different from people at a university. My view about innovation is that if it cannot be commercialized, if it remains as a laboratory curiosity, then to me it really wouldn't have much value. I wouldn't even know whether it's an invention or not. If it's innovation, it has to have some practical value. It cannot be a laboratory curiosity. That's my view.

TRAYNHAM: What do you see as the future of chemical R&D in these times?

LI: I thought about this topic. In the future—first of all, I think we're going to live more and more by the integral designs. What do I mean by integral designs? We have, I think at this stage, so much intellectual capital, if you will. We have accumulated so much knowledge. From an industrial point of view, what we've been doing is we always invent, develop, then sell. This is always the sequence: invent, develop, sell. Then you move on to do another project. And this invented knowledge or developed knowledge is then set aside. Of course, it may help you in an indirect way, but not consciously. What I am thinking now is that you have the information technology, you have the computational methodology technology, you have the artificial intelligence, you have the combinatorial chemistry approach. We should now really be utilizing our existing knowledge to try to develop new things. So that's one thing.

I think in the future we also have to really very much keep in mind the speed. We need to develop things quickly into the market place, at least from a company point of view, because the competition is global and there is also the so-called "speed of life." I think another important factor is that—we need to pay attention to green chemistry; the environmental issue is very important. I also think in the future, a lot more inventions would come out from the interface. For example, organic chemistry—not so much from organic chemistry itself, but from the interface between organic chemistry and other sciences. That interface could give you new inventions, new insights. If we take chemistry broadly—you put chemistry together with biology and maybe new catalysts can be generated. I worked with enzymes, as I mentioned. Now, in nature, enzymes are very specific. Their selectivity is extremely high, and their requirements are so benign. They just need an ambient temperature, and enzymes always love water. It's not like our industrial catalysts, which sometimes require high temperature and all these kinds of things. So if you put chemistry and biology there together, maybe at the interface, maybe we can produce new catalysts, for instance. Or you put chemistry with physics, maybe you can invent new materials. We are talking about nano materials. I think they are definitely at this interface, where more new things can come out.

TRAYNHAM: Sounds almost as though you're proposing that we somehow develop liquid membranes between disciplines so there can be facilitated transport of ideas!

LI: Yes! Liquid membranes enabled me to get into different fields. I am never a traditional chemical engineer. As a matter of fact, I consider myself really quite a bit on the chemistry side. The liquid membrane enabled me to work with enzymes, so I worked with bioscientists, I worked with people in fertilizer industry to do encapsulation and all these kinds of things. The more I get experience on this and make more inventions, the more I believe this interface concept.

TRAYNHAM: Near the end of your career as an employee with industries other than your consulting firm, you received several significant awards from professional societies and it finally led up to the receipt of the Perkin Medal this year. Tell me something about the impact of those awards on you and your outlook.

LI: Well of course, with the Perkin Award, I felt very much honored, but also it really makes me feel very humbled that I was given this great honor. It kind of made me feel that I should do more, maybe even better things—almost like to justify to myself and to the society that, you know, the award indeed was properly given to me. [laughter] I could, of course, feel contented and say, "Stop here. I already got the highest honor in chemical industry." But I didn't have that feeling. I didn't have this contented feeling.

TRAYNHAM: Since it has come just this year, it's hard to assess its impact on your career. What about the earlier awards that came in the late 1980s? Did you notice that those recognitions by professional societies and your peers had an impact on your career with companies you were employed with, or did they not?

LI: Well, no. I think that's the sad part of it. I think industries usually only recognize your direct contribution to the companies. However, I think those awards of course mean that you are being recognized by your peers. I was fortunate. I think in that time period that you referred to, I have maybe three major awards or major honors. I had a major award from the American Chemical Society; that is the award on the separation science and technology. I had a major award from American Institute of Chemical Engineers; that's called Alpha Chi Sigma Award. And then I had the third honor of being elected to the National Academy of Engineering. These are three honors. Although I didn't see any immediate benefit from the company, like, "Oh, okay, you got into the Academy so we promote you." No, it's not like that. But I think, personally, it was just tremendous. I felt a satisfaction that I was recognized by my peers.

TRAYNHAM: Certainly. What has been your experience since your election to the National Academy of Engineering? How have you been involved with the National Academy?

LI: I was involved in several committee activities, actually three. Based on my separations work, we studied certain aspects of separation technology as applied to industries, and one on biotechnology. So these are my involvements. I told the Academy that I would be involved more with them. So starting this year, I will be on their Nomination Committee.

TRAYNHAM: You have mentioned several times your wife, your close relationship with her, and her success in an independent but related career. Tell me something about your children whom you have mentioned. You've had two children. What has become of them?

LI: We are very proud of them. We have two very good kids. We raised them in a Christian family and they both are chemical engineers. [laughter] That's amazing, but not by design.

TRAYNHAM: You didn't discourage them from becoming chemical engineers as your father discouraged you from becoming a writer?

LI: No. [laughter] As a matter of fact, I encouraged them, but not to the degree they felt they had to go into chemical engineering.

TRAYNHAM: You just told them what a good opportunity it was.

LI: Right. What I told them was this: "If you know exactly what you're going to do, if you are so talented in music, or you're so talented in painting, you should be doing those. But if you are not so sure about which way to go, then you may want to consider chemical engineering for the simple fact, it's very broad." Chemical engineering will enable you to go into bio, or into chemicals or petroleum. As a matter of fact, when I gave a seminar at Princeton's Chemical Engineering department, the chairman told me, "We surveyed our graduates of chemical engineering, B.S. degrees. They are in all walks of life. Some are even on Wall Street, doing things relating to the technology, of course." So chemical engineers can do many things. But to that extent, I think if you are a civil engineer, for example, your field is narrow and well defined. You know, like working on, highways, bridges. You cannot do bio. [laughter] But anyway, they both ended being chemical engineers.

Our daughter, who is older, went to University of Illinois in Champagne for her B.S. degree, then to The Johns Hopkins University to get her Ph.D. She did initially want to go to medical school and we actually discouraged her because of her health. She used to have some asthmatic attacks and we believed the medical school's training would be too strenuous for her. However, since she went to Johns Hopkins, although she's in chemical engineering, she got into excellent bio research. Now she's working with a bio company in Boston in the forefront research of tissue engineering. So I think she's very happy; instead of being an M.D., she's a Ph.D. doing bioresearch.

Our son has a very different personality. He has a B.S. degree from Purdue University and he is not interested in going on to graduate study. Instead, as I mentioned to you last night, he's now getting an M.B.A. degree, meanwhile working at the Cabot Company as a chemical engineer. So he's more interested in business. A fortunate thing from the parents' point of view—although our daughter lives pretty far away in Boston—our son lives right here. He lives in Chicago. So many times he would come home and we go to church together. I should mention that Chicago is very fortunate to have this church called the Willow Creek Community Church. It's a very large church, non-denominational. Believe it or not, the membership is like twenty thousand. We're not members, but we enjoy going there for the Sunday service. He is engaged to a lovely Irish girl who will be an M.D. She is studying for her M.D. degree at Northwestern University. They will be married next year. My wife and I feel that children would do well if the parents are good models and give them a strong family support. In that sense, I feel sorry to see some of my friends; they divorced and they separated. I think it must be painful for them and for their children as well.

TRAYNHAM: Is your daughter married?

LI: Yes. She is married to a very caring person, who happens to be a physician.

TRAYNHAM: Any grandchildren yet?

LI: No, not yet. [laughter] So, we're still waiting. Anxiously waiting. [laughter]

TRAYNHAM: You made reference two or three times during your interview to Christian affiliation. You remarked about your wife and just now about your son and the affiliation with the Willow Creek church. Was it unusual for persons in Shanghai at the time to grow up affiliated with a Christian denomination?

LI: Yes.

TRAYNHAM: How did that come about? Were your parents influenced by missionaries?

LI: Not really. In my case, when I was at National Taiwan University I had the opportunity of talking to the people in the church. I mentioned The Youths to Christ organization. As to my wife—I don't know how she became such a devoted Christian. I don't think her family gave her any influence. Both our children are Christians and I guess that probably is by our influence to some extent.

TRAYNHAM: But you and your wife both were essentially first generation Christians?

LI: That's right. You can say that.

TRAYNHAM: Well, is there any more than you think of that we should include to make the story complete?

LI: Well, I think one thing I wanted to bring out is, as an immigrant, I think many people talk about how bad this country has become, or things are going downhill, or they are angry about certain things. But I think the perspective should be that this is a very, very wonderful country. This country gains its strength through immigrants. I guess almost everybody is an immigrant, either second or third generation. But I really appreciate the opportunity to study here and to work in this country. To that extent, I feel that native Americans may not appreciate nearly as much as I do. I just hope that they live in other parts of the world for a while and then they probably appreciate more. Mary Good actually brought this point up when she introduced me at the Perkin dinner. She said this is what it's all about in this country. She used me and my family as an example to show that the immigrants who come to this country to get opportunities and to do well in this society.

[END OF TAPE, SIDE 3]

TRAYNHAM: You were speaking about your feeling about the country as an immigrant, and how important it is to you. Please pick up and continue with that.

LI: I just wanted to say that this is a wonderful country that provides opportunity for education to immigrants, for them to work to contribute to this country, and to excel in their professions. I think truly it is a wonderful country.

TRAYNHAM: I think you said that Mary Good used that as an example in the Perkin introduction.

LI: Yes, that's right. She mentioned that and she said, "This is what it's all about in this country. That it's basically a country of immigrants and they join force, so to speak, and build up this country." This is a wonderful country. It provides a lot of opportunities.

TRAYNHAM: Well, you have certainly used your opportunities to give back to the country and continue to do so in your continuing career. Thank you for your generous time and interesting story that will become an important part of the Chemical Heritage Foundation's oral history program archives.

LI: Thank you.

[END OF TAPE, SIDE 4]

[END OF INTERVIEW]

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