Dr. Marshall Nirenberg Interview

Office of NIH History
Oral History Program

Interviewer:	Lily Kay
Interviewee:	Dr. Marshall Nirenberg

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[Beginning of Transcript]

Lily Kay: Testing 1 2 3. Testing 1 2 3. Testing for an interview with Marshall Nirenberg, Washington, DC, Monday July 18th, 1984.

MN: The parts that I read I think are distorted also.

Lily Kay: Well tell me then, this is exactly -- I feel that -- well first of all I know that it's distorted because it's told -- everybody knows that it's told a lot from Crick's perspective. It's like -- Brenner makes fun of him. It's the history of the American biology, according to Crick.

MN: Well, I think that's probably a good assessment of it and --

Lily Kay: Yeah, and I think that you can see for example that in the index of the book you can't find Yanovski [spelled phonetically], which I find -- it's amazing, given that Yanovski did the collinearity --

MN: I didn't know that.

Lily Kay: He's not even in the index! It's true that later on Brenner and Crick had a more elegant way of showing collinearity, but Yanovski was first and it was very important. [audio skips] Also, the book -- things that I already know I can see that they're distorted. So I'm trying to find it in my own way by reading, going to archives, when I can and for historians it's very difficult when you get into the '50s and '60s because archival materials are not readily available -- [audio skips] -- don't write such long letters anymore like we used to. We talk on the phone a lot and so I -- interviews are just really important and hopefully if you have also correspondence at some point, you know --

MN: I have -- what I do have are notebooks [audio skips] -- telling what I actually did in the lab. The other was a notebook of ideas [audio skips] -- and so that ideas follow ideas --

Lily Kay: That's great!

MN: -- and also things to do for tomorrow and the next day and so, for laundry lists.

Lily Kay: Which years do you -- how long -- how many years?

MN: The entire coding years. From before the coding -- before and through.

Lily Kay: Could I look at them?

MN: You would be very welcome to. [audio skips] I promised them -- I promised to give them to -- [audio skips]

Lily Kay: That's a great idea.

MN: But I haven't done it yet.

Lily Kay: Oh good. So you have them in your possession.

MN: I have them, yes.

Lily Kay: Anywhere accessible?

MN: I have them at home.

Lily Kay: Could I come tomorrow? Would you bring them tomorrow?

MN: All right.

Lily Kay: Oh that would be great.

MN: I tell you, I loaned one out once only, and -- but I think that this is a good thing.

Lily Kay: [audio skips] But you got it back?

MN: Oh I got it back. No, only one of the notebooks. I have -- there's a whole pile of them.

Lily Kay: And which one is missing?

MN: No no. I have every one of them.

Lily Kay: Well, you know why I'm asking, because Brenner -- Crick threw out all of his correspondence. His secretary did. Allegedly there is nothing funny -- but the one-way correspondence between Benner and Crick was survived because Benner saved the correspondence. So I met him and interviewed him and we got along and he promised me he would give me this box -- he cannot find it.

MN: Oh my goodness.

Lily Kay: He's so upset. [audio skips] I no longer ask him to look for it because it upsets him, not so much with regard to me, but this was priceless -- this is the '50s correspondence with Crick as they were trying to figure the code through the phage and working with all this abstract numerology and you know, the period where Brenner wrote the paper on the impossibility of non-overlapping codes and codes without commas -- that whole thing, he lost it.

MN: Well, I don't have -- [audio skips] -- I have --

Lily Kay: [unintelligible] -- and then give them to the library of medicine so they don't get lost because that's priceless.

MN: How would you -- if I bring them in tomorrow, it is far more than one -- [audio skips]

Lily Kay: Yeah I know, in fact, I want to tell you what I want to talk to you today about -- [audio skips] -- I used this time to come to Washington because I had to do some work in Library of Congress, which I have to do now. I have an NIH grant for this new project, from the Genome Project -- the ELSI people gave me lots of money to do this and so I have to finish a lot of it during the grant period, which ends at the end of November. But I -- the chapter when I talk about the [unintelligible] experiment is chapter five -- chapter six in my book and I'm -- right now finished chapter two and I'm going to chapter three. So in that chapter I will talk about the work after the [unintelligible] experiment where, in your lab, you were working on figuring out whether it's two base code, or three base code, or four base code -- just all of that stuff which I can't get to today. I'm not prepared for it. But I have certain questions about this time period, from '60 to '61.

MN: I have notebooks on what I was thinking, all before I went into it, because I was deciding -- you know I was a postdoctorate fellow, and this was my -- [audio skips]

Lily Kay: That's exactly what I was going to ask you. Maybe we can just backtrack one question because I have one question before you came to NIH and that is -- I know you went to the University of Michigan and that you got your PhD there. Why did you go to the University of Michigan? Why --

MN: Well, it's -- I wanted to become a biochemist at the time -- [audio skips]

[low audio]

I was accepted, I think [inaudible] in graduate school. I don't really remember -- [audio skips]

Lily Kay: I'm sorry. It's acting up. I tested it millions of times but it's kind of stuck, I don't know why, but anyway. Should be okay. I'm looking at it this way.

[low audio]

[audio skips] -- stops and starts -- [audio skips] -- although I've used it forever interviewing and it worked really well -- brand new batteries, brand new tape, should be okay. -- [audio skips]

[low audio]

MN: Anyway -- [audio skips] -- and I came from --

Lily Kay: It is cold. And you came from where?

MN: From Florida. I was living in Florida at the time, and I really -- [audio skips]

[low audio]

Lily Kay: The department of biochemistry, was it a really good department? What did they specialize in?

MN: It was not a very [inaudible] -- [audio skips]

Lily Kay: Let's get another one, because it stops. It starts and stops, unless it's a hassle to get one.

[low audio]

This has worked really well but it looks like it stops and starts and stops and starts. But let's continue. I'm interested about Michigan because I want to know if your choice of topics later on had anything to do with your training.

MN: Absolutely zero -- zero. [audio skips] -- wasn't in molecular biology, wasn't in nucleic acids. I was trained in a totally different area.

Lily Kay: So, this is -- I was wondering, when you came to NIH -- I have your bibliography and I was interested in what you did before you started working on protein synthesis.

MN: Totally unrelated. Sugar transfer. We found the first evidence that existed for a sugar transfer -- [audio skips]

Lily Kay: But you were working on tumor cells?

MN: Yes, yes.

Lily Kay: So you were doing cancer research?

MN: Yes. Well, in a sense, yes.

Lily Kay: [audio skips] -- funded by a cancer grant, right? Because it acknowledged in -- [audio skips] -- so I was looking at -- I want to see where is -- sort of this moment where things begin to change, right? And so, I was really intrigued by this paper [unintelligible] in 1960, this little note here, because it still works within the same system --

MN: Is that -- who's work is --

Lily Kay: This is yours. [audio skips] -- You know what's so amazing about this paper, is that it refers to the works before with Jakoby about Gamma Hydroxybutyric Acid, and it refers to these systems, and to the enzymes, but it has a very different title. I neglected to mention to you that one the questions that I'm trying to follow in this history of the genetic code is: how did we come to think of organisms in molecules -- [audio skips] -- how did we start thinking about heredity in terms -- [audio skips] -- what impact did it have on the bench, on experimental design?

MN: You know, I only learned about these things about the history of the code after the fact. After the code -- we had deciphered -- [audio skips] -- have you ever spoken to him?

Lily Kay: No, no.

MN: He had a fantastic paper on -- [audio skips] -- some kind of -- [audio skips] -- nobody ever saw, I'm sure.

Lily Kay: Yeah -- [unintelligible]

MN: No, I thought it was the Oak Ridge proceedings of some symposium.

Lily Kay: In which year?

MN: About '54, something like that. And it was varied, absolutely varied, but after I picked it up and read it -- [audio skips] -- that he first became interested in the question of how -- [audio skips] -- when he's getting on his doctoral -- [audio skips] -- James Sumner [spelled phonetically] was his --

Lily Kay: Yeah, I know that story. That particular story I know, about what synthesizes the synthesizer.

[knocking on door]

MN: Come in.

Lily Kay: Oh yes, is it open?

[low audio]

MN: Ah, you found it. Great.

Lily Kay: Oh that's a real machine. My -- with a microphone and everything --

[audio skips]

MN: No, I haven't used this thing in so long, I don't know how -- you can use both of them if you want.

Lily Kay: Why don't we use both of them?

[low audio]

[audio skips]

So yeah, we were talking about --

MN: I worked with Bill Jakoby on this to learn -- [audio skips]

Lily Kay: HBA.

MN: Yeah. Because he was interested in -- [audio skips]

Lily Kay: Yeah. [unintelligible] -- the two sisters.

MN: Yeah. I'm surprised when I looked at --

Lily Kay: But you know what really caught my eye is that the same year, right after these two papers appeared, you changed language. In these papers you never talked about information and you never mentioned genetics. You were acting here like a biochemist and here you became a molecular biologist.

MN: I took a wonderful course here. They have a lot of courses in the evening. Well anyway, I became interested in molecular biology -- [audio skips]

Lily Kay: How?

MN: It was -- [audio skips] -- the work from, you know I just read it -- [audio skips] -- the genetic experiments -- [audio skips]

Lily Kay: So you took the course here. Sort of in between, between when these kinds of papers were published and the time you wrote this -- [audio skips] was up here, was the influence of the course?

MN: I don't know, I'm not --

Lily Kay: For somebody who is looking for -- breaks this continuity, new beginnings, I mean the fact that you used, in the title, shared genetic information -- you conceptualized these enzymes in terms of genetic information, which you didn't do just a few months before.

MN: When were they published?

Lily Kay: This was ’59 and this is ’60, so it’s only a few months. You can see a different perspective here.

MN: Yeah. Well -- [audio skips] don't remember exactly when I took the course, but anyway, while I was here -- [audio skips] -- I really became -- [audio skips] -- so excited, in particular, to -- [audio skips] -- and messenger RNA wasn't known and I assumed that messenger RNA existed, so I looked to see if DNA -- [audio skips]

Lily Kay: -- I have questions before we get to the messenger. I hope you don’t mind, because otherwise -- there’s another point that caught my eye, not just the genetics perspective but the fact that you used the word "genetic information". Where did that way of speaking come from? That’s new. In the '40s nobody talked that way. Really, this is something I’m interested in, that in the 1940’s nobody used the word "genetic information". You do not find it anywhere in the literature. Never. Anywhere.

MN: Really? When does it become used?

Lily Kay: In the '50s. And I was wondering if you had awareness that you were using this word, that this is a new way to talk, when you started using this. I was just wondering if you could remember.

MN: No. I -- [audio skips] -- and it made something out of a mundane enzymatic situation, made something more out of it, and I liked that.

Lily Kay: Absolutely. That’s -- yeah.

MN: That’s the reason I used it.

Lily Kay: Now, were you aware at that time -- in the '50s were you aware of the work of Gamow on -- [audio skips]

MN: I became aware of Gamow actually, and -- [audio skips]

Lily Kay: -- like later -- [audio skips]

MN: I met him, I met him. [audio skips] -- early coding years.

Lily Kay: [audio skips] -- in Washington --

MN: I didn’t know him during -- [audio skips]

Lily Kay: In the '50s were you aware of the work he was doing on the code, with his diamond code?

MN: I remember going to a talk here at the NIH -- [audio skips] -- the topic -- [audio skips] -- that they were really -- they both gave a talk, each gave a talk --

Lily Kay: Brenner gave a talk and Crick gave a talk?

MN: -- and Crick gave a talk. The room was packed and -- [audio skips] -- crouched down, like he was taking -- [audio skips]

Lily Kay: [laughs] Do you relate to those efforts when there were these guys -- [audio skips]

MN: No, I was very much -- I was aware of the -- [audio skips] -- messenger -- [audio skips]

Lily Kay: Wait -- I'm still not ready for the messenger, because I'm -- [audio skips]

MN: I used the term template RNA. Messenger RNA came -- [audio skips]

Lily Kay: I guess we're not going to go in order, so we might as well go according to -- comes natural to you. Now I was amazed -- I have three papers here, one of them is -- [audio skips] -- just basically characterize the system and talk about its properties --

MN: That was the first paper. That was the start of the whole thing.

Lily Kay: Right. I know, I know. I could see that this was -- this was the poly(U) experiment. This is just -- the system going --

MN: Yes. The first experiment worked. I remember coming back -- [audio skips]

Lily Kay: Which RNA was that, then?

MN: It was --

Lily Kay: It was ribosomal RNA.

MN: Ribosomal RNA.

Lily Kay: As a template.

MN: No, would contain a contaminate that would be the template. That's where the template -- [audio skips] -- RNA, and he actually showed that.

Lily Kay: Why did you use polyanions? -- [audio skips] -- ribosomal RNA had no effect upon amino acid incorporation to protein, the absence of ribosome -- the RNA could not be replaced by additions of equivalent concentration of polyanions such as polyadenylic acid, [unintelligible] -- [audio skips]

MN: No, it's interesting that poly(A) was -- [audio skips] -- they didn't use poly(A) at the time.

Lily Kay: Yeah, yeah. Why?

MN: Oh, because nucleic acid was a polyanion.

Lily Kay: Right, but what is the function of the polyanion in the system? This is my own ignorance -- why would you need to add it? What --

MN: I had forgotten that we did this with poly -- and we missed it because -- [audio skips]

Lily Kay: You'd think that you would have gotten translation for poly(A).

MN: We did. But polylysine is soluble in -- [audio skips] -- I've forgotten his name now, because a French -- [audio skips]

Lily Kay: A man?

MN: A man. And this was after [unintelligible] -- [audio skips] -- it must have been about the same time I was doing the experiments -- [audio skips]

Lily Kay: '50. -- [audio skips]

MN: I didn't remember that we'd used the poly(A) at that particular time because when we did -- when we started -- [audio skips]

Lily Kay: You didn't use it as -- in order to get -- I mean, it doesn't look like you added it as a message --

MN: No. When we added a synthetic polynucleotides, we added them with messengers -- [audio skips]

Lily Kay: But in using poly(A) here, you were not --

MN: We rounded up every kind of nucleic -- [audio skips]

Lily Kay: But here it's used -- in this sense it's used as a potential template?

MN: As a potential template. It has to. -- [audio skips] -- I thought that this time we used -- [audio skips]

Lily Kay: That's the question I have because it looks like poly(U) was not the first --

MN: No. What we did was to --

Lily Kay: I'm coming to it -- wait, wait, wait! I haven't finished yet, I have another question on this paper. You don't mind, do you? Because the order's in my head chronologically. What I want to know -- [audio skips] -- I don't know if it's fair to ask this after 30-some years --

MN: I think that the reason why it's stated as a kind of control here, polyanion control, is because it didn't work. In fact, what -- [audio skips] -- this didn't work, and so -- [audio skips]

Lily Kay: Yeah. I was just struck that there was poly(A) here

MN: I had completely forgotten.

Lily Kay: Here is another question. I don't know if it's fair to ask it 30-some years later, if you can really think about it --

MN: Sure, sure.

Lily Kay: -- but I found it incredible that you used the word "messenger RNA". This is --

MN: Did I use "messenger RNA" then?

Lily Kay: Yes! Without quotation marks.

MN: Really?

Lily Kay: In other words, you were --

MN: I thought I always used the word template RNA. I thought messenger RNA came later.

Lily Kay: No. See this is why I wasn't going to ask you -- the story, the official story, from Johnson's [spelled phonetically] book is that you did the experiment but you were not aware that Jacob and Monod were doing that experiment --

MN: Not a bit. It's not true.

Lily Kay: Oh. In other words that what was going on --

MN: I was aware of everything that -- [audio skips]

Lily Kay: You were aware of the pajama experiment? [inaudible] -- Jacob and Monod --

MN: Yes, in fact I wrote to --

Lily Kay: What year?

MN: No no, no no, when I was here at the NIH.

Lily Kay: Yeah, but which year?

MN: This was just before I -- [audio skips]

Lily Kay: So it's '59 or something like that?

MN: Yes. I thought that after I finished my postdoctoral in microbiology [audio skips] -- didn't accept me.

Lily Kay: [inaudible] -- this story that you were not completely unaware of the work going on --

MN: Crazy. It's wrong.

Lily Kay: Let me ask you this question -- the word "messenger" is used -- besides this, it's used for the first time in Jacob and Brenner and Meselson's experiment in '61.

MN: Is this the first use of messenger RNA?

Lily Kay: Yes! As far as I can tell.

MN: I --

Lily Kay: Because I don't know where you got that!

MN: I probably coined it. And I never knew it.

Lily Kay: But how did you come to that word? Where did it come to your mind?

MN: I never --

Lily Kay: Can you remember? This is hard 36 -- 34 years later.

MN: 31, thank you! I didn't know. If I coined it, I didn't know that I coined it.

Lily Kay: I know that you didn't know that you coined it because you didn't make anything of it. You didn't stop and say, "We will call this messenger RNA," you didn't put it in quotation marks -- there is no awareness there that you are coining a new term.

It almost looks as if it's like everybody knows what messenger is, and in '61 I find it incredible. And also what I find incredible is that you do not cite Jacob and Monod's --

MN: Well now wait a minute.

Lily Kay: -- '61 experiment of the messenger with Meselson, Brenner and Jacob.

[audio skips]

MN: That didn't --

Lily Kay: Right, no, because you don't mention it in the references.

MN: The only thing that I was familiar with at the time -- the only evidence for messenger RNA -- [audio skips]

Lily Kay: [inaudible] and Esther Heinz's [spelled phonetically] experiment at Oak Ridge, right?

MN: Was that Oak Ridge?

[audio skips]

Lily Kay: But there were a couple of people that saw a rapid turnover of a short-lived intermediate --

MN: Yes.

Lily Kay: There were several people who were --

MN: That's the only evidence I was aware of.

Lily Kay: But they didn't call it messenger. And so -- maybe I'm just back on this point but it seems to me that in this paper you're thinking -- because you say, "RNA used in our study in response to template or messenger RNA." But in this paper it seems like you're still thinking of template in terms of ribosomes.

MN: I never thought of ribosome line as a template. I always thought that protein was synthesized -- [audio skips]

Lily Kay: But you know, this is the paper you're talking about, right?

MN: Yep.

Lily Kay: You know what I find incredible about this paper?

MN: What?

Lily Kay: That here you became aware of the fact --

MN: [inaudible]

Lily Kay: -- I read the paper and what I find really interesting with respect to the paper that preceded it is that here you put "messenger" in quotation marks and you put references --

MN: Who are the references?

Lily Kay: You put references to Volkin and Esterhan [spelled phonetically] --

MN: Mmm-hmm.

Lily Kay: -- and also Spiegelman [spelled phonetically]. It seems that here you are self-conscious about the use of the word "messenger" because you stopped, you put it in quotation marks and you gave references, but before you didn't put it in quotation marks, you didn't make a big deal about it. It means that in between these two papers you became aware that other people had been working on it and --

MN: I was aware when I wrote the --

Lily Kay: Yeah, I --

MN: I didn't know when things precisely were published. I know that there was a meeting at -- [audio skips]

Lily Kay: This was the time -- Brenner was in America, Jacob was in America; they came to collaborate with -- [audio skips] -- that's when they came up with the messenger -- [audio skips] -- and finally Brenner figured out that -- [audio skips] -- that made all the difference and they were able to sediment -- [audio skips] -- that was the messenger, so '61.

MN: That had no influence --

Lily Kay: Yeah, I'm sure. I'm sure it didn't.

MN: -- on, I don't know, maybe just --

Lily Kay: I'm so intrigued that you used that word in 1961!

MN: I have no recollection of coining the word. -- [audio skips]

Lily Kay: You didn't seem like you had an awareness that you were coining a new term because you used it like everybody knew, and that's what's so --

MN: To me -- you have to put yourself in my shoes -- [audio skips]

Lily Kay: I'm completely -- I'm not pressing you because I don't believe you, I'm just trying to figure out how did you come up with a name?

MN: [inaudible]

Lily Kay: Yeah.

MN: But if I did, I don't remember it. I never knew where the name came from.

Lily Kay: But you used the word "messenger" and you used it as if this was the most normal thing in the world to do and I'm trying to figure out how did it come to your mind. I guess 35 years later it's a little difficult to reconstruct.

MN: You know what would be interesting would be to take a look at the --

Lily Kay: Journals --

MN: -- at the journals.

Lily Kay: I would love to take a -- because this is, as far as I know, this is the first use in the literature.

MN: Really?

Lily Kay: I think so, because --

MN: That's really interesting. That's really interesting.

Lily Kay: Because, -- you write it completely unselfconsciously and only later, with the PNAS paper you become conscious that this is an entity that people are discussing because then you put it in quotation marks and then you start referencing it. The first time it sort of falls out of your pen.

MN: Yeah.

Lily Kay: And that sometimes --

MN: When you live something -- when you're really -- you're living it, you're thinking about it, there wasn't much -- [audio skips]

Lily Kay: -- story, I mean you didn't really develop a -- [audio skips]

Lily Kay: -- and I have a reference of the thing you published which was un-interpreted, just found an intermediate -- [audio skips]

Lily Kay: Even then you were thinking about --

MN: Oh yeah, I liked neurobiology. Neurobiology always interested me. [audio skips] I knew in my heart you always -- [audio skips]

Lily Kay: -- It seems to me it's nothing short of miraculous that you just used that expression as if it was just -- [audio skips] -- nobody was talking that way.

MN: Well, I was talking that way.

Lily Kay: Yeah.

MN: I was thinking about it. -- [audio skips]

MN: -- but he really knew -- [audio skips]

Lily Kay: -- and so he understood your work.

MN: He understood exactly what I was trying to do.

Lily Kay: Because he's the person that you -- [audio skips] thought out loud with and --

MN: Yes.

Lily Kay: He understood your experiments?

MN: He understood what I was doing. He was extremely interested -- [audio skips]

Lily Kay: Do you think you were talking to him about the messenger and he would have understood?

MN: Absolutely. No question. No question. [audio skips]

Lily Kay: -- free association?

MN: Well yeah. Free association. [audio skips]

Lily Kay: -- stream of consciousness.

MN: Stream of consciousness. That's what I would say. The funny thing is --

Lily Kay: This was your closest colleague at the time.

MN: The person who -- [audio skips]

Lily Kay: Why do people like Leon Heppel and Tompkins why were they working on -- this one's very esoteric -- interested in -- [audio skips]

MN: -- interested in the synthetic -- [audio skips]

Lily Kay: I am coming to figure out what's going on, is that you've got these synthetic RNA samples from Paul and Gordon Tompkins that they'd essentially --

MN: No, not Gordon. Gordon didn't have them

Lily Kay: Did Heppel have them?

MN: Heppel --

Lily Kay: You need to push the play -- record.

MN: Dan Bradley was -- [audio skips] -- the first synthetic nucleotides that I got.

Lily Kay: Who's lab?

MN: He had his own section.

[audio skips]

Lily Kay: Were they interested in that?

MN: He was studying physical properties of the RNA.

Lily Kay: Saturating them and eletrophoresing them and that --

MN: And we would doing melting curves --

Lily Kay: Yeah, yeah. So this was just a physical chemistry approach.

MN: Yes. [audio skips] -- But Leon Heppel is the real McCoy. He was a biochemist who really knew -- [audio skips] at that time there were very few people -- [audio skips] bird-like individual who -- [audio skips]

Lily Kay: -- was doing what kind -- [audio skips]

MN: I'm not sure why he made them at the time -- [audio skips] -- I think he was well known -- [audio skips] -- any byproducts of an experiment he would simply freeze it and

-- [audio skips] -- decontaminate them, basically, after he had washed them -- [audio skips] -- so he would -- [audio skips] -- very, very meticulous -- [audio skips]

Lily Kay: So he was a very important resource for you, but the way Jackson puts it, is that he essentially gave you these samples and -- [audio skips]

MN: I never really had a conversation with him, because he was always busy.

[audio skips]

Lily Kay: I'll come back to you on that -- [audio skips] -- I haven't really prepared for the '62-'63 work, but I want to ask you --

MN: Who's responsible for that -- he suggested the idea -- [audio skips] -- a million years -- [audio skips]

Lily Kay: How does Matthaei get into this? He just -- [audio skips] -- I know that he was -- physiologist -- [audio skips] -- yeah and I remember he came here because he wanted to synthesize carrot protein and -- [audio skips]

MN: He wanted to work with somebody who was working in protein synthesis. He though the NIH -- [audio skips] -- who was looking for a laboratory to work on protein synthesis -- [audio skips]

Lily Kay: He didn't know any genetics, right?

MN: Didn't know any genetics, no. Knew nothing about genetics.

[audio skips]

Lily Kay: You know, what the story that interests me, Jackson told us -- [audio skips] -- ideas, but that two issues, this protein synthesis, which our chemists have been interested in for a while, and then there was protein synthesis as it began to be understood around 1960, and that is that it's genetically controlled protein -- [audio skips] -- from a metabolic way of looking at things.

MN: Well, I never doubted, never for a minute doubted that -- [audio skips]

Lily Kay: Matthaei, for example, he must have come from a completely different -- [audio skips] -- did you go to California, to Berkeley, to collaborate with -- [audio skips]

MN: [audio skips] -- Ginsberg, who was -- [audio skips] -- but to prove it, knew that -- [audio skips] -- believe it.

Lily Kay: [audio skips] -- the protein code varied according to the --

MN: I had to [unintelligible] and so -- [audio skips] -- it proved, it actually [inaudible] would characterize -- [audio skips]

Lily Kay: When did you find out that this was misleading?

MN: He published a paper in PNAS -- [audio skips]

Lily Kay: Yes.

MN: Really?

Lily Kay: Yes. I interviewed him -- [audio skips]

MN: How is he?

Lily Kay: He's a very nice man, he's a very nice man. I found him extremely honest and forthcoming -- [audio skips] -- the interview for self promotion, and his wife was very, very ill. He was just -- [audio skips] -- I basically asked him why he was interested in doing -- [audio skips] -- he was working on, when he was publishing the full map of the amino acids he said that he was just interested in characterizing the system. -- [audio skips] -- you know why I was asking the question, is that Jackson says that [inaudible] -- [audio skips] -- used that to solve the coding problem.

MN: Oh really?

Lily Kay: That's what Jackson says.

MN: I didn't know he said that.

Lily Kay: [audio skips] -- I asked him just questions and then I said, "Well, since Knight [spelled phonetically] did those experiments years back and he was still continuing to work on correlating mutations" -- [audio skips] -- changes in amino acids -- [audio skips] -- this came back from the days when they thought the gene was a protein, and if you had a mutation it was a -- you know, it started that way -- yeah, yeah. But then he had this really beautifully worked out system where he had all these mutants and correlating different codes with different strains, and Jackson portrays it as a way to solve the coding problem, to try to line up --

MN: Well, I know that -- [audio skips]

Lily Kay: Kind of does the same thing.

MN: What we specifically wanted to do was to show that this piece of -- [audio skips] -- and wanted to prove -- [audio skips] -- every 15 minutes -- [audio skips] --

Lily Kay: To ask him?

MN: And almost immediately, one of the students came over -- [audio skips] -- [unintelligible]

Lily Kay: No, that's fine --

MN: [audio skips] -- he was trying to -- [audio skips] -- in the middle of the day, he would [audio skips] in fact I kind of understood what was going on --

Lily Kay: Oh, he did.

MN: And so, he responded, and insulted [unintelligible] and after five minutes of that -- [audio skips] -- and go back to their experiments, and I didn't know what was going on, I had never heard -- [audio skips] -- was explained to me -- [audio skips]

Lily Kay: When did you find out that [unintelligible] misled you?

MN: He published a paper in -- [audio skips] -- off of the title -- [audio skips]

Lily Kay: So, when you -- so you started work as long as you --

MN: I stayed for one month.

Lily Kay: Were you planning on staying for one month, or were you --

MN: No, no. The reason I came back is -- [audio skips] -- was really so excited that I came back -- [audio skips]

Lily Kay: Yeah, I was wondering because I noticed -- I was going to ask you those -- in your bibliography, a few years later, a paper was published with -- [audio skips]

MN: This thing, the thing that we were -- the first thing from my head that we were wrong on -- [audio skips] and only then did I realize this -- [audio skips] -- taught me a -- [audio skips] -- when I found out [audio skips]

Lily Kay: Yeah. So then when you came back from Berkeley did you just -- [audio skips]

MN: And the activity of -- [audio skips]

Lily Kay: What you said here -- [audio skips] -- and I don't know if you want to reconstruct, in this sort of -- [audio skips] -- when did you realize that this was the first -- [audio skips]

MN: -- opportunity -- [audio skips]

Lily Kay: I had that in mind.

MN: I think it's in -- [audio skips]

Lily Kay: That's what I -- I would love to see those books, because I'm so influenced by now by what Jackson has written --

MN: Do you know what Jackson -- [audio skips] in the notebook written in after the fact --

Lily Kay: [unintelligible]

MN: Really?

Lily Kay: [unintelligible] angered a lot of people.

MN: He's the only person in the world that I won't have anything to do with.

[audio skips]

Lily Kay: [audio skips] -- do you know, he mentioned in this this book, he has a little paragraph that says, "Nirenberg kept a journal, things to do, things to read," kind of sentences -- uses, he says, it's the kind of list of things to do that a man who's in a hurry produces, or something like that --

MN: Well, there were long lists to do, things to do each day, as well as --

Lily Kay: But he doesn't say what's in it.

MN: It's ideas, and mostly --

Lily Kay: But he doesn't -- [audio skips] -- got a feeling that -- [audio skips] -- is not using it because it does not confirm his story, or that somehow he invalidated it in his own mind, and that's what I was going to ask you.

MN: No, no. One thing I find tremendously pleasurable -- [audio skips] -- that it's a pretty buoyant -- [audio skips]

Lily Kay: I've met him, yeah.

MN: [inaudible] But what he --

Lily Kay: You know what we're going to do -- since this is -- I can't tell if this is moving or not moving.

MN: Let me get another tape.

Lily Kay: I have a tape.

MN: You have it? Okay.

[low audio]

Lily Kay: Yeah, so you're talking about the journal -- keeping the ideas on paper and --

MN: Yeah, but anyway, Carlton [spelled phonetically] -- he kept this journal with the idea -- with the understanding that he would publish them later on, and he's published maybe 50 -- and he traveled to the most outlandish places in the world, the most primitive places in the world.

Lily Kay: He adopted these kids right? I met them.

MN: Yeah, yeah. Fantastic individual. Did you meet them? Really?

Lily Kay: Yeah, yeah.

MN: Well anyway, but his journals -- he saved all his letters, he has pictures in the things and whatnot. But the interesting thing to me in reading -- he's given me a few of these books that were published by the public health services, it wasn't a commercial publisher -- they're fascinating, absolutely fascinating, but they're all about his interactions with people and with different societies and so forth. Now that I think about it, that kind of thing -- interactions with people -- anybody can respond to and it really is like an adventure story. But when you talk about just interactions with --

Lily Kay: Your own ideas, your own mind.

MN: -- ideas, ideas and not people, you can't really relate to it unless you're redoing the work -- similar work at the time because -- well you would know the literature well.

Lily Kay: I would know the literature, yeah. I know the literature of the time better than I know the literature today! You see what I do, I go and look for this paper --

MN: That's fantastic, that's really fantastic.

Lily Kay: Yeah, so hopefully -- I'm sure that I'm at least up to the point where I have followed your work. From '62 on that's a separate story and I will get to it and I will come back to you in a year from now when I get ready for that chapter. But I was going to ask you -- Johnson mentioned that you talked to Szillard.

MN: To who?

Lily Kay: Leo Szilard.

MN: Oh yeah, yeah. That was absolutely fascinating. The two PNAS papers -- this paper -- I needed to find a sponsor for, wanted to find a sponsor for, before leaving for Moscow in 1961. And since he was a member of the National Academy, I went down to -- made an appointment with him at the old Dupont Hotel at Dupont Circle, where -- his office was in the lobby of the hotel, he would just sit in the lobby --

Lily Kay: Yeah I know, he lived in hotels.

MN: Yeah, he was a remarkable individual. So I was really interested -- I spent the entire day with him, telling him about what we had done.

Lily Kay: This work here? This was before the poly-U experiment?

MN: This was after the -- the poly-U experiment plus [unintelligible], these two papers were published together. I needed a sponsor for those papers and I wrote them and submitted them, actually, just before leaving for Moscow. But after talking to him all day it was really an interesting experience because every five minutes somebody would come through the lobby and would interrupt and tell him something about -- something to do with the Defense Department, or one thing or another --

Lily Kay: Did he understand it?

MN: I spent the day with him, talking to him, but later --

Lily Kay: Did you need to spend the day with him to get his sponsorship or was it just because it became so interesting and --

MN: He kept asking questions about it.

Lily Kay: That's typical, yeah.

MN: But then at the end he said he didn't understand it well enough to feel that he could sponsor it.

Lily Kay: You must have been disappointed.

MN: Well Stetton [spelled phonetically] asked Smondell [spelled phonetically], who was the person in charge of the NIH actually, of the intramural NIH program, to sponsor it and that's who sponsored it. They were sent off before I left.

Lily Kay: Did you remember his comments at all?

MN: Well, later on he invited me out to dinner after -- or in the middle of the deciphering of the code, and so I had dinner with him and with his wife and he told me some interesting things. He told me about his PhD thesis.

Lily Kay: Yeah I know.

MN: You know that?

Lily Kay: Yeah. Under von Laue.

MN: Pardon?

Lily Kay: Under von Laue. He studied with von Laue in Berlin, and it was related -- well we don't have to get into -- what did he tell you?

MN: Well, he told me that he did his PhD thesis in two weeks on a vacation mountain climbing, while he was mountain climbing, that he got the idea of a relationship between information and energy while mountain climbing and it took him two weeks to develop it and that was his thesis for his PhD.

Lily Kay: I have [unintelligible], but he's --

MN: Really?

Lily Kay: Yeah. Well you know, the thing is that I -- in my interest about the role of the word "information", and conceptually how it hooked up to other areas in science, von Laue of course prominently figures in this because he wrote this famous paper on Maxwell's Demon. Maxwell's Demon -- the way that he proposed to solve the Maxwell's Demon paradox is to show that the amount of -- the recording that the demon would have to do to keep track of the traffic, the molecular traffic, the intelligence and the memory that he would have to use in order to keep track of and record mentally the molecular traffic -- didn't use that word, "traffic", that's my word -- the amount of entropy would be exactly equivalent to the entropy gained by increased order. So he showed that there was no paradox; that there was exact accountability, that the amount of entropy gained is the amount of entropy lost through the thinking process of the demon.

That was not his thesis. This was a paper he published shortly after his thesis, which -- he wrote it and then he published it several years later, and --

MN: I thought he published the relationship between information and entropy for his thesis?

Lily Kay: He never used the word "information" anywhere?

MN: Really?

Lily Kay: Never.

MN: Really?

Lily Kay: Never. See, this is where historians come in. In light of later developments he went back and said, "Oh, well I was one of the first ones to use the notion of information," because later on, negative entropy was defined as information. So once it was defined as negative entropy he went back and said, "Look, I did this thing on information," because he -- see, he was not thinking in terms of information.

MN: What was he thinking of?

Lily Kay: He was thinking in terms of thinking generates entropy. That's what he was thinking. He was thinking that the thinking process of the demon is in the energy expending process. And the amount of energy that the demon has to expend in order to keep track of the molecules is exactly the amount of order gained by the system, and so the entropy balanced and there was no paradox. But he never used the word information. He used the -- [unintelligible].

So that's part of my story, ao you're getting a preview of part of my story. This was done in retrospect. That story goes to Leon Brillouin the physicist, who met Szilard in '51, and Szilard showed him, and he became aware of his work, and all of the sudden in 1951 Brillouin starts citing Szilard as an instant where information was the property of the Maxwell Demon system, and he cites the 1929 paper -- and this paper was translated into English much later, given all these, you know, ceremonial -- replacing it historically as an information paper, but it's not really.

MN: Really?

Lily Kay: It's not really. See, I don't know -- scientists think that historians are kind of pedantic but I think it's very important what word you use because words stand for concepts.

MN: Absolutely.

Lily Kay: And he did not have a concept of information in 1929. It's only in retrospect in the '50s, when the information -- negative entropy was defined as information, that Szilard went back and he said, "Well, you know, I used 'negative entropy' here as 'information'."

MN: I see, I see. Well, he told me that --

Lily Kay: I know, I'm sure he did. He told a lot of people --

MN: Really?

Lily Kay: Yes, yes.

MN: Well, I was fascinated just by spending the time with him because I had heard about him, and of course -- and I found it really interesting the way he operated. I mean, he seemed to know everybody. People would be going back and forth in this busy lobby, hotel lobby, and they would stop and say, "Hi, Leo, have you heard about so-and-so?" He was following the construction of various defense weapons systems and so forth, and these were the people who apparently were knowledgeable about such things, so --

Lily Kay: Such things meaning…

MN: Weapons systems and -- I don't know who they were. But it was a really interesting way of spending his time.

Lily Kay: Oh I know. I went -- his papers at UCSD -- I went and looked at all his papers. I have a sense of him now, you know, much more --

MN: I remember very vividly the confrontation between Kennedy and Khrushchev, the Cuban Missile Crisis. I heard that as soon as he heard about it he flew to Switzerland, to get out of the way basically. I remember my own reaction was nowhere nearly as perceptive. I was blind, virtually, compared to Szilard understanding of the situation. Szilard understood this as a tremendous threat that could result in a nuclear war.

Lily Kay: But he was so involved in this, you know. Since the Manhattan Project he spent -- he had like -- well, more than two hats, but two categories of hats: one was scientific and one was his public advocacy and his resistance to -- I mean disarmament, all his effort of disarmament, he was extremely politically involved. So he talked to everybody.

MN: Well, he had a very good sense of what was happening. And I remember my own reaction -- totally oblivious to the actual threat of the matter. I was alone, immersed in my work and totally oblivious to what was really happening.

Lily Kay: Yeah, but in some ways I think it was particularly true because you were at NIH and you did not have to have outside funding, and a lot of -- what I find that's so interesting in the 1950's and early '60s is that a lot of biology, including some parts of it that we would say now, molecular biology, were funded by the military. You really begin to see the presence of the Office of Naval Research and the Air Force and Army, I mean you see -- even the Cold Spring Harbor in 1963, the sponsors are acknowledged in the Navy and the Air Force and the Army and Atomic Energy Commission. There's changing social landscape of biology which, probably being at NIH, you might have not even experienced it that way.

MN: Well no, I wouldn't have experienced it because I don't apply to grants, but I was aware of the funding. I guess it's changing right now, back, away from defense --

Lily Kay: Right, right, but the ‘50s is a major change in the funding patterns. The Rockefeller Foundation moves completely out of biology by the mid-‘50s.

MN: Did they really?

Lily Kay: Yeah, by ’58, Warren Weaver retired and they were no longer funding. And in the states they were not funding that much, there was still funding in Europe in the mid ‘50s. But what you find is -- I have the statistics, annual statistics, of who was funding life sciences throughout the ‘50s and every year the military involvement is higher and higher and higher. Now I’m trying to figure out what it did to people who were funded by the military, how did it effect --

MN: Oh it must have had a tremendous effect.

Lily Kay: It must have, I’m searching for it.

MN: Absolutely, absolutely.

Lily Kay: What would you guess?

MN: Well, I think that if there’s money there that people are going to try to apply for grants to the military for --

Lily Kay: But how would that change the actual search? How would it influence the way people ask questions or the type of questions they might choose to ask instead of others? Would it influence at all --

MN: I think it would influence it, yes.

Lily Kay: I would think so too, but I am trying to figure out how.

MN: If you’re interested in using radioactive compounds as tracers or something maybe you would find some way of working in something that the military might be interested in -- radiation sensitivity or something of the sort. I’m sure that if you’re interested in basic research you’d do the basic research but it would have some kind of a slant --

Lily Kay: Yeah, you see this is what I’m trying to figure out -- what kind of slant it introduced of a period of a decade where so many scientists were funded by the military. What kind of slant --

MN: In biology I don’t think there was that much funding by the military --

Lily Kay: There was.

MN: Was there really?

Lily Kay: Yeah, yeah, that's what I'm saying. I was talking about -- not as much as in physics, not as much as in chemistry or engineering, that's absolutely true. But the sponsorship of biology by the military steadily increased annually. I have the figures, and the question is: in what way did it influence in a subtle way --

MN: [inaudible]

Lily Kay: I know, but I still haven't figured it out --

MN: The same way that funding today influences research. There are fads in research for one thing -- even research funded by the NIH, now, will fund certain types of research but not others that they may consider old-fashioned.

Lily Kay: Right. This is what I need to find. It's not easy because the records of the military are not available -- even today it's still not available.

MN: Really? I thought that they were declassifying -- the Energy Department was declassifying many of the -- at least the results of the experiments that --

Lily Kay: Yeah, some of them. But in general you cannot get -- even through Freedom of Information Act -- I mean, things have been deleted. You get these transcripts, you get these documents and things are absent, still today.

MN: Really?

Lily Kay: Yeah. You know what I was going to ask you? I was going to ask you -- but before we finish with Szilard what I wanted to know is did he try to interpret your work differently? Did he try to introduce his own way of looking at things?

MN: No, no. He was trying to understand what I was saying, and I thought I was explaining it very clearly to him, that we'd synthesized -- that we'd obtained a synthetic polynucleotide that acted as a template for [unintelligible] consisting of a single amino acid. And he didn't -- I told him the whole background -- how we did the experiments, what the system was like and so forth and he just didn't feel as if he knew enough about the background of the situation to sponsor it.

Lily Kay: Interesting. You know he wrote a paper on the genetic code?

MN: Really? No, I didn't.

Lily Kay: In the '50s.

MN: In the 50's? He didn't tell me that. A paper about the genetic code? What did it say?

Lily Kay: What had happened was -- is that, he, typical Szilard, you know, he toyed with this idea and he sent his paper to Crick and said to him, "Look, here's this paper but I'm not sure it's right," and he was planning to submit it to PNAS and he said, "I will be very grateful for your comments and there's no problem -- I can withdraw the paper if it's not right." And he got terrible reviews from Crick and essentially never published it.

MN: Really? What was the paper? He didn't tell me that.

Lily Kay: I will send you the paper -- it's not the published version.

MN: What did he say in the paper?

Lily Kay: He was -- he was still working -- it was just, I think, before Brenner published his article on the impossibility of overlapping codes and he was suggesting another scheme for coding based on a triplet code of Gamow. I don't want to mislead you because I haven't looked at this since --

MN: Gamow told me that that paper that he published in *Nature* came to him, the idea came to him when he picked up an article of *Nature* that had just been delivered to his paper box -- do you know this story? And he read it right at the mailbox and it came to him immediately that maybe there was an amino acid recognized three bases in DNA, and that determined which amino acid it was. You know, of course, --

Lily Kay: I know, yeah, yeah.

MN: -- about the paper that he had written for publication at PNAS.

Lily Kay: Yeah, I know the story. But you have to be very careful with people's stories even back then. You know, Charlie Weimer [spelled phonetically] interviewed Gamow and did a long oral history and he asked him about his interests in biology -- and, "Were you interested in biology?" Gamow says, "No, when I got this paper from *Nature* in 1953 and I saw the structure of the double helix I immediately -- it triggered my imagination and I became so interested." And Charlie asked, "Well, what about in Russia, were you interested in -- " "No, no."

Well it turns out that Gamow was totally immersed in biology throughout the '40s.

MN: Really?

Lily Kay: I have correspondence between him and Delbruck. They were going to write a book together on the new biology --

MN: Really?

Lily Kay: -- the genes, as proteins -- I have the correspondence, which is going to be chapter one, which is chapter two, chapter three -- and then in 1946 here in Washington

there was this very important conference. It was organized by Gamow and by Merle Touf [spelled phonetically], so there was like the Carnegie Institute in Washington and Washington University collaboration. All the heavyweights came -- Niels Bohr and Teller and Delbruck and von Neumann, John Edsall -- I mean it was all --

MN: Really?

Lily Kay: -- yeah. And it was a conference specifically to discuss problems in biology. And all the physicists came and all started pontificating about what biology would look like if they would apply all these ideas from physics. And Neumann gave a talk about self-reproducing automata --

MN: Really? That little book that von Neumann wrote on calculators -- on [unintelligible] was superb.

Lily Kay: Which one on the brain?

MN: On the brain, yeah. I thought that little book was really fantastic. When I first went into neurobiology it made a big impression on me.

Lily Kay: But you know, he was very interested in genetics and he corresponded with Lederberg and with Sol Spiegelman and they were all very interested to see if the idea of self-reproducing automata -- the schematics of reproduction -- could be helpful to geneticists.

Anyway, so Gamow -- there is Gamow in ’41, ’42, ’46 -- the whole time he’s totally involved in biology, it’s just a continuation. But in his own mind I don’t think -- he didn’t lie, I think he just forgot that he was totally involved in biology, and the ’53 paper was a continuation of an ongoing interest. Not that it didn’t have an effect, the paper, but he was already very involved.

MN: I didn’t realize --

Lily Kay: Well, he doesn’t realize that either because he told Charlie that --

MN: He was -- he’s probably the most interesting man I’ve ever met in my life. He was a nonstop talker. And everything he said was beautiful -- was really interesting. I remember in going to a Cold Spring Harbor meeting that he was at and a group of us, about eight people, went for lunch, walked around to a little restaurant around the bay, and for like four hours he just gave a monologue, nonstop talking about interplanetary travel, interstellar travel and the problems involved and so forth. Everything he said was interesting. And nobody wanted to say --

Lily Kay: Nobody wanted to interrupt?

MN: Nobody wanted to interrupt him because it was such a remarkable outpouring of -- I mean, I can see how he could write those beautiful little books --

Lily Kay: I know, they came at the rate of one a year.

MN: Yep -- the way he talked.

Lily Kay: We're running late and you must be getting tired. Can I ask you just one question and then we can --

MN: Sure.

Lily Kay: In your Nobel address, since I'm so interested in language and how things get rephrased, you used the notion of genetic memory.

MN: Oh yes, absolutely. I was very taken with the relationship between neuromemory and genetic memory. Of course there's genetic memory, yeah. I wrote a paper on comparing -- actually, contrasting the two things.

Lily Kay: At the time? Like around the time?

MN: Yeah, this was during the '60s.

Lily Kay: Oh could you give me a copy? I guess it's on your bibliography but --

MN: Sure, sure, I'll find it.

Lily Kay: Because I was intrigued. This was -- before you didn't use that expression and I could see that there was sort of a new way of thinking. You never phrased it earlier in terms of the genetic memory.

MN: Well, when I wrote that thing I had given up -- I had already switched and had gone into neurobiology so I was thinking a lot about memory -- about neuromemory and the nervous system, and actually I hated to write that article because it was an interruption of what I was doing. I'd already left the field and I didn't like to stop doing what I was doing, which was really at the beginning of neurobiology -- I was all enthusiastic about it -- to go back to the old stuff to write this article. So this was like an albatross around my neck that had to be done and had to be gotten out of the way.

Lily Kay: But I could see you were already thinking in a different way and I didn't know how to interpret it but I guess you were already thinking from a neurobiology perspective.

MN: Yeah, yes.

Lily Kay: Because this notion of memory -- that sort of jumps out of the page all of the sudden.

MN: Really?

Lily Kay: Yeah.

MN: Well there was another -- an earlier article --

Lily Kay: Oh good! I would love to see it. I think I've kept you enough, for such a long time. You must be getting tired. I hope to be able to come back sometime later, not immediately, and talk to you about the later work --

MN: Do you want me to bring in those books tomorrow?

Lily Kay: Yes, yes. If you could I would be so grateful.

MN: Maybe you could Xerox the -- because I don't think you'd be able -- you're specifically interested in 1961 and around there?

Lily Kay: Yeah, from 1960 to -- well actually, whenever you started keeping them, in '59 or --

MN: I don't remember, I don't remember.

Lily Kay: I would like to see before. See, I would like to see how the thought process evolved and how the --

MN: I started to think about what I was going to do -- I wanted to change the problem that I was working on and change the area. I did it in a way that I wouldn't recommend anybody do it because -- you know, when you take your first job you're supposed to kind of hit the deck running and to be -- I changed my field, so I thought it would take two years just to learn the systems. And that's exactly what it did take -- two years. But that's not the way to do it. It's a very risky way of doing it.

Lily Kay: But you followed your natural instincts, I guess?

MN: Well, at that time protein synthesis was the hottest field in biochemistry. The best people in the world were working on protein synthesis, at the time, [unintelligible] -- and so really the question was, what chance did I have as a single individual working in a field that was totally unfamiliar, totally new to me, what was the probability that I would be successful? The probability was very low and so that's what I was concerned about. But it was --

Lily Kay: Oh that must have been so exciting. I can just imagine your first project, essentially --

MN: It was, it really was. Fantastic, it was fantastically exciting. I remember when I was in San Francisco I sent a card to my wife -- actually I wasn't married then but I sent it to Perola telling her I felt like Marco Polo exploring the New World, because it really was a new world, doing those experiments.

Lily Kay: And it so quickly -- you got such beautiful results.

MN: Yeah it happened -- it was asking the right question at the right time.

Lily Kay: Yeah but they were also very good experiments, very clean experiments. You obviously knew the system so well, the cell-free system.

MN: Well, Zamecnik --

Lily Kay: I know, I was going to say --

MN: Zamecnik and --

Lily Kay: Hoagland.

MN: Hoagland, Zamecnik, and who was that other fellow?

Lily Kay: The one in --

MN: -- in Rockefeller. Sienkiewicz [spelled phonetically].

Lily Kay: Sienkiewicz.

MN: Sienkiewicz was a hero of mine, actually, he -- they laid the foundations and so basically I used their system and modified it somewhat.

Lily Kay: A very close friend of mine, a colleague of mine, has just written a book -- it hasn't come out yet -- on the history of protein synthesis in the '50s.

MN: Really?

Lily Kay: Interviewed Zamecnik and got records from the MGH on the runnings of the lab over the period of the decade of the '50s, talked to Hoagland and all the technicians who worked in the lab -- the whole book is just on the establishment of the cell-free system. His name is Hans-Jorg Rheinberger, he's a trained molecular biologist, he used to be at the Max Planck, and now he's a historian and philosopher of science and does very technical kind of stuff, maybe at some point you'd be very interested to read his stuff. He's looking at the development of transfer RNA and from soluble RNA how they got to transfer RNA and how from microsomal RNA to messenger RNA. He hasn't talked to you -- he sent you two letters --

MN: Who?

Lily Kay: He sent you two letters a couple of years ago asking for an interview but --

MN: I never answered. That sounds like me. But what's his name?

Lily Kay: Hans-Jorg Rheinberger. He was a little bit envious of me that I got to talk to you because he wanted to talk to you too because --

MN: Well I'm terrible at correspondence.

Lily Kay: No I understand, I understand.

MN: But if he'd picked up the telephone it would have worked.

Lily Kay: That's what I tell him, that's what I tell him! I always call because it's much easier -- it's immediate and you can negotiate immediately. Most people do with their mail what I do with my mail -- whatever doesn't seem urgent gets --

MN: Yeah. Same here. And finally a pile builds up and you never get to it.

Lily Kay: Anyway, this has been very helpful --

MN: Let me get that article on genetic memory…

[end of interview]

[duplication -- same audio as previous + some audio editing, midway through interview]

Lily Kay: Yeah, so you -- talking about the journal, keeping the ideas on paper, and --

MN: Yeah, but anyway -- he kept this [unintelligible] journals for -- with the idea, with the understanding that he would publish them later on. [audio skips]

Lily Kay: Adopted these kids, right?

MN: Yeah. Fantastic individual. [unintelligible]

Lily Kay: Yeah, yeah.

MN: He [audio skips] and so forth, and [audio skips] now that I think about it, [audio skips] kind of thing, interact [unintelligible] [audio skips]

Lily Kay: [unintelligible]

MN: Ideas, ideas, and not people -- [audio skips]

Lily Kay: -- I know the literature of the time better than I know the literature of today. Because you see what I do, I go and [unintelligible]. So hopefully -- I mean, I'm sure I am at least up to the point where I have followed your work. [audio skips]

I was going to ask you -- Jackson mentioned that you talked to Szilard.

MN: Oh yeah. That was absolutely fascinating. These -- [audio skips]

Lily Kay: -- work here? This was before the -- [audio skips] -- [unintelligible] experiment?

MN: This was after -- the [unintelligible] experiment plus this paper -- these two papers. [audio skips] -- after talking to him all day.

Lily Kay: You need to spend the day with him to get his sponsorship or is it just because he became so interesting and absorbed --

MN: He kept asking questions about it. [audio skips]

Lily Kay: Remember his [unintelligible] --

MN: Well, later on he invited me out to dinner. [audio skips]

Lily Kay: -- by now, he was by now in Berlin. [audio skips] Well I don't want to get into -- but what did he tell you?

MN: Well he told me that -- well, he was a mountain climber and he got the idea of the relationship [audio skips] --

Lily Kay: -- I have [unintelligible] --

MN: Really?

Lily Kay: Yeah. Well you know, I'm sure he -- the thing is that in my interest about the role of the [unintelligible] information and conceptually how it hooked up to other [audio skips] -- prominently figures in this because he wrote this famous paper [audio skips] -- way that he proposed to solve the Maxwell Demon paradox is to say that the amount of the recording that the Demon would have to do to keep track of the traffic, the molecular traffic -- the intelligence and the memory that he would have to use in order to keep track of and record mentally the molecular traffic -- he didn't use that word "traffic", that's my word -- the amount of entropy would be exactly equivalent to the

entropy gained by increased order. So he showed that there was no paradox, that there was exact accountability, that the amount of energy -- entropy gained is the amount of entropy lost. That was not this easy, this was a paper he published shortly after his thesis, which -- he wrote it and then he published it several years later.

[audio skips]

-- use the word "information" anywhere.

MN: Really?

Lily Kay: No, no. See, this is where his [unintelligible] come in. In light of later development he went back and said, "Oh! Well I was one of the first ones to use the notion of information because later on negative entropy was defined as information. [audio skips] -- Once it was defined as negative entropy he went back, he said, "Look! I did this thing with information." Because he -- he was not thinking in terms of information.

MN: What was he thinking?

Lily Kay: He was thinking [audio skips] -- generate entropy. That's what he was thinking. [audio skips] -- process of the demon is an energy-expending process. The amount of energy that the demon has to expend in order to keep track of those is exactly the amount of order gained by the system. And so the entropy balanced and there was no paradox -- that he never used the word "information', he used it [audio skips] -- that's part of my story so you're getting a preview of part of my story. This was done in retrospect. That story goes to Leon Brillouin, the physicist, who met Szilard in '51 and [audio skips] -- all of the sudden in 1951, Brillouin starts citing Szilard as an instance where information was the property of the [audio skips] -- 1959 paper and I went and this paper was translated into English and given a [audio skips] -- ceremonial, replacing it historically as an information paper, but it's not really. It's not really. It's the saddest thing for historians, a kind of [audio skips] -- but I think that's very important, what word you use, because words stand for concepts.

MN: Absolutely.

Lily Kay: [audio skips] -- he did not have a concept of information in 1929. It's only in retrospect, in the '50s [audio skips] -- Szilard went back and he said, "Well, you know, I used negative entropy. There was information." [audio skips] -- No, I'm sure he did, he told a lot of people.

MN: Yes. Really?

Lily Kay: Yes.

MN: Well I was fascinated just by [audio skips] -- would stop, say, "Hi Leo," [audio skips] -- and I don't know who they were. I remember my own reaction to the [unintelligible] --

Lily Kay: More than two hats. Two categories of hats. One is scientific and one was this public advocacy and government, all his efforts at disarmament [audio skips] -- politically involved.

MN: Yes. My own reaction [audio skips] --

Lily Kay: [audio skips] -- some parts of, we would now say molecular biology, were funded by the military. We begin to see the presence [audio skips] -- force -- [audio skips] -- the '50s is a major change in the -- [audio skips] -- in the States they were not funding that much, they were still funding in Europe -- [audio skips] -- figure out what it did to people who were funded -- [audio skips] -- must have, I'm searching for it.

MN: Absolutely, absolutely.

Lily Kay: What would you guess?

MN: Well I think there's money there.

Lily Kay: How would it change the actual research? How would it influence -- [audio skips] -- I think so too, but I'm trying to figure out how --

MN: If you're interested in using radioactive -- [audio skips]

Lily Kay: See, this is what I'm trying to figure out. -- [audio skips] -- period of a decade is so many -- [audio skips]

MN: But in biology -- [audio skips]

Lily Kay: Not as much as in physics, not as much as in chemistry and engineering, that's absolutely true. But the sponsorship of biology by the military -- [audio skips] -- what way did it influence in a subtle way --

MN: [inaudible]

Lily Kay: I know, I know but I -- haven't figured it out.

MN: The same way that -- [audio skips]

Lily Kay: This is what I need to find, it's not easy because the records of the military are not available even -- [audio skips] --

MN: Really?

Lily Kay: It's still not available -- [audio cuts out]

-- things have been deleted. You get these -- [audio skips] -- documents today.

MN: Really?

Lily Kay: Yeah. You know what I was going to ask you? I was going to ask you -- well before we finished with [unintelligible], what I wanted to know is did he try to interpret your work differently? Did he try to introduce -- [audio skips] -- did you know he wrote a paper on the genetic code?

MN: Really? No, I didn't. When did he do -- [audio skips] -- in the '50s? He didn't tell me that. A paper about the genetic code? What did it say?

Lily Kay: What had happened is that he -- typical Szilard, he toyed with this idea and he sent his paper to Crick and said to him look -- [audio skips] -- I'm not sure it's right, I would be very grateful for your comments -- [audio skips] -- no problem, I can just destroy the paper -- [audio skips] -- terrible reviews from Crick and essentially never published it.

MN: Really? What was the paper?

Lily Kay: I don't remember. I will send you the paper.

MN: He didn't tell me that.

Lily Kay: He was still working, it was just before Brenner published his article on the impossibility of overlapping codes and he was suggesting another scheme for coding based on the triplet code of Gamow. I don't want to mislead you because I haven't looked at this since this --

MN: Gamow told me that that paper got to him -- [audio skips] -- the idea -- [audio skips] -- right at the mailbox. And it came through -- [audio skips] -- about the paper that he had written -- [audio skips]

Lily Kay: You know, you have to be very careful with people's stories, even -- [audio skips] -- interviewed Gamow -- did the long oral history -- [audio skips] -- interested in biology -- [audio skips] -- I'm sure in 1953 -- saw the structure of the double helix, I immediately -- it triggered my imagination and I became so interested in it and [unintelligible] ask about, "Well what about in Russia? Were you interested in" -- [audio skips] -- Gamow was totally immersed in biology throughout the '40s.

MN: Really?

Lily Kay: I have correspondence between him and Delbruck.

MN: Really?

Lily Kay: They were going to write a book together on the new biology, the genes and proteins, but even -- I have the correspondence, which is going to be chapter 1, which is chapter 2, chapter 3 --

MN: Really?

Lily Kay: Yeah. And then in 1946 here in Washington there was this very important conference, it was organized by Gamow and -- [audio skips] [unintelligible] so it was like the Carnegie Institute of Washington --

MN: Yes, yes.

Lily Kay: -- and Washington University collaboration. All the heavyweights came: Niels Bohr and Teller and Delbruck and von Neumann -- [audio skips] -- it was a conference specifically to discuss -- [audio skips] -- physicists came and almost it would look like -- [audio skips] -- all these ideas from physics -- [audio skips] -- came and gave a talk about self-reproducing automata --

MN: [unintelligible] -- that little book that von Neumann wrote on --

Lily Kay: On the brain?

MN: On the brain. -- [audio skips] -- went into neurobiology -- [audio skips]

Lily Kay: -- very interested to see -- [audio skips] -- the schematics of the production could be helpful to geneticists. So anyway, Gamow -- that was Gamow in ’41, ’42, 46 -- the whole time he’s totally involved in biology and it’s a continuation. But in his mind I don’t think -- he didn’t lie, I just think he forgot that he was totally involved in biology, and the ’53 paper was a continuation of an ongoing interest. Not that it didn’t have an effect -- the paper -- but he was already very involved --

MN: I didn’t realize that --

Lily Kay: Well he doesn’t realize that either because he told Charlie that --

MN: He’s probably the most interesting man I’ve ever met in my -- [audio skips] -- nobody wanted to interrupt him because it was so -- such a remarkable -- [audio skips]

Lily Kay: -- one a year.

MN: Yep. Well, that’s the way he talked. [audio skips]

Lily Kay: It's running late and you must be getting tired. Can I ask you just one question and then we can --

MN: Sure.

Lily Kay: In your Nobel address, since I'm so interested -- [audio skips] -- rephrase, you used the notion of -- [audio skips]

MN: -- taken with the relationship between [unintelligible] -- [audio skips] -- I wrote a paper on it. [audio skips]

Lily Kay: -- the time, like around the time?

MN: Yeah. This one -- [audio skips]

Lily Kay: -- I guess it's in your bibliography but --

MN: Sure, I'll find it. I'll find it.

Lily Kay: Because I was intrigued. Before you didn't use that expression and I could see that there was sort of a new way of thinking. You never phrased it earlier in terms of a genetic memory.

MN: Well, -- [audio skips]

Lily Kay: I could see that you were already thinking in a different way and I didn't know how to interpret it but I guess you were already thinking from a newer -- [audio skips] -- side of the page all of the sudden --

MN: Really?

Lily Kay: Yeah. -- [audio skips] -- good, so I would love to see it. I think I've kept you enough for such a long time. You must be getting tired. I hope to be able to come back sometime later, not immediately, and talk to you about the later work.

MN: Do you want me to bring in those --

Lily Kay: Yes! Yes, if you could I would be so grateful.

MN: Maybe you could Xerox it because I don't think that -- [audio skips]

Lily Kay: -- From 1960 to -- well actually, whenever you started keeping them in '59 or --

MN: I don't remember, I don't remember.

Lily Kay: I would like to see before. I would like to see how the thought process evolved and how the --

MN: I started to think about what I was going to do on the change of problem in the systems and it's a very risky way of doing it.

Lily Kay: You followed your natural instincts, I guess?

MN: Well, at that time protein synthesis was the hottest field in biochemistry. The best people -- [audio skips] -- it really was, oh fantastic, it was fantastic. When I was exploring -- [audio skips]

Lily Kay: -- was a very good experiment -- [audio skips] -- system so well. -- [audio skips] -- free system, I mean so many people --

MN: -- Zamecnik.

Lily Kay: I know, I was going to say -- Hoagland.

MN: Hoagland, Zamecnik, and who was that other fellow --

Lily Kay: The one in --

MN: -- in Rockefeller? Sienkiewicz [spelled phonetically]. Sienkiewicz was a hero of mine actually -- [audio skips] -- they laid the foundation for it and so basically I used their system -- [audio skips]

Lily Kay: -- very close friend of mine, colleague of mine -- [audio skips] -- of the lab over the decade of the '50s. The technicians -- [audio skips] -- book is just on the establishment of the -- [audio skips] -- Hans-Jorg Rheinberger [spelled phonetically] -- [audio skips] -- [unintelligible] RNA, how they got the transfer RNA and how from microsomal RNA to messenger RNA. -- [audio skips] -- Rheinberger. -- [audio skips] -- no I understand, I understand -- [audio skips] -- that's what I tell him! I always call, because it's much easier to mediate and you can negotiate immediately but what most people do with their mail is what I do with my mail -- whatever doesn't seem urgent gets --

MN: -- and finally a pile builds up and you never get to it.

Lily Kay: Yeah, yeah. Anyway this has been very helpful --

MN: Let me get that article on the genetic memory…

[audio cuts out]

[end of duplicative section]

[End of Transcript]