Gert Latzel

FILM G 225

Linus Pauling on his Life for Science and Peace
Interviewer: Hans Kuhn

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Allgemeine Vorbemerkungen

Pauling ist sicher eine umstrittene Person, aber ohne Zweifel eine Persönlichkeit von Ausnahmerang. Es ist daher begrüßenswert, daß das Institut für den Wissenschaftlichen Film die günstige Gelegenheit, Pauling in Göttingen mit einem seiner ehemaligen „postdoctoral students" im Film festzuhalten, spontan ergriffen hat. Denn viele einflußreiche Kreise, u. a. auch namhafte Wissenschaftler, sehen das „Auftreten" Paulings nicht so gern, wie es schon Watson, der Mitentdecker der Struktur der Desoxyribonukleinsäure (DNA), in seinem Buch „Die Doppel-Helix" zu Papier gebracht hat: „Mitanzusehen, wie Linus vor der Tafel hin und her hüpfte und die Arme bewegte gleich einem Zauberer, der dabei ist, ein Kaninchen aus seinem Schuh hervorzuzaubern, löste bei ihnen Minderwertigkeitsgefühle aus. Hätte er nur ein bißchen Bescheidenheit an den Tag gelegt, dann wäre alles so viel leichter zu verdauen gewesen! Selbst wenn er nur Unsinn vorbrächte – seine Studenten, hypnotisiert, wie sie waren, würden es wegen seines unbeirrbaren Selbstvertrauens nie merken. Etliche seiner Kollegen warteten in aller Ruhe auf den Tag, wo er irgendetwas Wichtiges verpatzte und damit gründlich auf die Nase fiel" (WATSON [3], 60).

Pauling war – und ist es heute noch – für viele ein unbequemer Zeitgenosse; aber gerade deswegen ist sein Lebensweg so interessant. Bereits als Kind wurde Paulings Interesse für die Chemie geweckt. Im Studium und in den ersten Jahren danach suchte er Gesetzmäßigkeiten, die chemischen Verbindungen zugrunde liegen, klärte eine Reihe davon mit umfangreichen mathematischen Berechnungen auf und verband mit seinen eigenen Hypothesen bereits vorhandene Ergebnisse anderer Forscher. Diese phänomenale Eigenschaft hat ihm vielleicht manche Mißgunst eingebracht, weil er oft Ergebnisse anderer besser und umfassender deuten konnte, da er offensichtlich ein enormes Gedächtnis und ein scharfes Auge für die zugrunde liegenden Gesetzmäßigkeiten hatte. Da er der Meinung war, daß allen Verbindungen, also auch den organischen Verbindungen, die gleichen einfachen Gesetze zugrunde liegen müssen, wendete er sich als Chemiker auch den Nachbardisziplinen Biochemie und Medizin zu und veröffentliche entsprechende Beiträge (über Sichelzellanämie, Anästhesie, Schizophrenie, Vitamin C und E u. ä.). Ich kenne keinen anderen Naturwissenschaftler, der ein annähernd so weitgestreutes Arbeitsgebiet aufzuweisen hat wie Pauling. Dies war für ihn v. a. in jüngeren Jahren der Schlüssel zum Erfolg, das war aber auch möglicherweise – v. a. in den späteren Jahren – der Ansatzpunkt für viele seiner Kritiker; denn Pauling hat manche festzementierte Schulmeinung ins Wanken gebracht, wie z. B. mit seinen Ausführungen über Vitamin C und Erkältungskrankheiten bzw. Krebs oder ganz besonders bei seinem Engagement in der Friedensbewegung, das er gleich am Ende des Zweiten Weltkriegs begonnen hatte und in dessen Dienst er heute noch als 93jähriger steht. Es ist bedauerlicherweise nicht selbstverständlich, daß sich Wissenschaftler mit ihrem teilweise tieferen Detailwissen auch über ihr Spezialgebiet hinaus Gedanken machen und sich öffentlich verantwortlich fühlen.

Pauling gehörte immer zu denjenigen, denen diese Verantwortung Anliegen und Bedürfnis war. Dies brachte ihn, obwohl er nie Kommunist gewesen ist, in tiefen Gegensatz zur amerikanischen Regierung, zu Standesverbänden wie der Amerikanischen Chemischen Gesellschaft oder auch zu vielen einzelnen Fachkollegen, die ihm gern solche Aktivitäten als Kompetenzüberschreitung auslegten.

Die Weltöffentlichkeit wurde auf Paulings umfassendes Engagement aufmerksam und ehrte ihn durch zwei ungeteilte Nobelpreise: 1954 Chemienobelpreis und 1962 Friedensnobelpreis. Und noch 1984 konnte ich in Göttingen junge Studenten beobachten, die sich freuten, daß ihnen Pauling die Übersetzung seines Buches über die Natur der chemischen Bindung (PAULING [1]) signierte.

Pauling hat mit den in diesem Buch niedergelegten grundlegenden Ansichten das Verständnis vieler Chemiker geweckt und beeinflußt, auch wenn heute abstraktere „molecular orbitals“ und „ab-initio-calculations“ an den Universitäten vorherrschen. Für die Behandlung der Chemie in der Schule sind auch heute noch weitgehend Paulings anschaulichere Betrachtungen und Näherungen ausreichend und vorteilhaft.

Filmbeschreibung

Wortlaut des Gesprächs von Linus Pauling mit Hans Kuhn

Hans Kuhn (H.K.): Dr. Pauling, how did you get into chemistry?

Linus Pauling (L.P.): Well, you know, my father was a drogist, and although he died, when I was still young, 9 years old, I am sure, that my watching him, make preparations in the drugstore, the backroom of the drugstore, had an influence on me. I began collecting insects and then minerals, when I was 11 years old, then, when I was 13 years old, another boy my own age, showed me some chemical experiments. I was extremely interested in these experiments, to see, how one substance can be changed into another substance. And at that age, 13, I decided to be a chemist or a chemical engineer.

I knew about engineering, and I first studied chemical engineering. I studied chemistry in the high school and physics, and then I went to college, Oregon agricultural college, and studied chemical engineering. At the end of 2 years in this college I was not able to return for the third year because of lack of money. My mother as a widow did not have much money, and I worked as an engineer laying pavement for roads. But the college offered me the job of teaching quantitative analysis to the second years students. For a year I worked fulltime as a teacher of chemical analysis, and at that time I came across the papers by G.N. Lewis about the nature of the chemical bond and about papers by Irving Langmuir on the same subject. I have been wondering during the preceeding years, why different substances have different properties, why paper has the properties, that it has, and why metal, such as gold, a metal has the properties, that it has. I can remember that I tried to see from the periodic table which elements should be ferromagnetic or paramagnetic and which diamagnetic. Already, when I was 18 years old, I was interested in that question.

Well, the work on the electronic structure of molecules and crystals, and the nature of the chemical bond seemed so interesting to me, that, when I received my degree in chemical engineering and went to the California Institute of Technology, when I was 21 years old, I began work determining the structure of crystals by X-ray diffraction.

I studied mathematics and physics as well as chemistry. So my Ph.D. was in chemistry and physics and mathematics.[1] So then there came the time, when I had my Ph.D. degree, and it was believed in the United States then that a chemist needed to study in Germany to work with the leading chemists in Germany in order to complete his education; I obtained a Guggenheim fellowship. And my wife and I came to Munich in the spring of 1926. This was a wonderful period. The quantum mechanics had just been discovered a few

[1] Pauling machte seine Doktorarbeit am California Institute of Technology (CIT) mit der höchsten Auszeichnung – wie keiner vor ihm!

months before by Heisenberg, who had himself taken his Doctor's degree with Sommerfeld, Geheimrat Sommerfeld, only 2 or 3 years before.

And Born and Jordan in Göttingen had recognized, I think Born recognized that the scheme for calculation, that Heisenberg had invented, was really matrix calculus. So Born and Jordan worked out the consequences of this observation, and I heard Born speak about matrix mechanics in California already before I came to Germany. Then, when I arrived in Germany, Schrödinger, working in Zürich, Professor Schrödinger, had just discovered the wave equation, the Schrödinger Wave Equation, and Professor Sommerfeld began giving lectures about wave mechanics.

The matrix mechanics didn't appeal to me. It was too difficult mathematically, but I knew how to solve a partial differential equation, I had studied this subject, and the wave mechanics, invented by Schrödinger, turned out to be a very powerful way of attacking physical and chemical problems.

The problems of the chemical bond, of the nature of the electronic structure of molecules and crystals and the method of doing this was being developed. There was a scientist, a physicist named Gregor Wenzel in Munich. He was the Privatdozent or Assistent, I think Assistent, by Sommerfeld. He published a paper on the properties, certain properties, of atoms containing any number of electrons, from 0 to 92, from 1 to 92. I read Wenzel's paper in Zeitschrift für Physik, when it came out, and I not only read it, but I worked through it, going from one equation to the next equation, to the next equation.

So, Wenzel had entitled his paper „Eine Schwierigkeit mit der Theorie des Kreiselelektrons", because his calculated values didn't agree with the experimental values. Well, my equations pretty soon turned out to be different from Wenzel's. He had overlooked one factor: that's he had made an approximation, an assumption, that he should not have made, so my equations gave these theoretical results agreeing with the experimental results. I showed this to Professor Sommerfeld. And he was very interested. And to Dr. Wenzel, too. Wenzel was rather dissappointed, but he could see that he had made a mistake that committed an oversight. Well, the important part about this – my own paper was published in Zeitschrift für Physik 1926 –, the important part was that Wenzel had proposed a way of making theoretical calculations for atoms that contain many electrons, and that was the sort of problem that interested me.

So I applied his method with my little correction. I applied his method to a discussion of the magnetic susceptibility of atoms and ions and the electric polarizability, the sizes, the extension in space and got very good results, and my paper was published in the Proceedings of the Royal Society. Professor Sommerfeld had just been elected a foreign member of the Royal Society of

London, and so he suggested that, he send my paper in for publication in their journal.[1]

Well, of course, it was a great experience for me to be there in the Institute for Theoretical Physics of the University of Munich. Just at that time I was very fortunate. Here I had the opportunity to learn the theoretical methods of attacking the chemical problems, that I was interested in. I had 2 friends there named Walter Heitler and Fritz London. My wife and I celebrated the doctor's degree given to Walter Heitler. And very soon Heitler and London developed a simple theory of the chemical bond in the hydrogen molecule, H_2. Well, of course, I went ahead then, too — and they worked also on the problem of extending this theory of the chemical bond to more and more complicated molecules. Well, the result of this was that it turned out to be pretty difficult. It was hard to solve the equations, to evaluate the integrals. And till much later, when computers, big computers, were developed, it was a very difficult job. I thought I want to try to simplify this treatment. So I went back to Pasadena as Assistent Professor, and then Associate Professor and then Professor, you know, what our laboratory is.

I carried out with another, with a new technique of electron diffraction by gas molecules, which I had learned about here in Germany 1930, exactly after it had been invented by Dr. Hermann Mark, who was in Ludwigshafen at that time. I built an apparatus with one of my students to do this electron diffraction work and to determine the bond lengths and bond angles in a large number of molecules, gas molecules, inorganic compounds and organic compounds.

Also my students and I continued to study the structure of crystals by X-ray diffraction. These 2 techniques gave a great body of empirical information, experimental information, about the structure of molecules and crystals: how far apart the atoms are, the bond lengths and the bond angles. Right from this start of my interest in chemistry I had been interested in bond lengths and tried to understand them, and I have been interested in the question of: what are the basic principles of the structure of various crystals? In 1928 I formulated a set of principles for crystals such as the silicates, mica for example, topaz. Topaz was the first one that I worked on, and Aluminiumfluorooxysilicate, $Al_2SiO_4F_2$. But then I worked on mica and chlorite and the zeolites, many other silicate minerals, making use of these basic principles that I had formulated.

[1] Hier zeigt sich Paulings Methode zu arbeiten, nämlich die Fakten anderer Autoren nicht nur zu speichern, sondern auch genauestens durchzuarbeiten, vor allem wenn Widersprüche auftraten. In einem anderen Interview betonte er, in seinem Leben besonders bevorzugt gewesen zu sein, da er bei seinen Arbeiten auf zwei Wissensspeicher habe zurückgreifen können, nämlich auf sein eigenes Gedächtnis und auf das seiner ihn immer unterstützenden Frau Ava Helen.

Then something very interesting occured in 1931, or perhaps December 1930, to end of 1930. One day, late in the day, toward evening, I think, I had an idea. The idea was the basic idea of hybrid orbitals. I was trying to understand why the carbon atom is tetrahedral, forms bonds directed towards the 4 corners of a tetrahedron. Even as early as 1924 I had made a model of methane, in which I said the 4 outer electrons of the carbon atom are in orbits directed towards the corners of a tetrahedron. This was before quantum mechanics. When quantum mechanics came along, a result was confirmed that had been accepted earlier, that the 4 outer electrons in the carbon atom are of 2 different kinds. One kind, that is spherically symmetrical, in the 2s orbital, and then 3 that are arranged along the x, y and z axes. This would suggest that the carbon atom might form 2 kinds of bonds. One bond involving that spherical orbital for the electron, and then 3 bonds, perhaps at right angles, involving the other 3 orbitals.

Well, I thought the basic principles of quantum mechanics permit us to combine these functions from the Schrödinger Equation in another way. And I said to myself: "Let's suppose that I look just at the distribution over the surface of a sphere; the distribution in various directions, and not worry about the difference in the radial distribution for these."

That permitted rather simple calculations to be made in a straight forward manner. The first result I got was that the best bonds that the carbon atom can form, are directed toward the 4 corners of a tetrahedron. So, in 1931, I had a simple theory of the tetrahedral carbon atom and explanation of great bit of organic chemistry.

So here in 1931 I had the answer to many of the questions, that I have been thinking about years earlier, 13 years earlier, when I was only 18 years old. I am sure that some young chemists, who are now students, will be able to make additional contributions in this field of work, as the time goes by. And to make applications to molecular biology and bioorganic chemistry. You, no doubt, remember, that I got interested in living organisms, before you arrived.

In 1929 the California Institute of Technology, where I was professor, started the Department of Biology. The head of this department was Thomas Hunt Morgan. He came from Columbia University of Pasadena and brought with him his students, the important ones, who had, with Morgan, discovered the gene, the basis of heredity, and that was done around 1910, 20 years earlier. So, here I had now some new collegues in Pasadena, who were biologists, geneticists, interested in the human body, in animals and in plants. That was something new for me to think about the properties of living organisms. Well, I became especially interested in hemoglobin.[1]

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[1] Pauling gibt damit eine einleuchtende Erklärung für seine biochemischen und biologischen Interessen.

The hemoglobin in the red cells of the blood. I thought: "What can I do about hemoglobin to learn more about its structure?" Since I was interested in magnetic properties, I had the idea of measuring the magnetic properties of hemoglobin by getting blood from a cow and putting it in magnetic susceptibility apparatus, a Gouy-apparatus, and measure the magnetic susceptibility. The unexpected discover was, that the iron atom changes its electronic structure, when you take the oxygen molecule away. And the result of that is, that the hemoglobin changes its magnetic moment, its magnetic susceptibility in a very striking manner. We made magnetic measurements of many derivatives of hemoglobin and obtained a lot of information about their structure and properties of these substances. So it was a very useful technique, which has been applied to iron-containing enzymes and other macromolecules in animal bodies by various investigators.
And then I got interested in a disease, do you remember, what that disease is?

H. K.: Sickle cell anemia. How did you come to this exciting new idea? Well, it seems to be something so complicated. How did you see the simplicity of it?

L. P.: Yes, well, that is an interesting story. You know during the Second World War some of my scientific work was continued, but I devoted a great amount of energy to military work, on explosives, ordinary explosives.
Oppenheimer asked me to come to Los Alamos to be the head of the chemistry section at Los Alamos, and I decided not to do it, because I was doing other things, that I knew more about; I thought: are more important.[1]
Well, I was working on these military problems; then the war came to an end. I was appointed about the time, that the war ended in 1945. I was appointed to a committee on medical research by President Roosevelt. In this committee I have been working on some medical problems, too; a substitute for blood for transfusions and some other problems and — it was for that reason that I worked on medical problems, that I was appointed to this committee. The committee consisted of 6 physicians and me as a nonphysician, and our job was to recommend to the government, the federal government, what they should do to support medical research after the war, and our recommendation was, that the National Institute of Health be set up. Some other recommendations, too, about support for medical schools.
Well, one day in 1945, this committee met all day in New York talking to the heads of medical schools, the deans of the medical schools, and the directors of

[1] In dieser Aussage offenbart sich bereits deutlich Paulings negative Einstellung gegenüber militärischer Forschung; sein Einsatz für den Frieden auf der Welt bestimmte seinen ganzen weiteren Lebensweg, wofür er mit dem Friedensnobelpreis ausgezeichnet wurde. Auch dieses Interview entstand anläßlich eines Aufenthaltes in Göttingen, wo Pauling an einer Friedenskampagne teilnahm.

laboratories of medical research such as the Rockefeller Institute for medical research. Then, after a long day, we were in the Havard Club in New York, having dinner together, and one of the physicians, a distinguished surgeon, told about an operation, where he had made a mistake and the blood gushed up into the air, he had trouble feeling around, sewing it up, you know the sort of medical talk.

H. K.: Yes.

L. P.: I felt out of. The one of the physicians mentioned a disease: sickle cell anemia, that he had had some interest in. He said: "This seems to be a disease of the red cells in the blood, the erythrocytes in the blood, that ..." – well, I was not paying too much attention; I thought: "I am interested in proteins, but cells, a cell contains thousands of different proteins, most cells, and just too complicated for me or anyone else really to attack." – I know you are working on complicated problems of all membranes and things like that now, and new techniques have been developed and progresses being made, but this was 1945. – So I was thinking, I wish I could go to bed, you know, when he said: "The cells are distorted into a sort of crescent shape, elongated in the venes, in the venous blood, but they resume their normal flattened spherical shape in the arteries." So when he said that, I thought: "What is the difference between the venes and arteries? In the venes the red cells contain hemoglobin, which has this blue colour, but when the blood goes through the lungs and gets oxigenated, then hemoglobin is oxyhemoglobin, the hemoglobin molecules have combined with oxygen. So it must be that this is a disease of the hemoglobin molecule."

H. K.: That's how you came to the molecular disease?

L. P.: That's right, nobody had ever talked about this molecular disease before. Here in Germany there was Virchow. Virchow, a 100 years ago, or more, 120 years ago, who began talking about diseases of cells, before that people talked about diseases of organs, the heart disease, where we still say heart disease, or kidney disease. But they thought about disease before that of humors, humorous liquids of different kinds in the body: bile, you can be bilous because of the bile and so. So we went from the humors such as bile to organs such as the gall bladder or the kidney or the liver or the heart. Virchow said: "The cell! You can have diseases of cell", and then I had the idea: diseases of molecules!
Well, I remember antibodies, how antibodies and antigenes interact by complementariness and so I thought: "Suppose, that the hemoglobin in these patients with the disease sickle cell anemia is a different kind of hemoglobin from that in other people, such that one molecule has a region, that is complementary to the other side and then a molecule could clamp on like this, and form a long rod. And then these rods, they line up side by side as they became longer and longer, they would twist the red cell out of shape."

Then I thought: "If you add oxygen, the oxygen molecules would stick out and keep the molecules from getting close enough together, to stick together, and so this crystal would break up, go back into solution, and that's, what happens then in the arteries in the arterial blood after oxigenation."

Well, I went back to Pasadena and pretty soon I had an application from a young medical student, who had received a fellowship to do some work in chemistry. And I accepted him as a student, when he came, and I wrote saying, I like him to work on this disease sickle cell anemia. So, when he came I had him go to the hospital and get blood from patients, and examine the blood, so he examined spectroscopically to see the absorption spectrum, so you know there is no difference. And he made some other measurements, measured solubility: no difference; and he said: "Perhaps I have to work on another problem, if I don't get any results, how can I get my doctor's degree, Ph.D. Degree?" And I said: "No, you must continue working. Why not measure the electrophoretic mobility? The mobility in an electric field. The way, Tiselius has done in Sweden."

Well, the problem then – 47, 48 – was you could not buy a Tiselius apparatus, no electrophoretic apparatus on the market. So I said: "Well, let us build one." And it took a long time, to build this apparatus, but we finally got it built, and when the normal hemoglobin was put in the apparatus, and the solution was neutral, pH 7, neither acidic nor alkaline, the hemoglobin from me and from other persons in our laboratory moved toward the anode, the hemoglobin from the sickle cell anemia patients moved toward the cathode. And the difference was 2 electric charges, 2 electronic charges on the molecule. So, this was a discovery, the verification of this disease as a molecular disease. Then a very interesting result turned up.

We looked at the blood from the father of a patient. And the blood from the father of the patient, put in this apparatus: half of it moved toward the anode and half moved toward the cathode! And this, the geneticists of course understood, could understand that. This was a proof. They did not know what about sickle cell anemia, but they knew about other conditions, that you have. That you have 2 genes, that ordinarily manufacture the same substance, the same molecule perhaps hemoglobin, ordinary hemoglobin, normal adult hemoglobin. And here was a mutated gene, that manufactured the sickle cell hemoglobin. And so the father was like that, and the mother was like that, too, and some of the children inherited both of the abnormal genes. It is a very nice illustration of the principles of genetics.

Well, so then in our laboratory this young man, Harvey Itano, working with me, got blood from another patient. It turned out to be another abnormal hemoglobin: hemoglobin C with another kind of disease associated with it, and then hemoglobin E was discovered, hemoglobin D and then hemoglobin E,

and then other people by that time began working in the field, and now there are about 300 human hemoglobins known.
Well, in the meantime, here I was working on hemoglobin and then on another protein, the γ-globuline, antibodies and on ovalbumine, and I got interested in the question of the structure of proteins. The German chemist Fischer had shown around 1900, that proteins probably consist of a chain of residues of aminoacids, a polypeptide chain. There was still some uncertainty as to, whether that was true or not: it turned out to be true, and it was Fischer, who had shown it.
So, here we have hair, and we know that hair consists of polypetide chains and the question is, what do the chains look like? Are they stretched out as long as possible, or are they coiled some way or what? So I worked on that problem for many years and my associate students determining by X-ray diffraction the crystal structure of the aminoacids and of simple peptides, and finally I sat down one day in 1948. Actually I was lying down. You know the story? You say, you know very well?

H. K.: You see, I was in Oxford with you at the same time.

L. P.: O yes, that's right.

H. K.: And I heard you very excitingly talking about your new structure. Just you were sick before.

L. P.: I had a cold.

H. K.: You invited us, a few people, to your home and you were very excited about your finding.

L. P.: Yes so.

H. K.: So, I think I was one of the first people that heard about your α-helix.

L. P.: Yes, that's fine that you were there. Well, I was excited. Because for 11 years I had been trying to find that structure. And this was the first structure, correct structure, for a protein to be determined. And of course it involved hydrogen bonds. The question was — I said, I pose this question: "How can a polypeptide chain be folded in such a way, that the NH-groups — hydrogen attached to nitrogen — can form a hydrogen bond with the oxygen atom of the carbonyl-group of an adjacent peptide, an amide-goup?" I tried to find the answer and other people, too, Bragg, Bragg and Kendrew and Perutz were all trying to find it.

H. K.: They were thinking more in symmetry and you more as a chemist.

L. P.: Yes, that's right. I was very happy, but I didn't publish this description for more than a year. And the reason, that I did not publish, was that this structure, the α-helix, which is shown here you see, the α-helix it's sort of represents molecular biology, now it is a symbol for molecular biology. This α-helix according to my calculations should have a sort of pseudo repeat in 5.4 Å and the X-ray patterns that you get from a hair, indicate that 5.1 Å, about 6 % less, and I knew, that this 5.4 was right, if the structure was right. But the X-ray photographs suggested 5.1. So, I thought there must be something wrong with this α-helix.

H. K.: Yes, aha! That was the reason – I was so much surprised that you have published this so much later than you were so exciting, you talking to as advantage.

L. P.: I kept trying to find out what was wrong. Well, the X-ray photographs, the interpretation of the X-ray photographs was wrong. I finally published the structure with my associate Dr. Corey – you remember – and, after more than a year, and part of the reason was, that in Cambridge Bragg, Kendrew and Perutz had published a long paper, 30 pages, describing many possible structures, ways of folding, all of which were wrong, but I thought: "Surely they run across this one, if they keep working." So, I published that structure and the pleated sheets, the 2 pleated sheet structures. And of course now Kendrew determined the first structure of a globular protein and it had these α-helices in it. It was the main structure! Now there have been several 100 protein structures determined and almost all of them have α-helices and pleated sheets. They are the almost the only secondary structures that one finds in protein molecules.

H. K.: Dr. Pauling, why didn't you just go on and start making the structure of DNA?

L. P.: Well, you know, it isn't easy to make discoveries and I never have claimed, that I would have discovered double helix, but I can see that I was suffering under some difficulties at that time around 1952, I was being harassed by the government of the United States because of my work for world peace, my contention, that the United States and the Soviet Union and also other countries should work together for the benefit of the human race, of human beings everywhere. The Royal Society of London decided to hold a symposium, a two-day symposium, in 1952 on my work on the α-helix, this structure and the pleated sheets and the work, that other people had started to do along the same lines. I was to be the first speaker at the symposium in London. I applied for a passport, my passport had expired. I applied for a passport and the government of the United States refused to allow me to go.
Now, the reason of that had significance, for DNA is that an investigator in London, Rosalind Franklin, Dr. Rosalind Franklin, had obtained better X-ray

photographs of DNA, fibres in DNA than anyone else had obtained. We had made some preparations of DNA and made X-ray photographs. Astbury in England had done the same. And later it was recognized that the preparations did not consist of one modification, but rather 2 modifications. So the X-ray photographs were misleading. I was working on DNA, but not very hard, because I was being harassed by the government having to go to be investigated and answer questions and that sort of things. Well, I couldn't go to this conference.

It is believed, and I think probably true, that I would have gone to see Rosalind Franklin, and would have seen her photographs, which Watson and Crick did see. And probably that is true, I wrote to Professor Wilkins, Dr. Franklin was in his institute, and asked for copies of the photographs, but he was not willing to send them to me. So he said, they had not finished analysing them themselves and so he thought he shouldn't let me see them.[1]

Well, perhaps I would have been able to determine the double helix structure, but I am not at all sure that I was, I am pleased that Watson and Crick discovered it, because it revolutionized biology, it was a very great contribution. My wife afterward said to me: "If that was such an important problem, why didn't you work harder at it?"

Well, there is more than one reason, one reason is, that I was being harassed by the government having to go, to be investigated in my time, I had to gather information, documents in effort to protect myself. But another reason is: an investigator at the boundaries of a science never can be sure, what there remains to be discovered. So there was something, too, well, there is another answer to my wife's question, not everyone was sure, that it was an important problem. Watson, Jim Watson was sure, that it was an important problem and it's fine, that he continued to stimulate himself and Crick, Francis Crick, who knew the crystallography, you see, and was involved to determine this DNA structure, the double helix.

H.K.: But soon later you made this tremendous contribution with Zuckerkandel on the molecular concept of Darwin.

L.P.: You know, Dr. Zuckerkandel is still with me. He was born in Vienna, famous family, his grandfather made important discoveries in anatomy, and he came in 1949 to work with me, he came, he wanted to work on oxidation processes in animals, but I got him to work on hemoglobin. We had discovered sickle cell anemia hemoglobin and other human hemoglobins, and I thought we should look at hemoglobins from animals. He went to the San Diego Zoo and got blood from a gorilla, a rhinotine schimpanse and then he got blood from cow and horse and dog and from fish and from a worm and investigated

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[1] Vergleiche auch WATSON [3].

these various hemoglobins, that different animals produce, with very interesting results! He found that he could set up an evolutionary tree, showing which animals are closely related and which more distantly related on the basis of the nature of the hemoglobin – the aminoacid sequences in the different hemoglobin molecules.
We, he and I, were then able 22 years ago to make an estimate of the time, at which different animals separate from one another. And we decided that monkeys separated from the other primates 20 million years ago and human beings separated from schimpanses and these primates, the monkeys, these animals had seemed to be rather closely related to man, we separated from then only 4 million years ago. This was the start of the field that is called molecular evolution. Many people work in this field. Dr. Zuckerkandel founded a journal, the Journal of Molecular Evolution, which he is editor of, doing the whole dozen years of its existence. So, this study, that I began of sickle cell anemia, where we were able to show that one aminoacid residue is different from that in the other in normal human hemoglobin, led to further consequences of development of the field of molecular evolution.

H. K.: A controversial field is certainly your work with vitamin C. And it would be nice to hear about it.

L. P.: Yes, well, the history about is this: after 8 years of working with me, Dr. Zuckerkandel, Dr. Itano, whome I mentioned, was working with me on sickle cell anemia, went to Washington D. C., to continue work on the hemoglobin hypothesis and I decided to look at some other diseases to see what extent they might be molecular diseases.
So, I worked on mental disease for 10 years, schizophrenia and other mental diseases. At the end of 10 years I learned about some work, done by 2 psychiatrists in Canada. And this work involved vitamins. They were giving vitamins to schizophrenic patients, patients with this disease: schizophrenia, and the astonishing thing to me was that these vitamins, a little pinch of vitamin B_3, niacinamide, will keep you from dieing of pellagra, 5 mg a day is enough to protect you against pellagra, very powerful. A little pinch of ascorbic acid, vitamin C, will keep you from dieing of scorbut, 5 mg a day! – We believe. And yet these substances are so free of toxicity, that you can take 10 000 times that much, 50 g or 100 g without any serious consequences.
I thought this is really astonishing. If you take a big dose of aspirine, it kills you, you have to be careful about all of these drugs, but the vitamines are powerful substances almost free of toxicity. So I asked: "What is the amount, the intake, that will put you in the best of health – not just the intake that will keep you from dieing, but the intake that will give you the most energy, the best resistance against disease?" Now for 18 years I have been working in that field. And I wrote a book in 1970, "Vitamin C and the Common Cold", in which I said

that, if you take enough vitamin C, then it will protect you against the common cold. I take 12 000 mg a day, this is 1 g, 1 000 mg, so I take 12 000 mg of vitamin C a day, that is 200 times, what the authorities recommend.

H. K.: And you look perfect!

L. P.: I think, yes, and I say it's the vitamin C, but I take large doses of the other vitamins, too. So, I believe that that's very important. And you know, I was asked in 1971 to speak at the opening of a new medical school, no this was a new laboratory for cancer research in Chicago, a fine big building, and a friend of mine was director of it, he asked me to come to speak. I thought I should say something about cancer, so I had found I have an argument about cancer. I had read a book by a surgeon in Scotland, Dr. Ewan Cameron, with the title "Hyaluronidase and Cancer", and in it he said, if we could strengthen the normal tissues in the body, make them stronger, they might be able to resist the growth of a cancer, and he said, if we could strengthen the intercellular cement, that holds cells together, that would might provide protection.
I knew that vitamin C strengthens the intercellular cement. It is required for synthesis of collagen and their fibrilles, of collagen, in this intercellular cement. So I have made the statement, when I gave my lecture. And Dr. Cameron in Scotland heard about it, he wrote to me, to say how much vitamin C should he give to his patients. And he was astonished. The patients responded so well to the – they were terminal cancer patients, very sick, scheduled, thought, expected to die in a few weeks, and they got lively, full of energy and were able to go home, and many of them died, but they lived longer, much longer, a year longer than expected, some of them have continued to live year after year.
So, it astonishes me that I have got him to this particular field of nutrition medicine, but I have, and I am still working, I am beginning now a project to study the value of vitamin C to protect against heart disease. There is some evidence already. And some arguments about the effects of vitamin C, that indicate that it should have much value against heart disease. There is also epidemiological evidence; people, who take large amounts of vitamin C, have been shown in an epidemiological study to live longer and to have a smaller incidence of heart diseases than people, who don't take extra vitamin C.
So, I find life interesting still, I have new interests, – even after I was retired at the university, I have kept working.

H. K.: But the reason why you came here to Göttingen was not, to see friends in chemistry, but your deep concern in the future of the human race.

L. P.: Well, yes to some extent, that's true, part of the reason for my coming was that that enabled me to see old friends in chemistry, such as you, and to visit the chemistry department. But I was invited to participate in the great meeting against nuclear weapons and against the antisatellite weapons that are

being proposed, by the professors here in Göttingen university, who have arranged this fine meeting.
I have been working on world peace, since the end of the Second World War, and since the first atomic bombs were made and exploded. Albert Einstein got me, to work with him on the Einstein-Committee, to help educate people about how dangerous the presence, this situation is in a world, where we have these nuclear weapons, that could destroy our civilization, and probably wipe out the earth, even wipe out the human race. So, for many years, since 1945, I have devoted much of my time to work on world peace, and, of course, this got me in trouble with the American government, with the California Institute of Technology, where I finally gave up my job. But I am glad, because I stayed in favour with my wife, you knew my wife?

H. K.: Yes.

L. P.: She felt very strongly about these matters, and had a great influence on me. I hope all professors, other professionals and young people, students will all work hard on this problem of getting control of nuclear weapons, and especially the United States and the Soviet Union. They are the great threats to the world, to civilization, to the human race, because they continue to build more and more weapons, and the danger becomes greater and greater. The weapons become more and more complicated. There is a greater and greater probability, that some accident will occur, that sets off the final culminating catastrophe, that would mean the end of the human race.
I am glad that the medical students, the associations of medical students, have joined together and are working hard, and that we have physicians against nuclear weapons, physicians for social responsibility.

H. K.: What do you recommend to young chemists?

L. P.: Well, young chemists? There are two things. One is: do something. Do what you can, to save the world from destruction by nuclear weapons – but I have hope, I believe that we are going to come through this crisis – and build a world, in which every human being can lead a good life!
So a young chemist, a young scientist should also be preparing himself for work as in the best way possible. My advice with respect to education is: to gather broad education. Don't spezialize on synthetic organic chemistry or aromatic chemistry early, but learn other aspects of chemistry and physics and mathematics! And keep up a continuing interest even after you leave the university! Try to learn something more!
Just, I have astonished myself by moving into new fields. Part of the reason perhaps is, that I have developed early a feeling of confidence in my own intelligence. This is very important to a young scientist! Don't rely just on what you read in the books! Think for yourself! Develop this confidence in yourself. Go

ahead and be bold! Try out something new. It may fail! You know; people have pointed out, that some of the things that I have written, turned out not to be true. But some of them turned out to be true.

H. K.: A considerable amount!

L. P.: Yes, it has been great, to have lived in the world during this period, when science has developed, the way it has. We have so much greater understanding of the world now than 50, 60, 70 years ago, just when I have started the study of chemistry. Not on the university yet, but when I first began carrying out my own chemical reactions, just 70 years ago!

H. K.: Thank you very much, Dr. Pauling!

Ergänzungen zum Interview mit Professor Dr. Linus Pauling am 6. Juli 1984 im Haus von Herrn Professor Dr. Hans Kuhn

Hans Kuhn war nach dem 2. Weltkrieg als „postdoctoral student“ bei Pauling am California Institute of Technology in Pasadena und hatte danach mehrmals wieder Kontakt mit Pauling und dessen Frau Ava Helen, u. a. auch an einer besonderen Nahtstelle im Leben Paulings, als dieser nämlich die Struktur der α-Helix aufgedeckt hatte und öffentlich darüber in London berichtete.
Pauling weilte im Juli 1984 aus Anlaß des Kongresses „Verantwortung für den Frieden (Naturwissenschaftler warnen vor der Militarisierung des Weltraums)“ in Göttingen. Somit ergab sich sehr kurzfristig die Möglichkeit zu einem Interview mit ihm. Obwohl aus Zeitgründen kaum Vorbesprechungen möglich waren, nahm Pauling selbst in seinen ausführlichen Statements die wesentlichen Punkte auf, die auf Grund eines früher für ein Unterrichtsfilmprojekt erstellten Manuskripts wünschenswert waren. Es war für alle an den Aufnahmen Beteiligten beeindruckend, wie überlegen der damals 83jährige weißhaarige Pauling das etwa eineinhalbstündige Interview absolvierte. Allein schon hierin zeigte er seine weiterhin ungebrochene Vitalität und Aktivität, die er auch später auf dem o. g. Kongreß eindrucksvoll und publikumswirksam demonstrierte.
Aus verständlichen Gründen bestand bei einem Life-Interview keine Möglichkeit, den genauen Ablauf des Gesprächs vorzuprogrammieren. Daher mußten einige Passagen des Interviews gekürzt bzw. herausgeschnitten werden, v. a. auch eine interessante Stelle, an der Pauling erzählte, daß er 1936 mit Landsteiner, dem Entdecker der Blutgruppen, Kontakt hatte und so zu seinen immunologischen Forschungen angeregt wurde. Ein Teil mußte auch umgestellt werden, damit die weitgehend an Paulings Biographie orientierte chronologische Abfolge erhalten blieb.

Verwendung des Dokuments

Anhand dieses Dokuments kann Studenten und Schülern eine heute bereits historische bekannte Persönlichkeit vorgestellt werden. Pauling steht hier stellvertretend für den allseitig interessierten Naturwissenschaftler, dem es nicht egal ist, wie die Ergebnisse der naturwissenschaftlichen Forschung angewendet werden. Aber auch in vielen kleinen Details, die Pauling erzählt, wird deutlich, wie sein Interesse für die Nachbardisziplinen seine eigenen Forschungen positiv beeinflußt hat (s. o.). Ich glaube, daß dieses verständige Hinhören auf andere Disziplinen und das Bemühen um eine Verknüpfung mit den eigenen Forschungen heute für viele hochqualifizierte Spezialisten nicht typisch ist; oft kommt es zu einer engstirnigen Denkweise, die wir leider auch allzuhäufig in der Schule bei Lehrern und Schülern beobachten können. Dies zu vermeiden zu suchen, dafür könnte der Film eine Anregung sein!

Biographische Daten

Linus Carl Pauling wurde am 28. 2. 1901 in Portland, Oregon, USA geboren. Nach dem Collegebesuch machte er seinen Ph. D. in physikalischer Chemie 1925 am California Institute of Technology, Pasadena. Zwei Jahre Studium in Europa folgten, u. a. in München bei Arnold Sommerfeld, in Kopenhagen bei Niels Bohr, in Zürich bei Erwin Schrödinger und in London bei Sir William Henry Bragg. Ab 1927 lehrte und forschte er wieder am CIT und stieg zum Direktor der Gates and Crellin Laboratories of Chemistry auf. 1963 verließ er das CIT, wohl weil er kein Verständnis und keine Unterstützung für seine Friedensbemühungen fand, und wirkte seither an verschiedenen Orten.
Sein Buch über die Natur der chemischen Bindung und die Struktur der Moleküle und Kristalle (PAULING [1]) hat lange Zeit die Chemieausbildung entscheidend geprägt. Für die Aufdeckung dieser grundlegenden Einsichten über die Bindung in Molekülen und für deren Anwendung auf komplexe Substanzen erhielt er 1954 den Chemienobelpreis. Sein wissenschaftliches Werk ist äußerst vielfältig, und seine Interessen sind breitgestreut, aber fast immer suchte er Beziehungen zwischen Struktur und Wirkung von Molekülen aufzuklären: die Sichelzellanämie als molekulare Krankheit, Immunreaktionen, Proteinstrukturen (α-Helix-Modell) und die Bedeutung der Wasserstoffbrückenbindungen in Proteinen. Auch an der Aufklärung der DNA-Struktur, an der Erklärung der Anästhesie und der Vorgänge im Gedächtnis hat Pauling gearbeitet. Er wandte sich auch noch weiteren medizinischen Problemen zu, wie der Bedeutung von Vitamin C als Schutz vor Erkältungskrankheiten und Krebs. Als ich ihn 1980 besuchte, arbeitete er mit seinen Mitarbeitern an Früherkennungsmethoden für Herz- und Kreislauferkrankungen und Krebs. Er ist auch heute noch aktiv an vielen Problemen interessiert, zur Zeit beschäftigt ihn das Thema Aids (nach PODAK [2]).

An seinen 90. Geburtstag erinnerte ein Bericht in der Süddeutschen Zeitung (PODAK [2]) unter der Überschrift „Immer alle zwanzig Jahre voraus". Dies trifft auch für sein wichtigstes Lebenswerk zu, nämlich für seine Bemühungen um den Weltfrieden.
Gleich nach den ersten Atombombenabwürfen warnte er vor den Gefahren der radioaktiven Strahlen. Seine Friedensbemühungen wurden immer intensiver. Zusammen mit Albert Einstein und Albert Schweitzer organisierte er eine Kampagne gegen die atomare Aufrüstung. 1958 überreichte er den Vereinten Nationen eine von 11021 Wissenschaftlern unterzeichnete Petition für die Beendigung von Atomwaffenversuchen. 1962 erhielt er für diese Initiativen den Friedensnobelpreis.
Erst 1975 überreichte ihm Präsident Ford die Science Medal, die höchste amerikanische Auszeichnung für einen Wissenschaftler. Diese späte Ehrung spiegelt deutlich seine Schwierigkeiten im eigenen Heimatland wider.
1952 wurde er wegen seiner tiefen Überzeugung, daß die Vereinigten Staaten und die Sowjetunion und auch die anderen Länder zum Wohlergehen der Menschheit zusammenarbeiten sollten, immer wieder verfolgt und in seiner Arbeit behindert. Heute jedoch arbeiten die beiden großen Mächte zusammen, und sogar eine teilweise Abrüstung von Atomwaffen ist in Sicht. Für Pauling sicher eine Erfüllung seiner Träume und eine späte Genugtuung für die ihm zugefügte ungerechte Behandlung in seinem geliebten Heimatland!

Bibliographie

[1] PAULING, L.: The Nature of the Chemical Bond and the Structure of Molecules and Crystals. An Introduction to Modern Structural Chemistry. 3. Aufl. Ithaca – New York 1960 (Cornell University Press).
[2] PODAK, K.: Immer alle zwanzig Jahre voraus. Süddt. Ztg. 28. 2. 1991, 51.
[3] WATSON, J. D.: Die Doppel-Helix. Reinbek 1969.

Angaben zum Film

Video (Originalton, engl.), farbig, 58 min. Hergestellt 1984, veröffentlicht 1991.

Der Film ist als Dokument für die Verwendung in Forschung und Hochschulunterricht bestimmt. Die Aufnahmen entstanden unter der Leitung von Professor Dr. G. LATZEL, Universität Erlangen-Nürnberg. Aufgenommen, bearbeitet und veröffentlicht durch das Institut für den Wissenschaftlichen Film, Göttingen, Dr. S. DOLEZEL, und Dr. G. GLATZER; Kamera: K. LECHNER und T. SPIELBÖCK; Ton: K. BERTRAM; Schnitt: T. SPIELBÖCK; Videotechnik: J. ZEDEL.

Inhalt des Films

Linus Pauling über sein Leben für Forschung und Frieden – Interviewer: Hans Kuhn. Pauling erzählt aus seinem Leben wichtige Stationen, die seine Studienwahl und seine wissenschaftliche Entwicklung verdeutlichen. Dabei zeigt sich eines seiner wesentlichen Erfolgsprinzipien, nämlich seine Fähigkeit, auch die Ergebnisse anderer kritisch zu verarbeiten und in seine Sichtweise zu integrieren. Paulings menschliche Größe kann man daraus ersehen, daß ihm sein Eintreten für den Frieden mehr bedeutete als unbehelligtes wissenschaftliches Forschen. Daß er trotzdem auf vielen Gebieten Wesentliches geleistet hat, ist auch aus diesem kurzen Interview zu ersehen.

Film Summary

Linus Pauling on his Life for Science and Peace – Interviewer: Hans Kuhn. Pauling relates important milestones in his life that elucidate his choise of studies and his scientific development. One of his essential principles for success is illustrated here, namely, his ability to critically process the results of others and integrate them into his philosophy. Pauling's human greatness is demonstrated in that his commitment to peace meant more to him than unchecked scientific research. That in spite of this his accomplishments in many areas were of crucial importance can be seen in this short interview.

Résumé du Film

Linus Pauling sur sa vie pour recherche et paix – Partenarie d'interview: Hans Kuhn. Pauling parle sur les étapes importantes de sa vie, élucidant le choix de ses études et son développement scientifique. L'on découvre un des principes fondamentaux de son succès, à savoir sa capacité de prendre en considération aussi les resultats des autres et de les intégrer de manière critique à son point de vue. Le fait que son engagement pour la paix lui était plus cher qu'une recherche scientifique non importunée prouve la grandeur humaine de Pauling. Cette courte interview montre qu'il a néanmoins accompli de travaux importants dans des domaines multiples.