THE WORLD OF CHEMISTRY

Program #25

CHEMISTRY AND THE ENVIRONMENT

Producer Robert Kaper

Air Script: October 31, 1988

PRODUCED BY

EDUCATIONAL FILM CENTER
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THE UNIVERSITY OF MARYLAND

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Annenberg/CPB Project Logo and Music

Funder Credits

MONTAGE: Chemical plants, microorganisms, pollution, chemical waste dump, lake

NARRATOR (NAT SOUND under): Chemicals. From industrial plants, as from living cells, all molecules have to go somewhere. And just as that has been a problem for cities and for ordinary householders, so has it been a problem for industry. Chemical waste provides a challenge for both society and science, a challenge to be met by understanding chemistry and the environment.

SUPER: CHEMISTRY AND THE ENVIRONMENT

THE WORLD OF CHEMISTRY OPEN: Montage, Music, Logo

RH next to water

ROALD HOFFMANN (SYNC):
We've seen in the last program that our bodies are intricate chemical factories. They take in molecules, they break them down, and then reshape them into still more complex ones. And in our bodies all kinds of ingenious cycles shuttle around molecules and energy. But we are not closed systems. We take in things and we put out molecules. The planet that we live on is, however, a reasonably closed system. It has those marvelous cycles of carbon dioxide, of water, of sulfur, of other elements and compounds, and we are part of those cycles. It would be fine if the earth had to deal only with our bodies, but we also make tools, and not only hammers, but cars, and chemical factories, and power plants. And these tools magnify our actions, and as we use them to better the way that we live, we sometimes discard into the environment something, or a lot of it. What we dump or spill, however we foul our nest may hurt us. It may hurt other species. It may interfere with those grand cycles. In this program, we will look at how we and our tools affect the earth, how chemistry gives us the ability to assess what we do, and we will look at some possible solutions.

MONTAGE: Pollution, shots of nature, fungi and bacteria, clouds, lakes and forests

NARRATOR (MUSIC and NAT SOUND under):
Recycling. We're turning to it more and more as a way to get rid of waste. Though it may sound new, recycling has been going on in nature for billions of years. Plants absorb waste carbon dioxide that animals exhale. Animals eat plants and breathe the oxygen plants give off. Animal wastes return to the earth. Sooner or later, animals themselves return to the earth. There, fungi and bacteria break them down into simpler compounds that are absorbed, again, by plants. And the cycle continues. Life is a complex web of chemical cycles, sets of balanced reactions ultimately powered by sunlight. The whole earth makes up a giant bank of chemical compounds. Until humans appeared, withdrawals and deposits stayed more or less in balance. But that balance can be tipped. Carbon dioxide is a vital plant nutrient. Without it, life couldn't exist. But humans are producing too much of it, by burning coal and oil. Cutting down forests adds to the problem. Trees that could absorb the excess CO2 are gone. More and more carbon dioxide traps more and more heat, the greenhouse effect. Ultimately, there may be too much of it for nature to recycle. (cont.)

NARRATOR cont:
Natural recycling is also affected when we add to the environment new synthetic molecules. Nature has not had time to evolve fungi and bacteria to break them down. Dr. Peter Raven is a member of the National Academy of Sciences.

INTERVIEW: Dr. Peter Raven, National Academy of Sciences

SUPER: Peter Raven

DR. PETER RAVEN (SYNC):
Obviously, it's more and more apparent that the world is not an endless sink or an endless disposal area for things that we manufacture. But equally obviously, we're gonna go on manufacturing things for our own benefit. What we need to do is measure the benefits and the, and the disadvantages of manufacturing those, decide what we're doing with them and how we're disposing of them, on a case-by-case basis.

MONTAGE: Spraying DDT, dead fish and birds, rain, microorganisms, nature shots, PCBs in use, analyzing PCBs, pollution

NARRATOR (NAT SOUND under):
In some cases, we've started to do that. DDT was once used worldwide to kill insects. (cont.)

NARRATOR cont:
It probably saved hundreds of thousands of lives from insect-borne diseases like malaria. Today, DDT is banned in most western countries, because it also killed fish, and nearly wiped out several types of birds. It interfered with the formation of their egg shells, causing many to break in the nest. Rain washed the DDT into the water. Algae and other microorganisms absorbed it. Larger creatures that fed on the algae accumulated the chemical in their bodies. Fish-eating birds were at the top of the food chain, and they accumulated the most. PCBs, polychlorinated biphenols, another group of environmentally persistent chemicals now banned in most countries. They're oily liquids that make a good coolant and insulator for large electrical transformers and capacitors. Like DDT, PCBs have stable carbon-chlorine bonds, and like DDT, they're nonpolar, so they dissolve and accumulate preferentially in body fat. We've banned DDT and PCBs, but there are other pollutants that still cause concern. Are we concerned about these forms of pollution just for the sake of a few endangered species? Or is there a more compelling reason?

INTERVIEW: Dr. Peter Raven cont.

DR. PETER RAVEN (SYNC):
Well, by and large, pollution damages biological productivity of one kind or another, and human existence is largely based on biological productivity. Agricultural productivity is one obvious example, and there's productivity of forest, of forests for timber, for fuel. Forests are the source of fuel for 1.5 billion of the world's population. There's productivity of the oceans, there's productivity of lakes. Now, all of these forms of productivity can be altered, limited, or shut down by pollution from chemical and industrial processes.

MONTAGE: Chemical plant, hazardous waste sites, pollution

NARRATOR (NAT SOUND under):
Chemical and industrial pollution. It's a controversial subject, particularly when it comes to hazardous waste. Leaking drums, storage tanks, thick chemical sludge. The threat of pollution and illness from hazardous waste has spurred a major government cleanup effort, the Superfund program. It was signed into law in 1980, with total funding eventually nearing $10 billion. (cont.)

NARRATOR cont:
The Environmental Protection Agency expects to clean up several thousand hazardous sites under Superfund. Yet there's still controversy about just how dangerous they really are. The originator of the test for determining whether a chemical has the potential to cause cancer is Dr. Bruce Ames, biochemist at the University of California, Berkeley.

INTERVIEW: Dr. Bruce Ames, biochemist, University of California, Berkeley

SUPER: Bruce Ames

DR. BRUCE AMES (SYNC):
People have been very worried about toxic waste dumps but, in fact, the evidence that they're really causing any harm is really minimal, there's not very much evidence. And the levels of chemicals are very tiny, so we don't really know whether there's no hazard or a little bit of hazard.

French Ltd. dump site, shots of town, church and parishioners

NARRATOR (NAT SOUND under):
Texas Bayou country, just east of Houston. Sand-mining operations have left open pits in the swampy ground. They made convenient dump sites for hazardous wastes from oil refineries and chemical plants. (cont.)

NARRATOR cont:
The French Limited dump site holds nearly 140,000 cubic yards of toxic sludge and contaminated soil, metal finishing acids, benzene, PCBs. The site is now part of the Superfund program, and work is going ahead to clean it up. But in nearby towns, there's concern over the dump's health effects, although many experts feel there's no danger. These opposing views illustrate the poor communication between scientists and the public. Inside St. Martin de Porres Catholic Church, parishioners' opinions show how public fears can outrun scientific fact.

INTERVIEWS: Church parishioners

PARISHIONER (SYNC):
Definitely we have problems. We have people, we have at least 13 people that I know of that died of cancer since this dump has been there. And you didn't have that before. When we were little children, our people didn't die with cancer. They just died of old age, a hundred and six years old, or somebody killed them or they got killed in a car wreck. Everything now in Barrett Station is cancer. You better not go to a doctor if you don't want to hear it's cancer.

PARISHIONER (SYNC):
So it's got to affect the people, because special, you know, when the wind is blowing from the west, or the people in this end gets it real bad. And quite natural, when your wind change direction, well, the other people, you know, wherever the wind be blowing, they gets it. And it's just I don't think it's healthy. I know it's not.

PARISHIONER (SYNC):
I be short-winded, I done have four surgeries, one for cancer. I done have a spot on my lungs. I had pneumonia every year. So I don't know what the cause of it.

NARRATOR (NAT SOUND under):
The fears of those exposed to hazardous wastes may not be realistic, but they are real. Dr. Halina Brown is a Professor of Toxicology at Clark University.

INTERVIEW: Dr. Halina Brown, Professor of Toxicology, Clark University

SUPER: Halina Brown

DR. HALINA BROWN (SYNC/VO):
What is the disease that we are talking about? Cancer, dreadful disease, disease that everybody fears. What if that risk of one in ten thousand means that it's my child is going to get sick? (cont.)

DR. HALINA BROWN cont:
It's not enough abstract concept anymore, it's an extremely personal concept.

Shots of church parishioners

There is a tremendous gap between how people who are affected by the exposure to this environment and carcinogens perceive the risk and how a scientist would perceive the risk.

Shots of chemists working in labs, hazardous waste site

NARRATOR (NAT SOUND under):
How do scientists perceive the risk from chemicals and the environment? Most chemicals, even vitamins, can be toxic at large doses. Most chemicals, in fact, have a threshold dose of toxicity. A dose above the threshold is dangerous, a dose below it is not. But there's a great deal of debate over whether potential carcinogens have such thresholds, that is, concentrations below which they won't cause cancer. Given conflicting and imprecise evidence, some scientists talk about carcinogens in terms of risk or probabilities. Risk is relative. For example, some think the cancer risk from hazardous waste is negligible compared to the naturally occurring carcinogens we successfully resist every day.

INTERVIEW: Dr. Bruce Ames cont.

DR. BRUCE AMES (SYNC):
The world is full of carcinogens, because half the natural chemicals they've tested have come out as carcinogens. Some plants have toxic chemicals to keep off insects, and we are eating those every time we eat a tomato or potato. And mushrooms have carcinogens, celery has carcinogens, an apple has formaldehyde in it. So there are an incredible number of carcinogens in nature; we're getting much more of those than man-made chemicals.

INTERVIEW: Dr. Halina Brown cont., hazardous waste sites

DR. HALINA BROWN (SYNC/VO):
If we accept those risks, why can't we accept small risks from chemical carcinogens in the environment? It's a valid argument. But then there is, of course, the counter argument. The counter argument is we cannot do much about trace amount of carcinogens that are present in food, why should we add to this burden that we already have by increasing the amount of exposure to carcinogens. But then it boils down to money. Unfortunately, it takes tremendous resources to reduce the levels of exposure in the environment to carcinogens, especially when you get to very low levels. (cont.)

DR. HALINA BROWN cont:
Reducing it by another order of magnitude may take millions of dollars at one hazardous waste site. And the pie is not unlimited.

Pollution

NARRATOR:
Even those who don't consider hazardous waste dumps a health threat think the money should be spent to clean them up.

INTERVIEW: Dr. Bruce Ames cont.

DR. BRUCE AMES (SYNC):
I mean if Congress has put ten billion dollars for cleaning up toxic waste dumps, you might as well find the worst ones and clean them up. Now, whether you're getting anything -- whether it's really a public health -- you're gaining much in public health for cleaning them up is a matter one could argue about. I think probably very little. But, in any case, you can -- you might as well spend the money cleaning up the worst dumps.

Hazardous waste site and cleanup operation

NARRATOR (NAT SOUND under):
Toxic waste cleanup. Why is it so expensive? One reason is the huge amounts of material that have to be handled. A dump may cover many acres and extend 15 to 20 feet deep. (cont.)

NARRATOR cont:
Another reason is the degree to which the dump must be cleaned up. Contaminants in water and soil may have to be reduced to several parts per million, and that can require intensive treatment of millions of gallons of water and hundreds of thousands of cubic yards of contaminated sludge and soil. The first step is to remove leaking drums, tanks, and other containers that are contaminating the site. The next stage is the hard part, treating the remaining chemical sludge and removing the contaminants from the soil and water. Several methods are available.

Hazardous waste site, cleanup operation and analysis

NARRATOR (MUSIC under):
Most involve chemistry. One technique is incineration. Chemicals are burned at high temperatures to oxidize them completely. Carbon dioxide and water vapor go out the stack. Hazardous waste incinerators are often equipped with devices called scrubbers. They trap harmful substances in the exhaust gases, such as metals and chlorine compounds. A close imitation of nature's own recycling is the use of bacteria to break down chemicals. (cont.)

NARRATOR cont:
It's called biodegradation, or bioremediation. Many synthetic compounds cannot be degraded by bacteria, but there are always a few bacteria at a waste dump that can metabolize the complex organic molecules found there. Scientists cultivate these bacteria in the laboratory. They are fed only the toxic chemicals in the dump. Those that can digest the chemicals will prosper; those that can't will die out. It's evolution in fast forward. The survivors are thrown back into the waste dump, where they go to work. This technique is being tested on a full scale at the French Limited chemical dump. At the bottom of the shallow lagoon is a thick sludge of toxic chemicals. Floating compressors pump air into the water to help the bacteria oxidize the wastes. To make it easier for the bacteria to get at the chemicals, the sludge is stirred up with a dredge. The black foam looks awful, but it's actually a good sign, like the head on beer. It's made by enzymes which the bacteria produce to break down the chemicals.

Hazardous waste cleanup
and analysis

NARRATOR (NAT SOUND under):
While cleanup continues, so does monitoring. The untreated sludge is sampled to determine what chemicals it contains. Samples taken from the core are sent to a laboratory for chemical analysis. Lab tests identify the specific compounds present and their concentrations. Other monitoring at the site includes checks for chemicals escaping from the lagoon either by leaking into the ground or evaporating into the air. Escaping gases are measured at the edge of the lagoon and at selected locations in the surrounding area. Ground water is sampled through pipe wells sunk at several locations around the pit. The pipes extend to different depths. Chemical analysis of the water sample reveals how far contamination has spread outward and downward from the dump. Eventually, the bacteria will break down all the organic chemicals to harmless concentrations. The water will then be pumped out of the lagoon and discharged, and the pit will be filled in. Four years of work and fifty million dollars later, one chemical waste dump will be history.

Exxon Chemical: plant shots

NARRATOR (MUSIC and NAT SOUND under):
Baytown, Texas, home of a giant Exxon chemical complex, third largest in the world. Nationwide, cleanup is under way, yet industry will always produce chemical wastes. They are an integral part of manufacturing process. Today, however, much is being done to minimize those wastes and their effect on the environment. Exxon makes several different chemical products here, including polypropylene plastic. The company is engaged in a major waste reduction program in order to meet today's stricter environmental regulations and to save money. Chemical waste is money down the drain, or up the stack. So good environmental practices are also good business. Charles Seay is Environmental Manager for Exxon Chemical.

INTERVIEW: Charles Seay,
Environmental Manager,
Exxon Chemical

SUPER: Charles Seay

CHARLES SEAY (SYNC):
When we look at waste management, our first priority is to reduce the generation of waste, and then we look at recycle and treatment next, and disposal only as a last resort.

Exxon Chemical: plant shots, waste analysis

NARRATOR (NAT SOUND under):
Reducing the generation of waste takes many forms, but one very simple and effective technique is regularly checking for leaks into the air from the plant's thousands of valves. Leaking gas is drawn into a measuring instrument. A catalyst inside oxidizes it. The amount of heat produced is a measure of the hydrocarbon concentration. Tightening the packing around the valve stem usually stops the leak. If not, a maintenance crew will repair it. All valves in the plant are numbered. They're entered into a computer to keep track of their leak status. The system helps control the thousands of tiny gas emission sources that could otherwise be overlooked.

INTERVIEW: Charles Seay cont.

CHARLES SEAY (SYNC):
It doesn't appear to be much in any particular single valve or instance, but in aggregate it represents a significant quantity.

Exxon Chemical: plant shots

NARRATOR (NAT SOUND under):
But waste production can only be reduced so far. There's always going to be a certain amount of unwanted by-product that has to go somewhere.

INTERVIEW: Charles Seay cont.

CHARLES SEAY (SYNC):
We've learned to recycle and recover many of our waste streams in the form of energy, to use them as fuel. And we've also learned to look at other product applications for some of these wastes.

Exxon Chemical: plant shots

NARRATOR (NAT SOUND under):
An example is the main by-product of polypropylene manufacture. It consists of branched chain molecules instead of the straight chain polypropylene that makes up the white plastic product. At present, it's burned as a fuel. But the company hopes to convert it to a putty-like plastic that can be sold as weather stripping and window sealer. Even straight chain polypropylene beads are considered waste if they're the wrong size or shape. So to eliminate the cost of disposal, the company recovers them from the plant waste water system for sale. Buyers are companies that don't need high quality plastic, such as toy manufacturers. The waste water collection system picks up spills and chemical leaks from all plant operations. As much waste as possible is separated from the water and recycled. Oil can be skimmed off and used as fuel. (cont.)

NARRATOR cont:
The dirty water remaining is decontaminated with bacteria in a waste water treatment plant. It's basically the same treatment given to chemical waste dumps in bioremediation. Chemicals in waste water are costly to the company in two ways: useful materials are wasted, and it costs money to remove them from the water. So the water from each separate plant operation is sampled daily to keep track of discharged chemicals. Chemists will analyze the water in the laboratory to determine how much waste it contains, and the operation that produced the waste will be charged for the cost of treating it. The same principle applies to solid waste and sludges that have to be trucked off site for disposal. Those that can't be recycled or broken down biologically are disposed of in pits lined with heavy plastic or clay to prevent leakage. It's an expensive way to dump garbage, but for this industry, it's worth it.

INTERVIEW: Charles Seay cont.

CHARLES SEAY (SYNC):
Clearly the rapid escalation of disposal cost has provided an increased incentive to become more effective at reducing waste. (cont.)

CHARLES SEAY cont:
You know, I think it's -- we've seen increases of 15 percent or more a year for some length of time, and there's no reason to assume that they won't continue to escalate, looking ahead to the future.

MONTAGE: Pollution, hazardous waste sites, church parishioners, plant shots

NARRATOR (MUSIC under):
Chemical waste, then, and its effect on the environment, can be minimized both economically and safely, and the polluting dumps of the past are being gradually eradicated. How can people be reassured that technological and economic progress will not harm the environment or health? Through more accurate and open public communication, and through improvements in the science and management of waste disposal. Chemistry has brought enormous benefits to the largest numbers of people. Sometimes it has brought problems, problems that, in turn, can be understood and resolved through chemistry. To maximize living standards and life expectancy in the future, industrial and environmental planning must go hand in hand.

INTERVIEW: Dr. Bruce Ames cont.

DR. BRUCE AMES (SYNC):
Chemical companies are making all these useful chemicals and plastics that we need in our lives, and weren't worrying too much about where they were dumping their waste products, and then people realize, well, Lake Erie gets polluted, and then we started making rules. And so I think we've done really quite well. The U.S. is probably the least polluted country in the world, when you look at it. And it's again a question of learning new things and adapting to them, and the country has done that very well.

INTERVIEW: Dr. Peter Raven cont.

DR. PETER RAVEN (SYNC):
We're not really willing to do away with the industrial processes, so what we need to decide is how much disruption of the atmosphere we're willing to tolerate, what the atmosphere can absorb, what the atmosphere can't absorb, and then decide on a kind of a collective compromise. The operational point, though, I think is that human beings are already running the whole global ecosystem very intensively, and we need then to make choices between degrees of management and make them sensibly and on a global basis.

Credits, Closing Montage, Closing Music

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THE WORLD OF CHEMISTRY

Program #26

FUTURES

Producer Robert Kaper

Air Script: October 31, 1988

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THE WORLD OF CHEMISTRY

Program #26: Futures
Producer Robert Kaper
Air Script: October 31, 1988

Annenberg/CPB Project Logo and Music

Funder Credits

MONTAGE: Chemical models, chemists working in labs, cells under microscopes, chemical plants

MUSIC

SUPER: FUTURES

THE WORLD OF CHEMISTRY OPEN: Montage, Music, Logo

RH in office

DR. ROALD HOFFMANN (SYNC): What is ahead in the future for chemistry and for the society that is so affected by chemistry? Much excitement, deeper understanding, new molecules that no one has yet thought of. But one thing is not going to change. This science is done by people, people such as yourselves. (cont.)

ROALD HOFFMANN cont:
Oh, they may have fancy titles, Chief Executive Officer of this company, head scientist, professor, Nobel Laureate, but behind these titles are just people, people obsessed by curiosity. Chemistry has been a democratizing force. It has brought a wider range of products to more people than could ever afford them before. Chemists care about their science and about their society. And so, in this program, we brought some of those people together. They have some intriguing and dramatic opinions. And because I'm one of them, just a chemist, I'm going to join my friends in this half hour. We will look at the future as best we can. What lies in the years ahead is certain to exceed our vision.

INTERVIEW: Dr. Jacqueline Barton, Columbia University

DR. JACQUELINE BARTON (SYNC):
Where I think chemistry is going is outwards, in different directions, outwards towards the areas of biology, and that's -- those are the sorts of things that I'm involved in. It's outwards towards physics, towards the areas of engineering, towards the construction of different kinds of materials, and also towards the construction of different kinds of biopolymers.

INTERVIEW: Dr. Howard Schneiderman, Chief Scientist, Monsanto

DR. HOWARD SCHNEIDERMAN (SYNC):
So if I had a career plan that I wanted to be part of 21st Century shock troops that are attacking the major diseases of plants, of animals, and so on, I want to clean up toxic waste, I want to clean up the ocean, I want to get rid of AIDS, I want to get rid of the great -- I want to get rid of malaria, schistosomiasis, and so on. That's gonna be accomplished by manipulating molecules. The chemists will be in the middle of it.

Shots of the STM, images of the atom

NARRATOR (MUSIC under):
As they broaden their horizons and ours, chemists are linked to new instruments and techniques. For example, the latest electron microscopes image objects in ways impossible only a few years ago. Dr. Howard Schneiderman, Chief Scientist, Monsanto.

INTERVIEW: Dr. Howard Schneiderman cont.

SUPER: Howard Schneiderman, Monsanto

DR. HOWARD SCHNEIDERMAN (SYNC):
We have gotten to a point where we can see a molecule. We can see a molecule. With a tunneling electron microscope, with a variety of techniques we can see molecules.

Shots of lasers

NARRATOR (NAT SOUND under):
Chemists can now probe the interior of molecules with lasers, and a hydrogen fluoride chemical laser may have future applications that its inventor never fully intended. Dr. George Pimentel.

INTERVIEW: Dr. George Pimentel, University of California, Berkeley

SUPER: George Pimentel, U.C. Berkeley

DR. GEORGE PIMENTEL (SYNC):
It turned out to be a very effective and powerful laser, so powerful, in fact, that it was considered as a possible weapon, that is to say, a chemical reaction which could produce a light ray, a laser light ray, with sufficient intensity, sufficient power, to possibly do some damage.

Scanning the brain

NARRATOR (NAT SOUND under):
And there are scanners in medical diagnosis using radioactive isotopes. Emissions maps the functions of different organs, including the brain in action. Another application of this technique is in testing new drugs. Dr. Michael Welch.

INTERVIEW: Dr. Michael Welch, Washington University

SUPER: Michael Welch, Washington University

DR. MICHAEL WELCH (SYNC):
If drug companies label the new drug with a positron-emitting radio nuclide, administer it to patients or normals, they can find out the mode of action, they can find out how much concentrates in a particular part of the body, they can find out how long it stays in that part of the body. They can find out if it goes to a part of the body they don't expect it to go to.

Computer graphics

NARRATOR (NAT SOUND under):
And there are computers in chemistry. Computer graphics illuminate molecular architecture. They enhance innovation in design. Dr. Bertram Fraser-Reid.

INTERVIEW: Dr. Bertram Fraser-Reid, Duke University

SUPER: Bertram Fraser-Reid, Duke University

DR. BERTRAM FRASER-REID (SYNC):
Imagine that you want to bring two bodies together, to fuse them together. Now, what is the best way to do that? Is it better that they come together in this way, or in this way? What forces govern this choice versus this choice? A computer can tell you that because you can probably plot in the various things that favor coming together this way versus some things that favor coming together in this way.

Microscopic images, lasers, scanners, computer graphics, material being stretched

NARRATOR (MUSIC and NAT SOUND under):
Super microscopes, lasers, scanners, computers and more, new technologies linked to chemistry. Chemistry is spreading outward, a vigorous new partner in other domains of science, like material science. Dr. Frank DiSalvo.

INTERVIEW: Dr. Frank DiSalvo, Cornell University

SUPER: Frank DiSalvo, Cornell University

DR. FRANK DI SALVO (SYNC):
We have to both make materials and look at their properties, which is the overlap between chemistry and physics, if you want. In order to do the kinds of things you want to do with a chemist, or as a physicist, you have to have appreciation for what went in to making the solid, or what I can do to the solid to change its properties, for example. So you need to understand both sides of the fence, and that's becoming a larger and larger requirement in the field of solid state chemistry, solid state physics. If you look at physics today, you look at physicists and ask what they are doing, more than half of all physicists are working on materials, and that means that they're working on things that have to be made by chemists or someone, material scientists, making materials, and they're trying to understand why these materials behave the way they behave. And so the overlap between chemistry and physics is already very large.

INTERVIEW: Keith McKennon, President, Dow USA

NARRATOR:
Keith McKennon, President, Dow USA.

SUPER: Keith McKennon, Dow U.S.A.

KEITH MC KENNON (SYNC):
The new kinds of materials that are being developed have remarkable, remarkable properties. I mean, they have thermal properties, and tensile strength properties that are almost unbelievable in the context of the materials we are used to seeing. So, for very sophisticated kinds of application, and high speed aircraft are an example of those, so-called Orient Express, and projects like that will, I think, find a use for those kinds of materials. The space program, as I'm sure people are aware, has been a major impetus in developing new materials and developing the whole field of material science. I believe that's gonna continue, and that, in the next century, as I say, we'll see materials that we can only imagine today.

INTERVIEW: Richard Heckert, Chairman, The DuPont Company

NARRATOR:
Richard Heckert, Chairman, the Du Pont Company.

SUPER: Richard Heckert, DuPont

RICHARD HECKERT (SYNC):
We've discovered that you can fill polymer systems, even ceramics, with high modulus inorganic materials, carbon fiber, some organic materials too, things like our Kevlar, or glass fiber, or inorganic fibers of various types from different minerals. Some of these old systems, filled with those materials, produce remarkable compositions that will do jobs that we never thought plastics capable of doing.

Superconducting materials, periodic table

NARRATOR (NAT SOUND under):
And then there are the superconducting materials. Their invention shows how a chart a hundred years old will still have a great future a hundred years hence.

INTERVIEW: Dr. Frank DiSalvo cont.

DR. FRANK DI SALVO (SYNC):
Copper oxide superconductors are made by combining copper with oxygen. That bonding is rather covalent, making, in just combining copper and oxygen, a binary compound that's not so interesting. But if I combine them further still with elements from the left-hand side of the periodic table, like lanthanum or strontium, I obtain interesting superconductors. That appears to come from the interplay between the ionic bonds that these materials want to have with oxygen and the covalent bonds that copper wants to have with oxygen. If you were to ask me to summarize on one sheet of paper all the potential things that could happen in chemistry, not only in chemistry, but in all fields of science, physical science that is, and maybe in engineering, the one sheet of paper I'd give you would be the periodic table. That's everything we ever will do in science is summarized here. All the compounds that we'll ever make will come just from combining these elements, these hundred-odd elements on this one sheet of paper.

Periodic table graphic, computer graphics, molecular models

NARRATOR (MUSIC and NAT SOUND under):
The periodic table was a product of basic research. Tomorrow, as today, there will be those who seek purely to acquire new knowledge for its own sake, with no regard to eventual application. Much fundamental research in the future will be done to create new molecules. Nobel Laureate Roald Hoffmann.

INTERVIEW: Dr. Roald Hoffmann, Cornell University

SUPER: Roald Hoffmann, Cornell University

DR. ROALD HOFFMANN (SYNC):
People make molecules for all kinds of reasons. One of them is that a molecule is beautiful. That, for instance, is the case with this fantastic platonic polyhedron, as it's called, of dodecahedrane, with 20 carbon atoms in it, with 12 faces, all pentagons. This was made not too long ago by a friend of mine at Ohio State, Leo Paquette. Now, he made it because it was a goal, a mountain to be climbed. Many people had tried, no one had made it, and it's esthetically pleasing in its symmetry.

INTERVIEW: Dr. Jacqueline Barton cont.

NARRATOR:
Dr. Jacqueline Barton.

SUPER: Jacqueline Barton, Columbia University

DR. JACQUELINE BARTON (SYNC):
Now, where I think we're going is into bigger and, in some respects, more complicated structures. Those kinds of complicated structures allow us to design, in one respect, on a molecular level, macromolecular assemblies, multi-atom assemblies that have a particular material characteristic, as a particular macroscopic characteristic. And yet what we're really doing is we're tailoring, we're designing that material on a molecular level.

INTERVIEW: Dr. Roald Hoffmann cont.

DR. ROALD HOFFMANN (SYNC):
We see this gracefully curving triple helix. Now, this structure has not been made. What I see is that it's pretty, it's beautiful. And it also has some interesting properties. So, in a few months, we will publish something on this, and maybe someone will try to make it then.

Shots of insulin bottles on assembly line, insulin injection being drawn

NARRATOR (NAT SOUND under):
Beyond basic research, the synthesis of new molecules will sometimes have enormously beneficial applications. Increasingly, chemistry will enter the domain of medical science.

INTERVIEW: Dr. Bertram Fraser-Reid cont.

DR. BERTRAM FRASER-REID (SYNC):
The sophistication of drugs demands that we have a better and better understanding of biology, of biochemistry, how nature does things, because there is still so much to learn, and my goodness, the hardest thing that takes me years to do, nature does in a matter of seconds. The secrets there still have to be unraveled.

Chemist working in lab

NARRATOR:
Unlocking those secrets will assist in the rational design of drugs.

INTERVIEW: Dr. Michael Welch cont.

DR. MICHAEL WELCH (SYNC):
Monoclonal antibodies are molecules that are specific, again, to proteins in the body, particularly to, to sites on tumors, that if one can label these antibodies with radioisotopes, one can either see where the tumor is or ultimately, at a large amount of radioactivity, to, in fact, kill the tumor by radiation therapy. This is, in fact, called the "magic bullet" way of killing tumors. If one could get most of the isotope to the tumor, it will perhaps be the ideal way of destroying tumors. Instead of irradiating from the outside of the body, as one does in conventional radiation therapy, one would only radiate the tumor.

INTERVIEW: Richard Heckert cont.

RICHARD HECKERT (SYNC):
We've come to realize that drugs, obviously, need the right functional groups to attack the target in the body. They also have to fit the space available in attacking that target. The importance of shape, as well as functionality, is one that came to us fairly recently, I guess, not the last year, but within the last decade or so. (cont.)

RICHARD HECKERT cont:
The remarkable thing about the computer is that it will enable us to display in three dimensions, on a video tube, what our complicated molecule looks like, and it enables us to look at the pocket or target where we think a drug might be efficacious, if it were supplied there. And then we can examine different compounds that are potentially useful in the treatment of this disease, or attacking that target, to see if they fit. Now, fit isn't everything, but if it doesn't fit, you probably don't have a decent treatment, a good drug.

INTERVIEW: Dr. Jacqueline Barton cont.

DR. JACQUELINE BARTON (SYNC):
If we can understand the way those proteins work, we can understand the architecture associated with those proteins, then we can do things like, like design better drugs that target and recognize that architecture, and interact with them. And that's, that's really, in some respects, in my mind, the basis of new rational design of pharmaceuticals. That is, in developing any new pharmaceutical agent, what we have to do is either come up with a molecule that either recognizes the molecular architecture of a biopolymer or acts a monkey wrench, if you will, for interfering with the chemical reaction that occurs on that biopolymer.

INTERVIEW: Dr. Howard Schneiderman cont.

DR. HOWARD SCHNEIDERMAN (SYNC):
I think that it represents really the cutting edge of modern chemistry, trying to find mimics for peptides, mimics for proteins. No one has developed a very good technique for making a protein pill or a peptide pill. They get digested, proteins and peptides, in the stomach. It would be great if we could design a molecule that would do the same thing as insulin, but you wouldn't have to inject it, you could take it as a pill. People haven't found that molecule.

Cell research, microscopic close ups

NARRATOR (MUSIC under):
Chemistry may have an even greater effect on medical science and the host of other disciplines there is a revolution in biotechnology, genetic engineering.

INTERVIEW: Dr. Jacqueline Barton cont.

DR. JACQUELINE BARTON (SYNC): In some respects, you don't have to think about recombinant DNA technology, as Woody Allen's world in "Sleeper," with oversized bananas and tomatos. That's not what recombinant DNA technology is all about. What it is all about is our learning how to manipulate and change macromolecular structure and, in so doing, learn an awful lot more about that macromolecular structure and the chemistry that nature's been doing all the time.

INTERVIEW: Richard Heckert cont.

RICHARD HECKERT (SYNC): Biotechnology is of interest to us because it is an extension of good, plain old organic chemistry, a very complicated extension of it. I think at this time it's particularly intriguing because we are beginning to understand life processes at the molecular level. We really know what's going on, atom by atom, molecule by molecule. And at that point the organic chemist has a perfect right to be a player on the team.

INTERVIEW: Dr. Howard Schneiderman cont.

DR. HOWARD SCHNEIDERMAN (SYNC):
One of the really interesting questions is, what is the relationship between genetic engineering and chemistry, and I would argue that it's a very intimate relationship. It's manipulating molecules.

INTERVIEW: Dr. George Pimentel cont.

DR. GEORGE PIMENTEL (SYNC):
Chemists have a very important role to play in that particular area. That includes developments, using recombinant techniques, in the medical area. For example, hereditary diseases. It's going to be possible to understand which part of the gene is the part that's causing the problem, and do repair work on it. And perhaps thereby conquer the disease. Chemists will play a role in understanding just exactly what molecules are involved there.

INTERVIEW: Richard Heckert cont.

RICHARD HECKERT (SYNC):
In our early work with Interleukin 2, which we thought had potential promise as a cancer treatment, or at least as a pharmaceutical for related diseases, we were trying to isolate significant quantities of this material so that we could test it. It took us six months to isolate 10 milligrams from the conventional sources. Today, using recombinant DNA techniques, we can make that much in an afternoon, at one-thousandth of the total cost of the old process. So clearly, this is a very powerful tool.

Cells dividing under microscope

NARRATOR:
Biotechnology holds out the promise of engineering new molecules into cells of plants as well as of people.

INTERVIEW: Keith McKennon cont.

KEITH MC KENNON (SYNC):
Among the specialty chemical areas that many of us think have a lot of promise are agricultural chemicals. Again, the world population continues to increase. There are many mouths to feed, will be many more. (cont.)

KEITH MC KENNON cont:
Efficiency and effectiveness in agricultural production is something the whole world is trying to achieve. Agricultural chemical products I think will play a big role in doing it, both products as we think of them today and the new families of bioproducts which, I believe, will be part of the agricultural business of tomorrow.

INTERVIEW: Dr. George Pimentel cont.

DR. GEORGE PIMENTEL (SYNC):
One can see the potentiality for deliberate engineering of the gene that determines the characteristics of the crop, whatever it be, whether it be a food crop and you wish to enhance the amount of growth, or perhaps a food crop that's susceptible to a particular insect pest, or frost damage, or whatever, one has at least the potentiality of reaching into the genes that are involved in the reproduction of that particular plant, and engineering it to provide it protection or enhancement, whatever one wishes. That will involve some very sophisticated chemistry, biochemistry, and molecular biology.

INTERVIEW: Dr. Howard Schneiderman cont.

DR. HOWARD SCHNEIDERMAN (SYNC):
We can produce plants which are resistant to diseases for which there is no known chemical that you can use to give those plants resistance. What are such diseases? Viral diseases, viruses. There is nothing you can spray on a crop that will eliminate viruses. But we can genetically engineer tomatos, and a variety of other crops, so that they are resistant to not just one virus that normally attacks tomatos, a tomato mosaic virus. We can make those plants resistant to a whole string of viruses, a whole group of viruses. I think that, within the next five years, there will be commercially, in the marketplace, a whole series of crops that are resistant to viral attack.

Greenhouse shots, lab work, plastic bottles coming off assembly line

NARRATOR (MUSIC and NAT SOUND under):
Agricultural products, drugs, superconductors, structural materials, expanding avenues for 21st Century chemistry. But what of the polymers and plastics we so take for granted today?

INTERVIEW: Richard Heckert cont.

RICHARD HECKERT (SYNC):
I suspect we'll be still making ethylene and propylene and polyvinylchloride and all the traditional materials. The businesses that Du Pont is in today, I expect, at least all the good ones, I expect us to be in at the year 2000 and the year 2010.

Chemical reactions, laser disk, hazardous waste removal

NARRATOR (NAT SOUND under):
So chemists and the chemical industry will continue doing what they've always done, designing and producing new molecules that enrich the lives of us all. But, at the same time, they are assuming new responsibilities.

INTERVIEW: Richard Heckert cont.

RICHARD HECKERT (SYNC):
One of the most important challenges that the industry faces is to make its products for society without in any way degrading the environment. We have made some mistakes in the past. Most of those mistakes were unintentional, they were simply based on a lack of understanding. (cont.)

RICHARD HECKERT cont:
As we began to fully understand how persistent these by-products, even some products were in the environment, and recognized that some of them, at least, were probably undesirable and should not be there, we began a really a very broad effort to correct this problem. Our products are now being designed to be environmentally acceptable. Our waste streams are being minimized in every conceivable way. And this is a benefit to cost as well as to the environment. We are looking for new ways to recover small amounts of contaminates from drinking water and other parts of the environment that need cleaning up. In the long run, chemistry was gonna tidy up its own nest, and some day we'll win back that approval that we so much desire from the general public.

INTERVIEW: Dr. George Pimentel cont.

DR. GEORGE PIMENTEL (SYNC):
All of my colleagues in chemistry, my colleagues in biochemistry, molecular biology, they must devote more of their energy and learn to communicate with the public, not just the government, certainly including the government, but the public at large. And this is something that we have been reluctant to do. (cont.)

DR. GEORGE PIMENTEL cont:
Far too few of us have actually been willing to come out of the laboratory and take on this very difficult task. But we must do it, not in the interest of chemistry, but in the interest of society.

Chemist working in lab

NARRATOR (NAT SOUND under):
Chemists and chemistry, then, will play new roles in the decades ahead. The people who do the science and the people who direct the industry are confident in their reach.

INTERVIEW: Richard Heckert cont.

RICHARD HECKERT (SYNC):
Chemists are involved in everything. There is no limit. And that's finally recognized and everybody's having fun doing things they used to think were out of bounds.

INTERVIEW: Dr. Frank DiSalvo cont.

DR. FRANK DI SALVO (SYNC):
The number of compounds that could be made potentially out of this are practically countless. We now know of maybe 10 million compounds, but with only perhaps five elements, thinking of the ways we could combine them, we could potentially make 10 billion compounds. (cont.)

DR. FRANK DI SALVO cont:
So if we were to combine many, many, many elements from the periodic table, the number becomes absolutely enormous.

INTERVIEW: Dr. Roald Hoffmann cont.

DR. ROALD HOFFMANN (SYNC):
Look at what nature has done with the tetrahedral carbon atom. It's built up all of these molecules in life. There is an infinity of molecules based on the tetrahedral carbon atom that are still waiting to be made.

INTERVIEW: Keith McKennon cont.

KEITH MC KENNON (SYNC):
Right now, today, is the most exciting time that I've ever seen for chemistry and for the chemical industry. I think we have more opportunities, more exciting horizons, more contributions to make to humankind, and more capability to make those contributions than at any time in the thirty years or so that I've been part of this business, and I'm really looking forward to see how all that turns out.

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