Jesse H. Ausubel

The Liberation of the Environment

Di Renzo Dialogues in Science

The Dialogues: Science

The books of this series result from extensive discussions with the author, who, stimulated by our questions, similar to those which a reader might wish to pose, develops clearly the themes of his professional career.

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Jesse with his older brother Kenneth and his parents Anne and Herman aboard the passenger liner Queen Mary en route to England in 1955.

Note to readers of this English edition (13 April 2014): Setting aside translational matters, this edition differs by only about one hundred words from the Italian edition. In a few places I have added or subtracted phrases or sentences that may help either an Italian or English-language reader. The photograph above does not appear in the Italian version.

The "dialogue" might have mentioned scores more colleagues and friends by name for their crucial roles in the activities described, and in fact an early draft included many more names. Editorial action sharply reduced inclusion of names, as most of these, if unexplained, would only have bewildered an Italian reader. Apologies to those omitted. Thanks to Roman editor Maria Pia Felici and my long-time New York assistant Doris Manville.

My Roots

I was born in the year 1951 in New York City, at the peak of the American empire, and grew up in a time of enormous confidence in the United States. The fifties were a decade of prosperity and growth. The completion of the UN Headquarters made New York feel like the capital of the world. There was great excitement about the potential of technology and science. Many epic projects were underway, such as the interstate highway system, and in 1961 President Kennedy announced that before the end of the decade the US would land a man on the moon. It was the time of Polaroid cameras and American automobiles, the age of rockets. The general view was quite positive. There was little mention of unemployment. People had jobs and were buying cars and homes. Many young people at that time in the US felt confidence and optimism.

I come from a two-career family. My father was a professor of European history at Columbia University in New York. He taught courses about Europe from the Middle Ages to the 20^{th} century and researched 19^{th} century British history. My mother also had a long career, mostly in editing and education. My parents were faithful and devoted to one another's happiness and eager to raise children.

The family history I will tell has been confirmed by DNA tests. Several companies now offer to describe ancestry based on DNA. You swab the inside of your cheek, and you send the swab back to the company. They sequence the DNA, compare it against a library of tens of thousands of people that they have tested in different parts of the world, and send you maps with spots of various intensities for similarity. I did this a few years ago, and the result was amazing, several spots in Turkey, and very strong spots in central Italy. As will become clear, DNA verified a possible family Torah.

The culture from both sides of my family was European Jewish, although I had no religious training. My paternal grandfather came to America around 1900 from a village in Galicia, at that time a province of Austria, now southeastern Poland. My great grandfather did not emigrate and died of typhoid in Tatarstan in 1918. The family was lower middle class. They earned their living in small trade and crafts such as tailoring. The family village was not far from Kraców and Auschwitz. Had they not immigrated to America, the end would have been clear. My grandfather worked as a motorman for the New York City subway and remained securely employed even through the Great Depression.

My father, Herman, was born in 1920 just after World War I, one of eight children, and was the result of the great influenza pandemic of 1918 which killed at least 50 million people. My grandfather's first wife died in the pandemic. Afterwards he remarried, my grandmother, a nice example of how world history infringes on individual lives.

My father grew up in Brooklyn and was an exceptional student. He graduated first in his class from a large public high school and went to Brooklyn College and again graduated first in his class, in 1940. He then became a graduate student in history at Columbia University. When America entered World War II, he immediately enlisted in the Army, served uneventfully, and resumed his education at the end of the war. He spent the rest of his career at Columbia as a professor. He died at the early age of 56 from cancer. He was raised in an apartment that was a thick cloud of cigarette smoke and was a heavy smoker himself from his teenage years.

A scholarly relative of my father traced our ancestors back to Asia Minor. For many centuries the Ausubels (or Azubels) seem to have been pharmacists in Smyrna, now Izmir. They moved north as part of the Ottoman expansion. Jews under Turkish rule were able to travel quite freely within the Ottoman Empire. The migration probably happened in the 17th century. When the Ottomans were defeated and retracted, the Jewish families stayed behind, spread further north, and Germanized the family names.

When family members immigrated to America beginning in the 1890's, they were extremely grateful. My family on both sides had a tremendously positive feeling about America. This was communicated to me when growing up in the 1950's. There was the shadow of what would have happened, and what, in fact, did happen. There were memories of cruelty at the hands of the Cossacks towards the Jewish villages. There was the experience of being drafted into an army for something they felt had no purpose. The communities in that area, back then Austria-Hungary, and neighboring the German and Russian empires, today areas of Poland, Romania, Ukraine, and Belarus, lived a relatively good life while the Austro-Hungarian Empire was strong, but as it weakened in the late 19th century, the situation became more and more difficult. Many people chose to leave.

By the time my memories begin in the 1950s, most family members were quite successful in business, not multi-millionaires, but in the sense that they made a living, their children made a living, they owned houses in the suburbs, they owned cars and they had their Polaroid cameras. Compared to the memories of Eastern Europe of my grandmothers and grandfathers, my youthful memories are very positive.

My father's mother used to make fun of my brother and me because we always liked having animals in our apartment in Manhattan. We had a cat, hamsters, and turtles, and my grandmother would visit us and she would joke or sometimes criticize my parents. She would say: "We left villages behind where the animals ran in and out of the houses, and here you live in an apartment building in the city and have these children who bring cats and mice inside! We wanted to leave a peasant life behind!"

My mother's family came from a more prosperous background with Italian roots on her mother's side. My maternal grandmother, whose maiden name was Kawaller, grew up in Cernowitz, then Austria-Hungary, now Ukraine. The family was originally named Cavalieri and in the textile business, perhaps silk, in Ferrara and Venice. They may have been in Ferrara a long time, but some members may have come from Spain in the time of the Inquisition. In the late 18th century a Davide Cavalieri moved to Udine, and had an inn and a lumber business, importing wood from the Carpathian Mountains and selling it in the Veneto. In the Napoleonic period two of his sons moved to Transylvania in Austria-Hungary, probably to be closer to the wood supply, and Germanized their name.

We know this history because the brothers reportedly took with them a Torah, a scroll of the first five books of the Hebrew bible, and it descended to one of their grandsons, Abramo, who had moved a little further north into the Bucovina. Although Abramo, my grandmother's uncle, died in 1939, the Torah was saved during the Nazi period in an orthodox monastery, and was recovered a few years ago through a maze of book dealers and the Internet by a cousin of my mother who lives in America. The Torah, if not a forgery (and there is a market in such items) is early 18th century Italian with many generations of names inscribed it.

In 2009 my niece visited the town where my great grandfather lived and died. The gravestone still stands. The family lived in the Austro-Hungarian Empire for more than a hundred years, and culturally they were Central European. My mother's older brother and sister, born before World War I, went to the German-language Gymnasium and learned to play the cello and violin.

My maternal grandfather, Philip Weisinger, lived to be 96, so I knew him well. He was a plain soldier in the Austro-Hungarian army in World War I, first on the Russian front, and then in 1917 he was transferred to the Italian front. He was in the famous battles in Slovenia and Friuli, Monte San Gabriele and others. He used to describe the fear of the poison gas, the trenches, the mystery of what the generals were thinking. In a battle in the autumn of 1917 he had the strange good fortune to be taken prisoner of war by the Italian army and sent to Sardinia, to Asinara, where there is now a high security prison and also a Club Med luxury resort I believe. He was there for 2 full years, from 1917 until after the Treaty of Versailles in 1919, and they were two of the happiest years of his life. He used to say: "You can't imagine the change after three years of fighting with rags wrapped around your feet on the Russian front and then on the Isonzo, not enough food to eat, fighting over nothing. People in Sardinia had no idea that there was a war taking place on the mainland, they had no anger towards the foreigners. The people were warm, the sun was warm."

He didn't want to leave and only reluctantly returned in October of 1919 to what had become Romania. My mother was born 9 months later, but my grandmother never forgave him as he could have returned months earlier but he was in no hurry. He learned some Sardinian Italian.

My mother came to the United States in 1926 at the last moment before a restriction of immigration laws would have prevented entry. Had the family waited longer, they might have emigrated to Australia or Israel or more likely remained in Europe, as some of my mother's cousins did. My grandfather always had Italian friends and had a pro-Italian view of the world from his experience. He also always remained nostalgic for Emperor Franz Josef.

Like my father, my mother grew up in Brooklyn during the Great Depression. She was also a bright student and excelled in school. My mother started working when she was 17 and worked until she was 75, except for a few years when my brother and I were very young. Now 93 and still in good health, she is a person who has always made productive use of time.

Both sides of my family were extremely patriotic, not in a way many people think of patriotism nowadays, not chanting "USA" at the Olympics, but in the sense that they were extremely grateful to America. The safety that my mother and father and their brothers and sisters and cousins experienced in America was very striking to them. Some of them served in the US Army in World War II or Korea. There was this enormous feeling of gratitude to the US for having created spaces of physical and cultural safety, and of course also opportunities.

Both my parents were intellectuals. Notwithstanding the generation gap, my own life is very close to the life of my parents. They read the *New York Times*, and lots of books and magazines that I read, like *The New Yorker* and *The New York Review of Books*. Neither of them had much interest in science or engineering, but they were very interested in history, literature, films, theatre and music. They liked to travel.

The gap between my life and the life of all four of my grandparents was enormous in terms of cultural experience and technology. They were uprooted in a violent Europe, wanted to forget most of the world they left behind, and religiously observant. They took work to put dinner on the table and saw the arrival of electricity, telephones, and cars but never felt them as essential. In contrast, my own life was very comparable to that of my parents, who grew up modern with films and radio, chose most of their work, and lived most of their lives around universities, in a secular world of ideas. They took an interest in the world as a whole, not environmentally, but certainly culturally and politically. I was fortunate, however, to mature not during a depression but during a boom.

My Childhood

As a boy I loved arithmetic and especially statistics associated with sports. I am still a big sports fan, and I still love numbers. Early exposure to numbers came through studying all the statistics of baseball, football and basketball players. I also loved large jigsaw puzzles, maps, atlases, globes, and almanacs.

Although I later went to a traditional school, the first school I attended, from the age of 5 to 10, was an experimental school run by Columbia University. It was a laboratory school and no longer exists, but it was a wonderful school, within walking distance of our apartment. I think it was the best school I ever attended.

The students were all experimental subjects. We were like rats in the laboratory. There is a famous concept in psychology, the Hawthorne effect, that if you are studied, you might do better simply because you feel special as a subject. I suspect the school benefitted from such an effect. We were given lots of different curricula, for example, one in which music was very important. We used early “teaching machines”, which were computers that looked like slot machines in a casino. We were subjected to many learning experiments. Most students enjoyed the variety, we felt that we were special and engaged cheerfully in the experiments, although most of them probably had little impact on what actually stayed inside our heads.

The school was quite flexible, in that the students were usually allowed to learn as fast as they could. I was a quick learner, so I was able to advance rapidly in subjects like arithmetic and reading, which I enjoyed. By the time I finished fourth grade, by the age of 10, I was really advanced.

I then transferred to a famous and very traditional school, all boys, the Collegiate School, affiliated with the Dutch Reform Church and founded by the Dutch West India Company in 1638, when New York was New Amsterdam. The school operated very much on a traditional European model. For me the social change was dramatic, because in the experimental school I had attended students could speak to the teachers in a friendly way and rules about behavior in class were relaxed. Collegiate had much stricter rules about dress and behavior, but I arrived from my liberal school a full year ahead of my new classmates in most subjects.

I attended the school for 8 years, taking the #1 Broadway Local subway, and from my point of view the school was easy, too easy. There was a completely predictable curriculum, and you would know from the first day of school what you would be doing from September through May. Education was based almost entirely on text books, and you knew that each week you would do this chapter and then the next. Academically, I rarely found challenges. I could sometimes finish the learning weeks or even months in advance.

Though I received top marks in school, I was not an obedient student, so from time to time a teacher would call my parents about my behavior. One December during our Christmas service in the school's church I wore a necktie with battery-powered Christmas lights. The school officials were not amused. If I was bored, as quite often, I would sit in the back row of the class and not pay attention. And I criticized teachers. School was from Monday to Friday but when a student misbehaved during the week he would have to come to school and sit at a desk with hands folded for three hours on Saturday mornings. I received some Saturday detentions for rebellion in the classroom.

Like most long-lived institutions, Collegiate was very sensitive to social status. Children in the school came from famous families including the Rockefellers and the Kennedys. Another school parent was the actress Lauren Bacall, whose films my parents loved. I would guess that one-third of the students were enrolled because of the social standing of their families, one-third were admitted because they tested well on the admission test (I belonged to that group), and one-third were there for social balance.

I give the school a lot of credit for what is now called diversity. In 1964 my family could see Harlem burning from our living room window. Starting already in the early 1960s the school sought Afro-American and Hispanic students, including from poor families and poor neighborhoods. The white kids benefited enormously from the presence of the black and Hispanic kids, who had knowledge of the City and life that we could never access.

Of course, the school still wanted mainly to turn out students who would become bankers or business executives, like the successful parents. They wanted the children to have good social manners, and to have a "classical" education. The curriculum was very traditional, with French beginning in 5th grade, age 10, and Latin (which I especially liked) in 6th grade, age 11. In these areas the school was strong, but at that time it was not very involved in science and mathematics. Those were subjects that you took seriously only if you wanted to become a physician. I think science was, for the most part, foreign to most of the influential faculty and administrators, and the idea that you might become an engineer somehow suggested a lack of social status.

Each class was small. About 35 students graduated each year. In my class there was always a small group of 4 or 5 who were interested in math and science, and we tended to form our own voluntary groups. We engaged in projects of our own, and I was always part of a small group of close friends. We would read magazines like *Popular Science* or *Popular Mechanics* and undertake projects, some of which we would enter in the science fairs and competitions that the city or the region would organize.

Sometimes, we did well. In sixth grade we won the third prize in a regional science fair by building a big ear, a parabolic reflector one meter in diameter made of cloth and resin with a microphone at the focal point. Where the dish pointed, you could hear a conversation a hundred meters away. Later we learned on our own how to read electronics diagrams and how to build radios and also to dissect small animals.

In high school, we built a laser - actually just 2-3 years after the laser was invented - a one thousand volt ruby laser. We did some of the work on the machine in one of the science classrooms of the school - it's too much to call it a laboratory - and we were extremely excited about our progress. We were able to use the laser to pop red balloons. It was a great achievement, and we called one of the teachers to show our success. After a few days we were required to remove the laser from the school because the head of the upper school feared that we would use it to blind other students. This correctly gives the idea that we were both a bit rebellious and that the school did not know what to do with children who were interested in math and science.

There were a couple of science teachers, one in chemistry and one in physics, who were confident and friendly and current but they did not stay long at the school, while the English, Latin, and history teachers stayed decades. Often the young teachers were at the school because a recent college graduate could avoid the military draft (and service in Vietnam) by teaching until age 26, when you were no longer eligible for the draft.

Since my graduation in 1969 there have been changes not only in Collegiate but in many schools in the US. There is much more the idea that science and math generate wealth for society and that it is important to encourage familiarity and enthusiasm for science in many children. New York City has always had several outstanding specialized science schools. My parents might have sent me to one of those schools but they didn't. If they had, I would have had a very different experience as a teenager, with more hours of homework and less time playing with my most valued possession, a reel-to-reel tape recorder, with which I recorded a range of noises and creative efforts as well as many hundreds of popular songs. It would be hard to exaggerate the role popular music played in our lives.

I think most children in the 1960's who went to regular schools, even respected ones like mine, experienced a lack of science. If you like science, either you were segregated in a special track or, if you were in the regular school, it was ok provided that you were interested also in literature, history, sports and all those things the school was encouraging. There was this confusion, which I think still exists in many societies including America, on the social place of science and engineering.

New York was a city in which certain economic sectors, such as publishing and finance, had high social status, and at that time the parents of many students were engaged in one way or another in cultural industries, financial services, or management of corporations that had headquarters in New York. But if you said you were interested in chemistry or geology, well, maybe people knew what geology meant if you lived in Texas, but in New York City it did not make sense. The school showed this confusion.

Moreover, by the late 60's there was another big divide in American society, where you had the military-industrial complex and the huge sector of technology that was directed towards strengthening the machinery of war. Many young people objected to the Vietnam War and the activities necessary for it. And then along came environmental problems such as smog that were a side-effect of technology. Meanwhile, LSD and other popular hallucinogenic drugs were being manufactured in garages. One evening in July 1969 a lot of young people went to Central Park high on drugs wearing anti-war buttons to watch the landing on the Moon. It is not surprising parents and schools were confused about how to mix science and young people.

At the end of high school, I applied to university and was accepted at Harvard. Actually I made applications to only two universities - Harvard and Yale - and was accepted to both. In retrospect it was quite arrogant, because they were the two most selective universities. Many people apply to 5 or more universities, but somehow I felt that I would do fine.

Because my father was a professor, the family would go away for the entire summer. His teaching was seasonal from September through May. He would complete his teaching and his grading of examinations at Columbia, then he would be free during June, July and August, to do research, to read and to write. My mother usually had jobs in editing or educational administration, usually not full-time. Her work also allowed her to take off the summers or do some work by mail. If she was helping edit a manuscript, then she could do it by mail wherever she was. If she was working in a school, then the school would also have a break in the summer.

We went many summers to a beautiful island off Cape Cod, Massachusetts, the island of Martha's Vineyard, a famous place now, much less famous then. It's an island of about 200 square kilometers, 45 minutes by ferryboat from a town on the mainland called Woods Hole, one of the great centers of ocean science in the entire world. The sea is beautiful and full of possibility, and my older brother Kenny and I would arrive in early June, and my parents would give us bicycles, fishing rods, and nets and say: "See you at the end of August."

We were left to devise our own entertainment during the summer. My father was very much a scholar by temperament and had no interest in gardening, fishing, tennis, or any such activity. He loved being in the country but he would use the quiet just to study and think, while my mother read a great deal. So my brother and I were left to our own inventions, and both of us were very keen on all outdoor activities, swimming, fishing, clamming, crabbing, cycling and playing softball and other sports. We would spend day after day on the beach, in the ocean, in the coastal ponds, in the creeks, and learn to do things on our own. There were also some older boys around who would pass along the secrets of how to do things. A very good time to go fishing is at sunrise, so we would get up at 4:30 or 5 o'clock in the summer, before sunrise and go off by ourselves on our bicycles, carrying huge fishing rods, and buckets on the handlebars and doing things that weren't very safe, but our parents didn't know.

The summers on Martha's Vineyard had a big influence on me. Most young people imprint the idea of nature at a particular age. I think it's usually when you are between 4 and 7, when you have some particular experiences. It could be mountains, a river, a lake, prairie, a farm or ranch, the desert. For me nature became synonymous with the sea from an early age. Whenever I heard the word nature, I would think of the ocean and the shore environment, tidal pools, lagoons and beaches. When I think of life, I wouldn't think of goats and chickens, I would think of fish and sea stars. Standing so many hours as a young boy at the edge of the ocean was a very strong deep influence. I was always fascinated by the ocean.

Like most people, I think that as you look at the ocean there is always this immense question of what's under the surface. As a boy I wished I were like Superman and had x-ray vision. Even though we were notably successful in catching fish, clams, and crabs, I was never really that interested in actually capturing them. My older brother was. I was extremely interested in simply knowing what was there, solving the mystery of the opacity of the ocean.

Since my father was a professor of European history every few years we would travel to Europe. There he would search in libraries or the attics of country houses for letters or manuscripts written centuries ago that might illuminate his studies. Thus I had the unusual experience for a person of my generation of making many transatlantic crossings on British and Dutch and later Italian ships. I made five round-trip crossings of the Atlantic while I was still quite young and I loved them. In my 30s I crossed again a couple of times on the last regularly scheduled passenger liner, the SS Stefan Batory of Polish Ocean Lines, which sailed between Montreal and Gdansk. I have no happier memories than the weeks on the North Atlantic. I sailed on the "Raffaello", the "Colombo", the "Leonardo", on the original "Queen Mary" and "Queen Elisabeth". I loved being at sea and watching the ocean. The crossings had a big impact.

By the time I was 18 going off to university, I had a disposition in favor of math and science, for nature and the oceans, and an ambivalent view of science and technology spanning the happy heritage of ocean liners, tape recorders, and the "great big beautiful world of tomorrow" promoted by the 1964-1965 New York World's Fair, and B-52 airplanes bombing Vietnam. I went off to Harvard in September of 1969 in an optimistic but somewhat divided state of mind.

University Years

At the close of the decade the conflicts around the world, especially in Vietnam and usually associated with the Cold War with the Soviet Union, were casting shadows on the positive picture of my earliest childhood. By the early 1960's, the positive picture had already begun to turn into a more balanced view of the powers of good and evil and the neutrality of science, as in the 1964 movie of Stanley Kubrick, *Dr. Strangelove*. The 60's saw the growth of a counter-culture, an alternative culture, and when I was in high school I was very much part of that.

In August 1969, a month before starting university, I went with 500,000 other people to the famous rock music festival named for the town of Woodstock. I had long hair, I attended dozens of concerts of popular rock 'n' roll bands of the time - the Jefferson Airplane, the Rolling Stones, Grateful Dead – and saw Janis Joplin and Jimi Hendrix perform during their brief careers. The so called 'generation gap' grew between my parents, curious but also obedient, and the more rebellious, more confident new generation to which I and my older brother belonged.

It was partly a rebound against a planned purposeless prosperity. There were suburbs, electric toothbrushes, air conditioners, any number of things, but for what? This question led to a movement back to nature and attracted to less material values. Certainly, some of the interests that I have pursued in my career in relation to the human and natural environment come from the struggles or the debates of the late 1960's. What constitutes a good life? To what extent do all the comforts of modern technology bring safety? Can humanity tread lightly on the land?

By the time I started university in 1969 there were angry debates along the spectrum of views. Science and technology were frequently associated with the established power, the military establishment or the space program. Grassroots movements in science and technology (like Wikipedia) were then hard to imagine. By the 1970s, people became more concerned about the environment fallout. The first books popular in the environmental movement were about pollution, often exemplified by pesticides. My earliest "green" memory is from 1959, when we became worried about weed killer in the cranberry jelly Americans eat with turkey for the November harvest holiday.

When my high school friends hear of what I do today, 45 years later, they think that it's continuous with my early life, and normal that I have a career in science and work on the subjects I do. But many of my college friends are shocked because during the four years I spent at Harvard College, especially the first three, I didn't do much related to science and technology and I wasn't academically oriented in general.

The 60's and the early 70's were times of cultural excitement and Harvard College is still famously flexible for what students do. It is very hard to be admitted into the college but once you are, it is almost impossible to fail. I got good grades and did fine. But I didn't approach college with a vocational orientation at all. I took some science courses, for example in biology and computer science, but I also took courses in the literature of Scandinavia, Mexican history, and ancient Greek. I was self-indulgent. Whatever seemed interesting to me I pursued, so I didn't graduate with a concentration in any particular discipline. Harvard is very relaxed this way, and I did what interested me at the moment.

I had a wonderful time. First, I made many friends. Still today many of my closest friends are people whom I got to know in my college years. Harvard also has lots of opportunities for extra-curricular, non-academic activities. I spent a lot of time involved in drama and other activities.

In retrospect, I would distinguish drama as particularly important. I had a tremendously talented friend, an astronomy student named Joe Timko. The two of us wrote and produced plays together. We even completed a full-length musical melodrama about global cooling, before anyone was interested in global cooling or global warming. The hero of the play is a charming and fiendish genius named Fu Manchu, borrowed from English fiction of the early 20th century. In our musical, Fu installed a giant air cooling unit inside Big Ben in London to lower the temperature of the British Isles. Fu waits for the Thames River to freeze so that an army of abominable snowmen (yetis), who have floated on icebergs all the way from Tibet to the mouth of Thames, could march up the frozen river and take over the British government. They almost succeed but then the air cooling unit fails. The yeti did a dance routine.

I had a rewarding time writing plays like that. It was fun and we learned a lot about our subjects, which could be serious. We wrote a short play called "The Best Picture", a mystery about the murder in the 1930s of a member of the Vienna Circle of philosophers, Moritz Schlick, the founder of logical positivism. I played Schlick, who was murdered on the steps of the University of Vienna by a former student. Schlick was having an affair with a young woman, also a student, in whom the angry student was also interested. The murderer claimed that Schlick's philosophy caused him to lose restraint. In our play, which was later performed in Edinburgh, Detroit, and New York as well as at Harvard, the murder is investigated in parallel by Sigmund Freud and Ludwig Wittgenstein. Neither the psychiatrist nor the philosopher alone has sufficient method to understand the murderer. We wrote the play in 1972, and it now reminds me of British dramatist Tom Stoppard, who was just becoming popular at that time.

I was very much interested in Wittgenstein and logical positivism and some other parts of philosophy. For me Harvard's permissiveness was good. The creative work I did wasn't much in the courses, but in writing murder mysteries, musicals, and other informal activities.

We also wrote some songs, not only for musicals. One song, which I recently posted on our website, can be called the first certified organic love song: "Whole Wheat Woman". It was an American blues song and the refrain was "You're my whole wheat woman and you know I live by bread alone". It had some clever stanzas: "I once had some French bread, but she was just a lot of pain, give me back my whole wheat woman, and I'll never go against the grain". We thought we might become rich by writing these funny songs but of course we didn't.

I grew in all directions and I learned how to learn. I learned how to write academic papers as well as stories and plays. I got some confidence that I could create something original. I learned how to perform and to organize events. I was not a talented actor but I enjoyed theatre and did enough to become a comfortable public speaker.

When I got my first job a few years later in 1977, one of my tasks was to organize and produce the first United Nations World Climate Conference. It was like producing a play. There had to be a script, there had to be programs, there had to be lighting, the curtain would rise and everything had to be ready. I wouldn't have learned that only by doing experiments in a genetics course. I found myself qualified to organize a complicated international meeting.

I feel that the spray of courses I did as an undergraduate student was fine. Now when I speak to young people, I say there is too much emphasis, too early, on specialization. Most people live a long time now, people often don't get their first real jobs until they are 26 or 27 or even older, so you don't need to study at age 20 something obviously professional. Obviously acquiring tools like calculus, statistics, computer programming, or foreign languages is essential, but you also need to learn how the world works, and rehearse some roles. Like young cats or dogs, young people learn by play. It is valuable to work on a school radio station, newspaper, web site or drama society. These are activities for which American universities are very good and European universities tend to be less supportive. Later in your mid 20's you can always acquire the narrow expertise a particular kind of work may require.

Near the end of my time at Harvard I began to realize what I wanted to do for a career. One night in my fourth year while I should have been doing course assignments, I read long excerpts from the book *Super Ship* by Noel Mostert serialized in in the *New Yorker* magazine. It was a book about immense oil tankers transporting massive amount of oil around the oceans. This was just after the 1973 "oil crisis" and a time of frequent oil spills. The technology of tankers and the system of tankers was not well-developed. I could not go back in my university career and change it, but at the end of reading *Super Ship* I said to myself: "This mix of science, technology and nature really interests me. These are the kinds of problems I would like to work on."

At the end of university, I spent about two years living, I would say "growing", in Europe. I saved a little money from summer jobs and working during the year. With my little bit of cash I took a student fare on Italian Line, which used to have a $125 dollar transatlantic fare from New York to Italy if there were unfilled berths on the ships. You had to wait until a week before embarkation to know whether a berth was available, but it always worked out for me. Once on board you were treated like the passengers who paid much more for the 8-10 day crossing, which might include a stop in Lisbon or Casablanca or Mallorca.

When I reached Italy I met a friend, an American woman living in Florence, and partly owing to her encouragement and a lively social scene to which she introduced me, I ended up staying about six months. My parents helped, and I got whatever odd jobs I could to stay. Then I went off to Paris and, having friends there, I lived in the same way. I also read many books which I hadn't read in college, but that I had wanted to read. I attended a brilliant series of lectures at the College de France by Michel Foucault, who had the wonderful title of Professor of the History of Systems of Thought. The lectures were about prisons and schools, and became part of the book *Discipline and Punish*. I still have my notes. A little later I came back to Italy and lived in Rome for a while in Via del Tempio, a result of a humorous situation.

One evening I went out to dinner with some Italian friends, and I said to them that I needed a place to live. One of them replied that a friend of his had just gone off to make a movie in the Far East, and he was taking care of her large apartment. Her name was Nikki Arrighi, an actress who had some small parts in some good films such as "Sunday Bloody Sunday." Because of lots of calls to the Far East before she left, a huge telephone bill had just arrived which my friend did not have cash to pay. If I paid the phone bill I could have a room for a while in the apartment, a stupendous beautiful rooftop apartment overlooking the Tiber. I paid the phone bill and stayed for a few months. I never did meet Nikki but did become close with Vivian Pirzio-Biroli and her many friends and family. Vivian, who would die quite young from breast cancer, had as great a gift for social life as anyone I have ever known. To make a living, I picked up a little work doing translations. A few years later I made the first translation from Italian into English of the diaries of Vivian's mother, Fey von Hassell, which became a bestseller in Italy as "Storia incredibile: Dai diari di una prigioniera speciale delle SS" and in the United Kingdom as "A Mother's War." Fey's father served as the German ambassador to Rome during the 1930s and was later executed for his participation in the 1944 plot to kill Hitler.

The two years in Europe turned out to be extremely beneficial because at the end of that period my Italian and French were both quite good. Now 40 years later they have deteriorated. Learning Italian was valuable because a few years later it turned out that the single most important intellectual mentor in my career was Italian, a Tuscan named Cesare Marchetti. Learning my way around continental Europe and having more language skills turned out to be valuable not only in the relationship with Marchetti but also with French colleagues, as I will later relate.

Even though English is the language of science, people naturally prefer to relax in their own language. I almost always speak in English, but when I'm with French or Italian or German friends, the fact that we can understand each other in our own respective languages makes a big difference. Sometimes you want to send emails in your own language, you just don't want to write in English. To strengthen a relationship, you don't have to be fluent but have good enough comprehension to broaden and relax communication.

By the end of the two years it was clear to me that I was interested in world energy, food, and water and all these kind of issues, so I went back to the US, to New York, from which I had been away for 6 years. I got an apartment in exchange for serving as the superintendent of the building (a small building with 10 apartments), and did 6 semesters of graduate school at Columbia, taking mostly technical courses in statistics, operations research, microeconomics, almost an engineering orientation and got two master degrees. I worked as a research assistant on a project examining competing uses of the oceans. I also started a lifelong pastime to walk or bicycle down every street within New York City.

I thought I would get a doctorate doing either operations research or something to do with resources but during this time my father was dying of cancer and so the last 6 months I went back and forth frequently to the hospital or to help my mother take care of him in the apartment near Columbia where I had lived as a teenager. After my father passed away, I didn't feel like beginning another semester of school, so I applied for a fellowship to go to Washington DC for a year, encouraged by a college friend who anticipated a good match. The fellowship program was supported by a private American philanthropic foundation, the Alfred P. Sloan Foundation, which would become central in my career. A business executive made wealthy by far-sighted management of the General Motors Corporation, Sloan established the foundation in 1934 to foster science and engineering careers. The fellowship was designed for people who already had their PhD's, but I applied anyway and to my surprise I was quickly accepted.

In my application I proposed to work at the US National Academy of Sciences in Washington, DC, and suggested working on problems of marine pollution and petroleum in the marine environment. The Academy had produced a series of reports about oil spills that I had used in my work in graduate school on conflicting uses of the oceans and which I thought were very interesting. I was not expecting climate change.

The US National Academy of Science and the First United Nations World Climate Conference

I moved to Washington in October 1977, and when I arrived two people became my mentors in a way that teachers in high school and college had not been. The first was Robert M. White, a meteorologist who was just completing 14 years in the US government, as director of the National Weather Service and then as chief of its parent agency, the National Oceanic and Atmospheric Administration, which included the National Marine Fisheries Service and other environmental units. A man with an extraordinary ability to maximize the independence of science from politics and a huge capacity for work, White had recently agreed, along with a Soviet glaciologist, to chair what would become the first United Nations World Climate Conference.

This was a period in which it was unclear whether the world was warming or cooling, but in any case there had been some troublesome fluctuations. From about 1940 to the early 1970s global average surface air temperature had dropped. Experts worried that nuclear bomb tests in the atmosphere had caused cooling and that emissions or trails from supersonic aircraft would cause more. In the early 1970's there were prominent concerns about poor harvests in the Soviet Union possibly associated with long-term cooling. The Soviet Union purchased a lot of grain from the US and Canada, and there were great debates under President Nixon: Should America sell food to its enemy, the Soviet Union?

The Soviets were considering plans to dam some north-flowing rivers in Siberia and divert them south towards central Asia to create new lands for agriculture. Some experts worried that such a diversion would raise the salinity of the Arctic Ocean, lower the freezing point of its seawater, and thus change the polar and even global climate. Meanwhile, prolonged drought in the African Sahel, the southern edge of the Sahara desert, had harmed life in that region. Some experts associated the drought with cooling and even worried about the dawn of a new ice age.

Other experts, led by a geologist and oceanographer named Roger Revelle, my second mentor at the Academy of Sciences, argued that the dominant trend would be towards warming, because of human additions of greenhouse gases to the atmosphere. The gases came from burning coal, and also oil, natural gas (methane), and deforestation. The USA emitted far the most.

The future climate was a wide open question at the time, and controversially interesting. When I arrived, I declared to White my interest in oil spills. He asked me if I had ever thought about climate. I told him that I had thought about it only in a musical comedy. White said: "Well, you have two years because the fellowship is renewable after a year, and that is a lot of time for a young person to learn." He gave me published and unpublished reports to read, and sent me away to study. Within a few weeks, I appreciated that climate variability and change were very interesting and, what's more, few people were working on them. When I returned with wide eyes, White asked me to help him and others to organize the World Climate Conference and start a World Climate Program. White led the organizational and political aspects. Revelle concentrated on developing understanding of possible global warming induced by human activities.

I became one of literally a handful of people in the world at that time paid to work full-time on climate change. Now there are probably twenty-five thousand. My friends used to make fun of me because people didn't regard climate as a serious subject. Environment in general was only beginning to be a respectable subject. Universities did not have programs in environmental sciences, but in geology or ecology or other specific disciplines. Governments were just starting to operate ministries of environment. The idea that there was this thing called environment, which was a mixture of meteorology, oceanography, ecology, engineering, geography, economics and law, was just beginning.

The reputation of studies of climate in particular was shifting. Climatology was looked upon as a 19th century activity, a kind of accountancy belonging to the novels of Charles Dickens, scrutinizing columns of numbers to see which day averaged the highest amount of sunlight or least rain. Of course, such statistical aspects are very important, but the idea that one could do sophisticated mathematical modeling, that one could simulate Earth's climate over centuries and through ice ages – or nuclear wars - all this was just gaining respectability.

For the next six years I was immersed in understanding climate. The first United Nations World Climate Conference was conducted successfully in February 1979 in Geneva. It created the UN World Climate Program. It greatly elevated climate change on the agendas of many countries and international organizations. The conference also allowed me to extend my knowledge to much more of the world. I had numerous contacts with Western Europe, in my childhood because of my father and later because of my student wanderings. I had been involved with England, France, and Italy, but I had little contact with the rest of the world except Mexico, where I had spent two summers while in college.

It was a time of intense Cold War, so you had the Americans and the Soviets on the top, and the conference exposed me to the Soviet Union and their allies in Eastern Europe. And Africa, about which all the academic experts worried then as now. Not yet China, because China was not active internationally in 1979.

I had very good experiences with Soviet scientists in organizing and conducting the conference. As many people know, the life of the mind was extremely strong in the Soviet Union, science and the life of the mind in general were escapes from the poor material conditions and ugly politics. Many of the most talented people escaped into science, and scientists were treated quite well by the Soviet regime, given reasonable jobs and privileges.

The conference exemplified successful cooperation during the Cold War, but it was not isolated. After my experience at the National Academy, I had another opportunity at the International Institute for Applied Systems Analysis, which includes a spy story.

A bridge over the Cold War: The International Institute for Applied Systems Analysis

In 1972 the US Academy of Sciences and the Soviet Academy of Sciences, with symmetrical support from the UK, Poland, and a few other nations West and East, had jointly established a new think-tank near Vienna, Austria - the International Institute for Applied Systems Analysis - to work on common problems of industrialized societies. Back in 1967 at a Summit when Lyndon Johnson and Alexei Kosygin were the heads of state, they felt that even amidst the Vietnam war there should be some bridge between people, to speed work on air and water pollution and other common problems of industrialized societies, and perhaps to create some alternate, unofficial channels of communication. Five years later IIASA opened in the neutral nation of Austria, for whose Kaiser my grandfather had fought.

I stayed a second year at the National Academy when I was offered an extension of the Sloan fellowship, and then thought I would return to graduate school to complete a doctorate, but the Institute near Vienna invited me to go there. The Academy was encouraging young Americans to experience IIASA. Initially I had planned to stay for three months, but I remained for almost 2 and a half years, June 1979 to autumn of 1981. IIASA was an extremely important period in my career: while the Academy period established my interest in climate and environment, it was at IIASA that I met the people who would in a profound sense determine my world view, foremost Cesare Marchetti.

The Institute had about 100 scientific staff members, of whom about 20 were Americans and 20 Russians, and about 60 came from Italy, France, Poland, Bulgaria, East and West Germany, Hungary, Japan and a few other nations. Energy was the subject of one department, of which Marchetti was a member. I was a member of the Resources and Environment department, led by a Russian named Oleg Vasiliev, an expert on the flow of the great Siberian rivers. Vasiliev was one of the Russian experts who had argued against the schemes to reverse the flow of the Siberian rivers. He was my boss. Naturally, and especially being 27-28 years old, it was an incredible experience for me as an American to work with a Soviet, and not only a Soviet but a very intelligent man and fine person.

The Institute was designed in part to share new ideas. If new methods came along in numerical modeling of lakes or population forecasting or new ideas in risk management or how to schedule ambulances to pick up injured people, these were quickly shared. It was a think-tank: there were some computers but there were no laboratories, no real engineering or experimental science went on.

Although I was young, six months after I arrived I was put in charge of what was called the climate task because, after all, no one in the world knew about it either. I was free to organize studies and other activities about climate. We did some innovative work. We pioneered, for example, the use of interactive gaming in which we looked at the carbon dioxide emission of each country as part of a multi-player game. We built computer games and board games to gain insight into behavior that would occur under different circumstances. More than three decades ago, in 1981, we invented the idea of trading of carbon emissions and published the first paper about it.

The energy department where Marchetti worked was producing one of the first comprehensive, long-range studies of global energy supply and demand. I was enormously impressed by his problem-solving abilities. I have met many brilliant people, including dozens who have won Nobel prizes, but Marchetti is the only one who I am sure is a genius. He has an extraordinary ability to discern forms and patterns, to understand cause and effect, to describe exactly and objectively what he sees, and to remain silent about what he does not know. (As Wittgenstein said, Whereof one cannot speak, thereof one must be silent.)

I was impressed with what Marchetti would write and say, how he would approach problems. I was 25 years younger than he, and so I was a student in effect. He has a complex personality. He can be generous but also impatient and uninterested if things aren't worth his time. Gradually over the two and a half years that I was at IIASA, we developed a relationship where he would take more time to speak with me, respond if I had questions, and suggest reading or analytic exercises.

Trained as a physicist, Marchetti has a particular way of looking at the world. He believes much of what goes on from the origin of life to the growth of the Internet can be understood as the diffusion of innovations in waves, such as people starting to download mp3s instead of buying CDs. You have a wave like the growth of mp3 downloads, and you can quantify the waves, usually with a particular kind of equation, a logistic. The wave grows to a peak and then subsides. Basically you see the world consisting of waves diffusing on all scales of time and space. Sometimes there is one wave, sometimes two, other times three, sometimes there are five waves. Sometimes the waves interact with one another and then create what seems to be extreme complexity. The world consists of an epidemic of epidemics.

In fact, if you can decompose the result, then you realize that often what looks irregular or complex is the interaction, the overlap of some waves. This way of seeing the world sees endless innovation in all sectors of life, innovation within science itself, innovation in different industries, such as the semiconductor industry, but also in styles (such as the building of gothic cathedrals) and human behavior (such as accusations of witchcraft). All kinds of things, including culture and religions, can be looked at as waves. Marchetti has been endlessly daring in looking for waves in all sectors of life, not just energy, but agriculture, transport, and information systems. The novel is an innovation, the murder mystery is an innovation, the sonnet is an innovation, different sports are invented and diffused and within a sport you have a different particular technique.

If there are good data about these innovations over time, or about the creative career of an individual producing scientific papers or sonnets or homicides, then there is a simple mathematics that applies to them and allows *pre*-diction and *retro*-diction. You can understand the past, as well as the future, and historians like to note there is more disagreement about the past than about the future. Marchetti introduced me to a way of seeing the world, which I have largely adopted, and I have worked with him to extend it. We call the approach "Loglets," an abbreviation of "logistic wavelets." My Rockefeller University associates Perrin Meyer and Jason Yung developed the math and software.

Through the US National Academy of Sciences I had met another brilliant physicist, Elliot Montroll, who was interested in similar approaches. In the 1970's he co-authored a great book called *Quantitative Aspects of Social Phenomena*. Montroll described evolution as a series of replacements, a profound observation. Marchetti and Montroll influenced me with the idea that a few simple mathematical tools can be infinitely powerful in looking at an enormous range of problems. Today we look at the growth and diffusion of human empires, or electrical systems or the creative careers of individual painters or scholars or football players. This idea that these generic quantitative tools could apply to a wide range of problems, and allow prediction, including of the human environment, the area that interested me the most, was exciting.

During the years spent at IIASA my appreciation of analytic methods grew and my expertise in key fields deepened. It was exciting and inspiring and sometimes funny or scary work. Everybody who worked at the Institute in its first decade knew the rarity of places in the world where people from the East Bloc as well as the USSR could speak openly with people from the West, and there was a remarkably high level of open and honest communication.

IIASA created precious opportunities for Westerners to visit the East Bloc, and for Americans especially. In April of 1981, for example, I was in Moscow when the Soviet Union almost invaded Poland. It was the peak of the Polish "Solidarity" movement. Later I was able to visit factories of big Soviet companies that Americans normally wouldn't be able to visit. I saw many things that many people wouldn't have been able to see and developed relationships with Russians that lasted decades further. For example, in 1986 some of my Soviet colleagues became involved in the clean-up of Chernobyl, and I visited the dead zone not long after the accident for a few days and accompanied them in their haunting work. I reflected that my mother was born only about 500 kilometers from Chernobyl. Johnson and Kosygin were correct that science is a bridge between peoples. I think it is true that keeping channels open through science is always valuable. It's never good to eliminate all the channels of communication.

Science has the special feature that, while scientists themselves are rarely powerful, they usually know people who are politically or militarily powerful, because science is an instrument for prosperity and power. The political and military systems want their airplanes faster, their rockets more accurate, or they want communications or medicine to work better. Scientists are not generals, they are not politicians, they are not businessmen, they do not have direct power that those occupations have, but science has proximity to power. If there are times where one wants to pass messages between powerful people or to try to help them understand what might work or might not work, then scientists can act as go-betweens.

Whether it's about global warming or intercontinental ballistic missiles, having these bridges between scientists, whether American and Soviet, American and Chinese, Israeli and Egyptian, Pakistani and Indian, becomes valuable. Allowing freedom of scientific communication in the long run has benefits. If nations are in conflict, you can use these channels to reduce the conflict later when you want to.

Those years in the joint US-Soviet setting of IIASA strongly developed my interest in scientific cooperation between nations in conflict. There are always actual authentic neutral interests, for example there is still terrible tuberculosis in North Korea. If you find an expert on tuberculosis in California and that person can talk to an expert on tuberculosis in North Korea, they have something to talk about, it's not a forced and false relationship, there is something of genuine interest.

Of course the channels may have other uses. I promised a spy story. One of my Russian colleagues at IIASA was an expert on fusion energy. We became friendly because he was a big fan of the films of Woody Allen, whose detailed cultural references to New York City I helped explain. Unluckily, my Russian colleague was later videotaped in front of Vienna's comic opera (Volksoper) handing an envelope full of money to a Norwegian double agent for information about North Sea oil. The incident made the front page of the International Herald Tribune, and my colleague returned quickly to Russia. I do not know what happened to him, but espionage at the comic opera, where the Merry Widow plays, sounds like a Woody Allen film.

At the end of the two and a half years in Austria, I knew for certain I was interested in resources and environment, in particular long-term interactions between environmental and technological change, and I had fresh means to understand them. Through the contacts with other groups at IIASA concerned with energy and with agriculture I began to learn much more about the relevant technologies, the diffusion and the evolution of technologies and the importance of technical change. I also had a sensitivity, from having worked on the World Climate Conference and at IIASA, about how to work not just on a local or national level, but also globally.

Sometimes the term "Systems Analysis" suggests the world of computer science, but to me it meant looking at things as a whole, as Marchetti did. When you looked at a problem, whether energy or agriculture, you looked at it as a system. For the past 30 years I've continued to try to do systems analysis. I'm interested in forests as a system and cities as systems or indeed human empires as systems, so IIASA had a big impact.

Global Warming and Climate Change

My work at the Institute was rich like Austrian schlag and I was relieved in a certain way in the fall of 1981, age 30, to return to Washington DC and resume my work at the National Academy of Sciences. A late action of the administration of President Carter created a great opportunity. The White House and Congress had asked the National Academy of Sciences to perform the first comprehensive analysis of greenhouse gas emissions and climate change, and provided the money for it. From 1981 through 1983 I was responsible for the first study of global warming *ab ovo usque ad mala*, from seed to fruit, as the Romans said.

Five questions frame a comprehensive look at human-induced global warming. The first question is: "What will the emissions be?" Factors determining emissions include the size of the human population, its affluence, the amount and kind of energy people buy with each dollar, the efficiency of motors, and also changes in land use and land cover.

Ok, there are emissions. We emit greenhouse gases into the atmosphere. The second question is: "What fraction of those emissions will remain in the atmosphere?" Will two-thirds stay? Will one-half stay? Will one-third stay? The answer depends on how much the oceans and plants on the land absorb.

The third question is: "What will happen to the climate system itself?" Will the climate warm 2 degrees or 4 degrees Celsius if we double carbon dioxide in the atmosphere? Will there be more or fewer storms? Will there be more or less rainfall?

The fourth question is: "What will happen to other natural systems?" For example, will the Greenland ice cap melt? Will the ranges of plants and animals move toward the poles because of longer growing seasons? Will plants grow faster because of more carbon dioxide in the air? Will some kinds of marine microbe multiply in the oceans because of water that has warmed and absorbed carbon dioxide?

The fifth and final question is: "What will be the impacts on human societies?" Will climate change raise the price of food or water? Will it affect heart surgery? Will it affect the operations of cities? Will it affect the different occupations people have? Will it cause international migrations?

Between 1981 and 1983 we carried out the first assessment that looked in a serious and even way at each of the five questions, at the emissions, the airborne fraction, the direct consequences for climate, the immediate consequences for nature, and finally at the societal impacts and adaptations.

A talented and congenial group of senior American scientists, including Revelle, was appointed by the National Academy of Sciences to answer the questions and integrate the answers in a coherent panorama. The range of legitimate answers to each of the five questions multiplies into a wide fan of possibilities. The chairman was a physicist and oceanographer named William Nierenberg, the director of Scripps Institution of Oceanography near San Diego. A gruff person who had started his career working on the Manhattan Project to build the atomic bomb during World War II, Nierenberg had enemies as well as friends. He was not always respectful of others and their opinions. Some friends cautioned me about working with him, warning I might come out with many bruises. In fact, he was extremely kind to me in the course of the study, giving me exciting problems to work on and encouragement. We developed a warm relationship and stayed close friends afterwards. Nierenberg liked hard problems, problems in which you were given very few clues and then asked to solve a mystery. For example, suppose you have only a few measurements about the temperature and saltiness of the North Pacific, can you figure out the circulation of that entire ocean region?

Nierenberg always had a front pocket filled with many pens of different colors the way engineers do. He liked to make calculations and verify those made by others. He was also a clever manager. Appreciating the eminence of the members of the committee, he encouraged a healthy competition among them to impress one another with their hard work and insights. My job was to feed the creative competition and finally to prepare the report.

The report was path-breaking in many ways. For example, it was the first report to look systematically at the role of the greenhouse gases other than carbon dioxide. It pioneered consideration of methane frozen in the sea floor, the methane hydrates. It was the first report to quantify the potential power of carbon taxes to limit emissions. Thomas Schelling, who would win the Nobel Memorial prize in economics a few years later for his work on game theory, led the consideration of social and political consequences.

We produced what I think is still the best single document about global warming, *Changing Climate*. It is 600 pages long, but very clear, well-written and well-edited with excellent summaries. The report came out in the fall 1983 and made the front page of the *New York Times*. Something happened that I believe never happened with another report of the National Academy of Sciences. The 4-page summary which I had written was reproduced word-for-word inside the *New York Times*. Usually a newspaper article describes what a report says. In this case there was the article about the report and also the reproduction of the summary. The National Academy was extremely happy, not only to be on the front page of the *New York Times*, but that the report was shared this way. There is always the problem that a newspaper report may be inaccurate. The fact that the words of the Academy itself were reproduced was considered a triumph and a boost for my career.

The report judged the issue of greenhouse gas emissions and climate change to be very serious, and at the same time it asked rigorously what could be done in 1983 to make a difference. Basically it said the simplest step to take would be to restrict the emission of non CO_2 gasses, especially the CFCs, and to watch everything more carefully. That is what has happened, whether because of the report or not.

The report also found that, for political reasons, it would be extremely difficult to introduce effective carbon taxes or other strategies that would require international agreements. It was one of the first reports to say that forms of adaptation should be pursued actively because even in an optimistic scenario of restrictions of emissions there would be some change of climate. Examples of adaptation include more drought-resistant crops, infrastructure to collect and distribute fresh water over larger areas, and better weather forecasts.

Some people criticized the report because it did not call for immediate radical restriction of emissions. I think the committee was wise. It was better to make recommendations that would be taken seriously and not just take dramatic positions. If the report had called for restrictions of emissions CO_2 emissions in 1983, nothing would have happened anyway. We should also recall that in 1983 the global temperature was just starting to rise after the drop between 1940 and the mid-1970s. Abnormally warm years came only in the late 1990s.

The report led to an international non-governmental assessment, the so-called Villach process, which led in turn to the Intergovernmental Panel on Climate Change (IPCC). As the report was American and all its authors were Americans, it was clear that similar reports needed to be prepared by the global scientific community in order to have an impact on the governments and people of Brazil, or the Netherlands, or China or India.

I spent night and day during 1982 and 1983 working on *Changing Climate*. By the end of that time, I realized I had not been infected by what Americans call "Potomac fever." Many people who move to Washington DC are attracted to political power, love the city for the smell of power, and don't want to ever leave. I remained uninfected partly because I was a New Yorker who always felt Washington a bit narrow, but partly because I never desired political power and never wanted to enter in the American political system. I like to be on stage sometimes but I never wanted a key position in the White House or Congress or ministries. I enjoyed the privileged position of science in Washington -- having influence but without the obligations of a big manager, which might have been a possibility for me, or tight allegiance to a political party.

Within science in practice there are three domains of activity: teaching, research, and management of research. I've done very little teaching. I've been mentor to about a dozen early career scientists while they were graduate students and post-docs but never taught regular courses. Most people in science teach and do research. My career has been research and management, half the one and half the other. I have never had the desire to be a full-time manager or administrator, so I kept doing both management of research and research itself. It's difficult to do all three. There is not enough time. Distance learning with the Internet has improved education when people are not together, but students still want contact with the teacher, they want to touch you, see the language of your body.

Communication is in practice not a substitute for travel. The more people travel, the more they communicate. The more they communicate, the more they travel. Airports and now cars are filled with people on telephones. As soon as people have phones, they talk about meeting in person. Communication and travel are complementary goods.

Research and management of research exhausted my time and travel budgets. In some of my Washington years I was doing mostly management and hanging by my fingernails to my research career, because in Washington there are always infinite opportunities to be a manager. But some big ideas emerged from my Washington decade, including industrial ecology and dematerialization.

The mid-Eighties: A General Theory of Environmental Problems

I stayed in Washington for five more years, from 1984 through 1988. During this time I became a workaholic, working about 70 hours every week. I took my last vacation, ten days, in 1987. Anyway, after six years of climate change, I wanted to work on technology and the environment in a more general and theoretical way.

When one thinks about the environment and makes a list of all environmental problems, it isn't one hundred or one thousand items. It turns out that, qualitatively, there are only about 30 environmental problems. You have water pollution, air pollution, noise pollution, you have destruction of habitat, radiation, and so forth. It's a short list and hasn't changed much in my career. Most of the 30 problems have common roots, often processed materials ending up in the wrong place or energy wasted. Noise pollution, for example, is a problem of energy being wasted, because noise is energy. If there were less energy wasted in the form of sound, there would be less noise pollution.

The short list lifted my interest in trying to establish a general theory of environmental problems. In the mid-to-late eighties, together with yet another physicist, Robert Frosch, at that time head of research for the General Motors Corporation, we developed what we called industrial ecology. We had begun with the concept of industrial metabolism. But we knew nothing is really destroyed in the Newtonian world in which we operate for the most part, and so we invented industrial ecology.

Ecology is the branch of biology that deals with the mutual relations between organisms and their environment. Ecology implies the webs of natural forces and organisms, their competition and cooperation, and how they live off one another. It seemed to us that industries had essentially solved most of the quantitative problems of production. Factories could easily and cheaply make masses of shoes the world might want and stamp out fleets of cars like tin ducks. The skill in production helps explain globalization and the readiness of companies to relocate factories. But the massive production also generated massive by-production, in rich and poor countries. "Waste," a seemingly trivial offspring of early economies, now seemed prepared to impoverish or murder its parents.

Green nature appeared to have gone far in solving the problem of waste. In nature, webs connect organisms living together and consuming each other and each other's waste. The webs have evolved so that communities of living organisms lose little or nothing that contains available energy or useful material. Industrial ecology asked whether nature can teach industry ways to go much further both in minimizing harmful waste and in maximizing the economical use of waste and also of products at the ends of their lives as inputs to others. For example, could we design zero emission power plants (ZEPPs) that would emit no wasted carbon?

Under the banner of "industrial ecology", raised high by the US National Academy of Engineering, we began to explore whether we could massively reduce or do away with all waste. The banner captured attention in industry, government, and academia. Industrial ecology grew during the late 1980s and the 1990s until it became a discipline. There is now an International Society for Industrial Ecology and a high quality journal.

We came to emphasize a particular goal of industrial ecology, to lighten the environmental impact per person and per dollar of economic activity, and a particular role, to find leverage, the opportunities for considerable improvement from practical effort. Industrial ecology searches for leverage wherever it may lie in the chain from extraction and primary production through "final" consumption, that is, "from cradle to rebirth."

We became especially fascinated by "dematerialization," the trend of delivering equal or more services with less stuff. We performed case studies, for example, on the elements nitrogen and cadmium. Sold as fertilizer, one-third the nitrogen that humanity deploys is wasted: it doesn't go to grow crops, but it is left in fields and waterways where it pollutes. We looked at the element cadmium in a similar way. Used in paints or batteries, much toxic cadmium is carelessly distributed. We looked at the leverage of miners, processors, manufacturers, and users. With prosperity comes a functionality economy, and re-conception of industries as satisfying wants (such as floor coverings) rather than selling goods (carpets). A new device, the smart phone, can replace a dozen older, heavier ones, including an alarm clock, map, address book, and encyclopedia.

From our studies emerged a powerful mathematical identity in which population, income, consumers' behavior, and producers' efficiency jointly force environmental impact. Often working with Iddo Wernick, I had an exciting period developing general theory and have had endless fun applying the "ImPACT Identity" to environmental problems ranging from New York City trash to global farmland. Our greatest contribution has been to quantify the leverage of the actors in various environmental dramas. The rankings are usually a surprise. For example, recycling zinc turned out to be a top way to reduce cadmium releases.

A Question of Efficiency

Our research highlighted that industrial society as a whole is remarkably inefficient, even 200 years after the industrial revolution commenced. The efficiency in the energy sector is only about 10 percent. Automobiles and transport as a whole are perhaps 30% efficient. Water use efficiency in many societies is also low, maybe 30%, although there are some societies such as Denmark or Israel where it is much higher, and their existence proves that one can do a lot better.

On one hand, we can be horrified by the wastefulness of the existing system; on the other hand, as a scientist or engineer, or as a citizen or young person, one can be encouraged that there is a huge amount yet to do. We are not at 90%, we are not anywhere near the performance limits of the system. Science and engineering are still young, because we are so far from the frontier of performance.

I began to work on these issues in Washington DC for the National Academy of Engineering and National Academy of Sciences. In 1989, nearing 40 years of age and wanting to do more research and less research management, I had the wonderful fortune to return to New York City to The Rockefeller University, a paradise for research because of an absence of inhibitions. I have been blessed to work at Rockefeller. It is a privilege felt every day. I have had incredible freedom to pursue my interests. The charter of my group is to elaborate the technical vision of a large, prosperous society that emits little or nothing harmful and spares large amounts of land and sea for nature.

We were the first group to take seriously the question of land use efficiency. The question that intrigued me was: "How much land can 10 billion people spare for nature?" Most people haven't asked this question. Since the start of agriculture, for ten thousand years, people have extended more and more into nature. If you needed more food or more cotton - most of agriculture is for food - you brought more and more land into production, more arable land. There was intensification in some places, especially China, where farmers would grow more crops per hectare, more rice per hectare. When Europe needed more food, it extended into Argentina and North America. Land use efficiency wasn't much considered. Farmers would plough more soil and bring irrigation to create more arable land. A consequence was the destruction of enormous amounts of nature, the cutting down of forests, the replacement of forests and grasslands with farms. Agriculture is the greatest rapist of nature: this is something people tend to forget but remains true.

In 1992 I posed the question to Paul Waggoner, who was raised on a farm in Iowa and became one of America's most accomplished agronomists. Paul had also served on the National Academy of Sciences study of climate change, and we became close partners on many subjects. In 1992 the globe had about 6 billion people, while now there are over seven billion. "Let's accept the projection of the population experts," I said. "In 2050 or 2100 there may be 10 billion people: how much land do 10 billion people need? How much could they spare for nature?" We began to realize that land use efficiency has tremendous room to improve, like energy, water, and materials efficiency. We also realized that a high yield, responsibly achieved, is the best friend of nature. If you can grow a larger crop on a small area with little environmental pollution, then you can leave large amounts of land for the rest of nature.

In the late 1970's and 1980's when I worked on climate change, my friends used to tease me that my work existed in the realm of hypotheticality. They were right -- I was always talking about distant possibilities with uncertain probability. By the 1990's I was increasingly concerned about issues of the present, particularly the loss of biodiversity, which was happening every day in Indonesia, Brazil and other parts of the world. So the question of the land that 10 billion could spare for nature was not only a question for 2050 or 2100, it was a question for the present, because if farms (and cities) spread then obviously the habitat for the rest of life shrinks.

We began to realize that the chance is good for a great reversal of humanity's extension into nature. In fact, many trends point in the direction of a great restoration. Over the course of the past 20 years, we have published dozens of reports documenting that the extension into nature is coming to an end, that it is unnecessary, and that globally restoration of hundreds of millions of hectares of land to a wilder nature is possible and likely.

We developed one scenario called "skinhead earth", in which we shave all the trees and suffer a tremendous loss of biodiversity, problems of soil erosion and water shortage, and more carbon in the atmosphere with the elimination of forests. We think the skinhead future is unlikely and that a great restoration of nature several times the size of France or the size of India could be well underway by the year 2050. The key is what we call "precision agriculture": diffusion of intensive agriculture but with very little fall out or waste. Agriculture needs more information, like everything today. More bits need to go into agriculture, not more kilowatts or fertilizers. There's enough nitrogen, there's enough water: it's a matter of having better weather forecasts, and application of herbicides, pesticides and fertilizers at exactly the right moment, for example not before a rain. Spacing plants in an optimal way, using ever better seeds, this is the information required. One has to see genetics as part of the information revolution.

We've argued hard, and I think convincingly, over the last 20 years, that on land a great restoration of nature is likely, and one sees the trend now in many parts of the world. In America one sees restoration in the Northeast where I live, in Connecticut, Vermont, and New York State. These were deforested in the 18th and 19th century for wood, fuel, animals, to grow wheat and tobacco. Now most of the east of the United States is a forest again. The coast is quite urbanized but most of the interior is forest. If you leave the land alone, in 50 years you have inspiring re-growth.

Surveys on the ground and also satellite maps of Europe show that in Italy, Spain, Poland, and many others parts of Europe there is a re-growth of forests. Either areas that were farmland have been abandoned and become woodland again or areas that were woodland but thin woodland have become much denser. It makes sense, because the demand for wood products is stabilizing or shrinking. We have e-books now, we don't need much paper for newspapers or books. Construction materials for houses and residential commercial buildings can be synthetics, they don't have to be wood. We do not need many new railroad ties, and those need not be made of wood anymore. The demand for products from the forest is flat or even falling. Dematerialization.

Globally, ten billion people may need only half to two-thirds of the land that seven billion now use. The protein or calories, the food that we need to grow, we can grow on smaller and smaller plots of land for food and wood. In fact, if our diet changes from a heavy meat diet to one that's more vegetarian, more pasta and just a little "sugo", then the demand for land also falls. Italians have the right idea, use the meat or fish to flavor the bread or pasta, not as the main source of the protein or calories. I think the digression into meat over the last 100 years could diminish, maybe people will be completely vegan, but even if they are not vegans one can have a diet of 4000 calories a day, a very rich diet, with wonderful flavors but where the proteins and calories don't come from cattle. Producing a grain such as maize to feed animals represents an alternative to growing a crop such as wheat that directly adds calories to the human food supply.

As an American, I think that hamburgers are a kind of crazy accident of the over-success of agriculture. What were the farmers going to do with all of their surpluses? They grew more maize than they knew what to do with. If you have a huge excess, well you turn it into whiskey or hamburger, what else could you do? You try to sell it! This reversal of land use can, with better weather forecasts, seeds, and other features of precision agriculture lead to a great restoration of wild nature on land. The buffalo will roam America's Great Plains again.

From the Liberation of Environment to the Census of Marine Life

In 1996 we summarized many of these ideas in a special issue of the journal *Daedalus* called "The liberation of the environment". We argued that the great achievement of the industrial revolution, the past 200 years, has been largely to liberate humanity from the environment so people could live anywhere on the planet. We can live in very cold areas, even Antarctica. We can live in very hot areas, in very dry areas and very wet areas, we can live in areas with two seasons or four seasons, we can live in high altitudes or low altitudes. We have liberated ourselves, humanity has largely liberated itself from the environment. Now the challenge is to liberate the environment from us, to decouple more so that the fraction of the environment that humanity needs to make use of would be much less. In "The liberation of environment" we tried to show both how the liberation from the environment had been achieved and the possibility of liberation of the environment itself. An emblem of liberation is the magnetically levitated train traveling in low-pressure tubes at the speed of a jet plane but with ten times the energy efficiency of present transport systems, a super-subway at continental scale.

An important criticism of the 1996 report was that we didn't speak about the oceans. Of course I began my career working on the oceans, I was keenly interested in them, and it was true we didn't speak about the oceans, so I became very concerned about anecdotes alone and asked: "What truly is the situation of the oceans?" On July 2nd 1996 at the Oceanographic Institution in Woods Hole, Massachusetts, deep sea biologist Fred Grassle and I had the idea to try for the first time to count all the fish in the sea! To conduct the first ever worldwide project to look at all forms of marine life, from tiny microbes to whales, from the sea floor to sea birds, from the near shore to the middle of the ocean. During a decade, we would assess diversity: how many forms of lives are in the oceans; distribution: where they live; and abundance: how many kilos of each.

Much of my life between 1997 and 2010 was devoted to trying to catalogue and measure life in the oceans. To my surprise, marine biologists had never made a list of all the forms of life in the ocean. I thought surely because marine biology goes back to Aristotle somebody must have a list of what lives in the ocean. There was no list! There weren't even complete lists of all the sorts of marine fishes, and you couldn't find a list of the jellies or the mollusks or many other groups. There was a lot of basic work to be done to try to assemble what was known about life in the oceans.

It was also clear that there was an enormous amount yet to be discovered, and we wanted to estimate what remained to be discovered. Drawing on my experience with the World Climate Program and other international programs, I set out in 1997 to do some feasibility studies to see whether a worldwide Census of Marine Life could be carried out and how. By the year 2000 we were confident that a ten-year cooperative international observational program could answer three questions: What did live in the oceans? What does live in the oceans? What will live in the oceans?

The first question, examining life in the oceans when human exploitation began to grow large, was for historians, historical ecologists, and archaeologists. The great and expensive second job was to create the baseline description of the present, to go out and look in many expeditions at what is there now. The third question, about the future, is a question of modeling and projections. We set up a program built around the three questions.

We wrote many proposals, raised lots of money, and received indispensable core support from the Sloan Foundation, which had helped me early in my career. In 1994 Sloan had invited me to become a part-time program manager, and I started by assisting with some foundation programs in history of science and also in limits to knowledge in various disciplines. In 1999 Sloan very generously agreed to provide core support for the decade of the Census. While the amount was only about 15% of the total cost of the program, a reliable, enthusiastic supporter for the decade was indispensable. Sloan gave the marine science community confidence that the Census might succeed, and its commitment helped raise other money, so the program was deeply indebted to the Sloan Foundation. We created an international scientific steering committee with experts from Australia, France, Japan, China, India, Chile, Venezuela and other countries.

Over the course of the decade, researchers in the program conducted more than 500 expeditions. I was privileged to join some fantastic expeditions. Some especially memorable ones took place in polar regions. I spent a week when the sun never rose above the Arctic Circle one December counting herring on a Norwegian ship, and a week when the sun never set one July in the Beaufort Sea north of Alaska on an American ice breaker using a remotely operated vehicle to look at sea cucumbers three thousand meters deep. Two thousand seven hundred people received formal certificates of participation in the Census program.

The Census documented diversity of ocean life far richer than people knew. We found about six thousand species that experts had never observed before, amazing animals, fish, octopus, lobsters, small bug-like creatures, almost any variety you can think of and of incredible beauty. We were able to make the first list of all the known species of sea life, now a list of about 230,000, including 17,000 marine fishes. The lists are getting longer and better all the time, so finally we have catalogues of ocean life which we didn't have before. There has also been a reconciliation of the lists of Latin names with informal names and with genetic information, and most of the information is linked to a freely available online what/where database. We also made new estimates of the species remaining to be discovered, probably between 750,000 and 2,000,000. In addition, there may be between 100 million and 1 billion forms of microbial life in the ocean that will never have a Latin binomial (like *homo sapiens*) but will be known only with a gene sequence.

The Census also produced much new information about distributions of animals, and how animals connect the oceans. Some seals dive 2300 meters. Some turtles circumnavigate the entire Pacific. Tuna swim from Sicily to Cuba. We have "what-where" maps of what lives where and what might live where, for example, if the ocean warms.

The Census of Marine Life produced inspiring information about marine diversity and distributions but the news of the third aspect, the abundance, of course is heartbreaking. For many forms of ocean life that can grow large, 90% of the large examples of those animals are gone. So, for these forms of life only small animals now remain. A thousand years ago you would have had many large animals. Today if you want to survive in the present oceans, you need to mature fast and breed young. If you need ten years to have your first offspring, you are in trouble; if you need to grow large before you can have offspring, you are also in trouble. The ocean is fine for certain species, and they can be aesthetically magnificent species like some of the jellies or some of the squids, whose life cycle is just a year or two. They grow fast, some of the squids can grow an amazing ten percent per day, they can survive, they are small and can pass through nets. For many of the slow-growing long lifespan forms of life, deep sea fish for example, the situation is heartbreaking.

One of the great joys and accomplishments of the Census of Marine Life was a collaboration with a team of French filmmakers, led by the poetic and profound producer and actor Jacques Perrin. Perrin played the adult Salvatore as movie-director in the film *Cinema Paradiso* about the early years of a movie theatre in a Sicilian village. We assisted Perrin in making the 2010 film *Oceans*. *Oceans* isn't a documentary but pure, true cinema. It is not an external view but the world of the sea seen through the eyes of its creatures. Its aim, its triumph, is to be a fish among fish, to swim with a shark. I think *Oceans* is the greatest film ever made about nature. I wonder if the collaboration would have developed, if I had not lived in Paris in my student days.

After a dozen years counting fish, I concluded that, for conservation, the oceans are about 100 years behind the land. There is quite a lot of good news for the environment on land. Many national parks and forests have been established on spare land. There are still many problems but most of the problems are well identified. There is effective monitoring of many conditions on land, there are park services, forest services, agriculture ministries and other entities chartered to conserve, protect and manage resources on land.

In contrast, the oceans are, from a scientific point of view, opaque. People simply didn't know what was there, and much remains unexplored. And the oceans are still anarchic even with exclusive economic zones extending 200 miles from a nation's coast. Most nations do not have an effective coast guard or an effective navy. Even if there are regulations or laws, they mean little - the oceans are still full of piracy and disobedience.

Moreover, technology, which has been a friend of the terrestrial environment, is still, in many ways, a danger for the oceans. Stronger motors can trawl deeper. Refrigeration means that sea life can be chilled quickly and frozen, and airplanes can move it in hours from one corner of the world to another. I like to repeat that the problem of the oceans is the democratization of sushi. When only the emperor of Japan could eat sushi, his preferences didn't matter because tiny amounts were captured and then it had to be rushed by couriers to Tokyo to the Imperial Palace. However, when 1 billion people are wealthy enough to enjoy delicious Japanese food, then it means that many tuna, many octopus, must be captured. With good refrigeration and transport, sea life is simply too delicious for its own safety.

In our picture of the liberation of the environment the oceans remain an immense exception. It's not clear if we have reached a turning point for the oceans yet. People love seafood. For sea life to prosper, we have to do what we have done on land, what we have done on land a hundred years ago or much more. We must hunt fewer of the wild animals and succeed with aquaculture, and in particular the vegetarian or herbivorous forms of sea life. Oysters, clams, catfish, the forms of sea life that can live from the phytoplankton or from soybeans that we grow on land, those forms of life can increase greatly. But if we have to catch wild sea animals to feed to farmed fish, then we will not have a net increase in the sea animals.

We need also to learn to deceive the carnivorous marine animals that we want to eat, we need to fool the salmon into eating tofu. Maybe we can flavor the tofu with a bit of anchovy so that the salmon will eat it and grow large. Either we need to reduce the consumption of sea life or we need to substitute farmed sea life, if we want to liberate ocean life as well. This is one of the greatest environmental challenges and we must meet it soon.

Some people think that the climate issue is a master key to solving all environmental problems, but that's not true. Humanity could stop burning coal tomorrow, and it would do little to change the predicament of marine life. The climate could change in many ways, but if we remove all of the sea life now, it doesn't matter what happens to the climate in 2040 or 2080. I sometimes worry that we are transferring too much to the climate change issue. When I hear politicians or greens speak in America or Europe, they often sound as if addressing the climate problem will solve everything, but it won't. Greenhouse gas emissions are important but the liberation of the environment can only be accomplished if we also address the present direct destruction of sea life, and similarly if we stop cutting down the forests in Indonesia, Congo and elsewhere. One million windmills will not save the tuna.

Landless Agriculture

To save wild nature on land and in the oceans, we want to produce tons of wheat, rice, soybeans and maize on a few hectares using precision agriculture, a sophisticated high-tech agriculture. The great majority, 80% or 90% of the protein and calories needed, could be produced this way, along with "horizontal agriculture" that could survive essentially to provide the flavor.

With tofu or bread or pasta produced in bulk, then the question is the sauce, the "sugo". It may be possible to mass produce flavorful sugo, but to have the most delicious taste, then one may need horizontal agriculture or an artisanal fishery. We can reconcile the idea of local food, local flavor, if those provide a small fraction of protein and calories but valuable flavor and also income for those people who make it. They can charge a high price for a good product, a delicacy. It would be hopeless for the global environment if low-yield agriculture needs to produce all the protein and calories. With 7 billion people, or 10 billion people, we would completely demolish landscapes, no forests, no grasslands, no land for nature.

If you're a gardener, you know that this is already the division of labor. You may eat brilliant tomatoes from your garden, but I doubt you grow wheat to make the pasta. Cereals, the maize, wheat, soybeans and rice, are the bulk of calories and agriculture. One could similarly retain some wild fisheries producing small catches but supremely delicious. There would need to be some cultural adjustments for diners. In America the appearance of a half kilo of steak on a plate symbolizes satisfaction, even if little of it is eaten and the flavor resides in a few grams.

My mentor Marchetti likes to use the phrase "landless agriculture". In the extreme we could produce all the kilos in gigantic fermenters the way we make beer or wine. Maybe in 200 or 300 years one would approach that vision, but in the present we can move in the direction of agriculture that keeps using less and less land, not zero but less, and the land we use, we use it either to produce very high yields or to produce supreme flavors. One can have tasty vanilla beans from the Comoros Islands to flavor ice cream but the background milk will need to be produced in an efficient way.

We can move in the direction where we decouple the bulk production at the same time we preserve a very intimate horizontal production. The apparel industry works in the same way. In Florence or Rome there are wonderful clothing boutiques and shops that produce "alta moda" and set the style, and then there are big stores that sell imitations that millions of people may enjoy. It's just not possible for every woman to wear fashionable hand sewn dresses. The food sector is similar but we can maintain style and taste. Let's say McDonald's produces the bulk of the protein and calories in a rather industrial way but there can be special flavoring in McDonald's or there could be boutique restaurants.

The Last Decade: DNA Barcoding and the Encyclopedia of Life

Two other "of life" projects have gratified me over the last decade or so. When we began the Census of Marine Life, we knew genetic analyses would become more important. If you want to identify the species of a specimen, there are traditional ways to identify species. If I have an entire tuna, I can look at it and quickly say that it's a bluefin tuna because it looks like a bluefin tuna. However, it's also possible to take a tiny bit of the flesh of a bluefin tuna, examine its DNA and also say this is a bluefin tuna. Everyone is now accustomed to the idea of DNA identification. In courtrooms we all know that in cases of homicide or rape the evidence of DNA is powerful.

If you have a long sequence of my DNA, you can say this is Jesse Ausubel. But it also turns out that even if you have a very short sequence of my DNA, you can say this is a *homo sapiens.* Around the year 2000 several scientists concluded that there were some very short segments of DNA that are quite reliable for identifying animals and plants to the level of species. In 2002 together with Canadian zoologist Paul Hebert, geneticist Mark Stoeckle at Rockefeller, and other colleagues we started a worldwide effort called "The Barcode of Life initiative". The goal is a reference library of short DNA sequences for the 1.9 million known, named forms of life and especially the few hundred thousand that are most important for human activities and commerce.

DNA barcoding would be a powerful tool for field work in the Census of Marine Life because, when you go out to sea and collect a lot of specimens, sometimes you have only a fragment of an animal, or eggs, so you cannot decide visually what it is. Or, sometime you don't have the experts on board who will know if this is a particular kind of jellyfish or even a particular kind of fish. DNA identification can be extremely powerful and flexible. We set out to build the reference library of DNA sequences from well-identified specimens and a website where you could look for a match.

Then, if you have another piece of tissue, you can extract the DNA and you can say, "Well this matches the swordfish or this matches the bluefin tuna, or this matches the branzino." Over the past decade we have had enormous amounts of fun and a lot of technical challenges building up the library. It proved valuable for the Census of Marine Life, particularly for the groups that are not easy to identify, including marine worms, some of the plankton, some of the very small organisms, and some where we had only caviar.

Barcoding for societal benefit also turned out to be lots of fun. In 2007 two high school students, girls, age 17, came to my colleague Mark and me at Rockefeller. They were entering their final year in high school and wanted an extra-curricular science project, for some adventure and perhaps to help win admission to university. We inquired what interested them, and they answered that they liked sushi. We agreed that they would carry out a project on the genetics of sushi. They went around Manhattan buying sushi in fish stores and restaurants and they would extract the DNA and compare the barcode record with what the fish store or restaurant said the fish was. They found that about a quarter of the identifications in stores and restaurants were inaccurate and in every misidentification something inexpensive was sold expensively.

The students' study, published in an obscure fishing magazine, earned space on the front page of the *New York Times*. The news media called the story "Sushigate", like the Watergate scandal! The students appeared on national television and radio and became quite famous young women. Now their story and photograph are in biology textbooks. Their success spurred a series of studies - in Spain, London, Dublin, Boston and in Washington - on the accuracy of labeling fish in restaurants and fish stores. It's probably been done in Italy but I haven't checked. In every case, between 10% and 50% of the fish is inaccurately labeled. In most cases the fish is probably not dangerous, but it could be a species caught illegally, or a product that should not be in the market for some other reason. You are definitely paying more than you should.

We have assisted a series of barcode studies like this, conducted by high school students using high technology. One study looked at cheeses in New York markets. Cheese made from cow's milk was being sold as sheep milk cheese. Some groups have food taboos, some people won't eat pig or cow or horse, so DNA barcoding can be helpful from that point of view.

DNA barcoding has been one of the early areas where so-called "citizen science" has succeeded. With access to the Internet and cheap kits sold in toy stores or online, students or almost anyone can set up a home laboratory. With $4,000 we created a sophisticated laboratory on kitchen table in a Manhattan apartment where we tested many products.

There has been a lot of participation by young people in the development of DNA barcoding, and I personally think that this is healthy for science as a whole. Until the mid-20th century there were many people who participated in science who weren't full time scientists and who didn't have PhD's. If you look at the 17^{th} or 18th centuries, of course, many of the people who made scientific contributions had other jobs but were interested in astronomy or in agronomy. Gradually, science became isolated, but the Internet has now reopened the possibility for many more people to participate in an occasional way and the barcoding exemplifies this.

In New York City another group of high school students catalogued the mushrooms of Central Park. They collected "funghi", all the "funghi" they could find. They were able to collect about 80 kinds of mushrooms, barcoded the DNA, and wrote a useful monograph about the diversity of mushrooms of Central Park. Two or three hundred years ago, even 100 years ago, amateur mycologists would have done such work, then it became something for specialists, and now opportunities are widening again.

Yet another example comes from students in New York who did a project where they took small tiny samples of materials from artworks. There were no synthetics until about 1930. In the time of Leonardo and even in the 19th century all the paints, all the pigments, all the varnishes, canvas itself, everything would have been of animal or plant origin. The students found glues and feathers and all kinds of materials employed in the artworks, they extracted the DNA and then they were able to show that the glue came from a rabbit, or a sturgeon fish, or particular variety of orchid. They identified the species of birds that were the sources of feathers used by some American Indian tribes to make headdresses. This kind of problem-solving brings science back into the mainstream of culture. The DNA barcoding is sophisticated science but also an important example of 21st century science which re-engages a broad public.

The Census of Marine Life was a project to go out and look, to collect, while the barcoding is a laboratory project. Finally, the success of both depends on access to information. A third biodiversity project in which I have participated is about improving global access to knowledge about life on Earth. It is the Encyclopedia of Life, a simple concept: a web page for every single species. The Sloan Foundation helped launch DNA barcoding, and Sloan joined the John D. and Catherine T. MacArthur Foundation of Chicago in sponsoring the conception and growth of the Encyclopedia of Life.

If every person can have a page on Facebook, why can't every animal, plant or mushroom have a webpage? A well-known American ecologist, E. O. Wilson, came up with the idea to have an expandable web page for every species. He had the idea in the year 2000, before Wikipedia and Facebook. In 2006 we started to develop the Encyclopedia of Life and now over 1 million species have a web page at www.eol.org . The page may have images, sounds, and DNA sequences, as well as textual information and links to articles and books in the open literature. The EOL is available in Arabic, Chinese, Spanish, and other languages in addition to English.

This access is another wonderful reversal. As I mentioned earlier, science had become gradually more isolated from the rest of society over hundreds of years. The books of science were available only in the libraries of universities or special institutes, and most people didn't have access to the libraries. Subscriptions to scientific magazines and scientific books were very expensive. In the last 5 to 10 years the Internet has multiplied access to information and allowed direct access to all kinds of information that was once sequestered. In a way science is coming full circle in 300 years or so back to where it began in the 17th and 18th centuries. Back then, few people were full-time scientists but many people had a general interest in nature, the stars, plants, and minerals and observed them.

The 21st century may see a return to a greater integration of science into society, where you don't have to be a full-time specialist in a white coat to read, ask questions, and contribute. The areas of environment where I work provide excellent examples. In some fields few people may be interested and pre-requisites may be high. But people love to know about tuna, trees and climate, and I think it's much healthier for science itself to have deeper engagement with a much larger segment of society. The increased participation and communication can help science and nature. I hope in another 5 to 10 years millions of people have handheld devices that can link not only to databases like the Encyclopedia of Life but also read DNA.

The Deep Future

In the last decade or so, I have been occupied mostly with the trio of "of life" projects, the Census of Marine Life, the Barcode of Life initiative and the Encyclopedia of Life. A couple of questions interest me greatly for the future. One is a classic, fourth "of life" question: the origin of life. In the Census of Marine Life no matter how deep in the ocean we went, no matter how deep in the mud below the ocean we went, we always found life - small microbes perhaps, but life. Also, the deepest drilling on land - by geologists or oil companies - always brings life back as well. The deepest cores of sediment or rock or mud from 14 thousand meters deep in northern Russia contained microbes. We can say that humanity has never drilled deeper than life.

Empirically we have not reached the limit or the border of life, so the question remains open: What really are the limits of life? In boiling hot vents on the sea floor - hydrothermal vents called black smokers - chimneys with hydrogen sulfide and other gases, along the edges of these vents, there is no exposure to sunlight, no relation to photosynthesis. Nevertheless, there is life. Increasingly over the last few decades people have begun to wonder if it is possible that life originated very deep in Earth's crust and then moved upward. For many decades the leading theorists of the origins of life proposed that life began in a warm little pond on Earth's surface, then lightning struck the warm little pond, the molecules vibrated and formed bigger ones and eventually amino acids and then RNA and then DNA and life. For sixty years advocates of the theory of the warm little pond theory have been trying to recreate the sequence of chemical reactions leading to life, but they have not yet succeeded.

Now there are two other theories of the origin of life. One is that life came from outer space. A meteorite that crashed to Earth brought life with it, and it spread from the rock. The other idea is that at very high temperature and high pressure deep in Earth molecules were also swimming around, and jiggling, and dancing, and somehow these conditions provided the energy and protection for life to start. If life began very deep, it had the advantage of no exposure to solar radiation, which is harsh and abusive to many molecules. Life might have begun very deep, ten thousand meters deep or more, and then migrated upward. Intuitively the deep origin makes sense, because if you start in a situation of high temperature and high pressure, then as you go up it gets easier along the way, at least until you face the nasty sunlight. Theorists of deep life have been developing ideas how various kinds of molecules might have interacted and scavenged energy very deep and gradually created the origins of life as it exists today.

In 2009 a group of us - again a cooperative international project with experts from Russia, France, Canada and China - started a Deep Carbon Observatory, as we call it, and again boosted by the Sloan Foundation, to look for the limits and the origins of life. Carbon is of course the element of life. We hope that by 2020 we will have some strong evidence in favor or against the theory of a deep origin. Obviously we hope in favor. The project involves exploration. We want to drill deep holes and try to find some of the places where life may be at its limits. Experiments suggest that above 130 °C DNA and RNA molecules may lose their stability, at least at the pressure of Earth's surface. It may be possible to create bioreactors operable on a table in a laboratory at the temperatures and pressures which might exist deep in Earth's crust. The Deep Carbon Observatory may generate valuable information on the classic question of where life began.

A second question that the Observatory addresses is the origins of hydrocarbons, especially natural gas (methane) and other so-called fossil fuels. Most people learn in school that fossil fuels were trees or ferns or seaweed that was buried ages ago, for example, in the Carboniferous period and cooked in certain ways and turned into coal and oil and gas. Most petroleum geologists believe this.

There have always been alternative voices, for example, the famous Russian chemist Mendeleev, who created the periodic table of the elements. In the 1870's and 1880's he proposed the presence of primordial gas and oil in the rocks that formed Earth. After all, the meteors, rocks from elsewhere in the solar system, contain carbon. Mendeleev suggested a continuous exhalation or outgassing of primordial methane moving from the core into the mantle and then into the crust. At the various pressures and temperatures along the way, it was transformed and acquired the characteristics that we associate with the oil and gas that companies extract commercially. Diamonds, which are pure carbon and can come from 300 kilometers deep, prove that there is some deep carbon. The questions are its quantity and origins.

The origins and quantity of non-fossil or abiotic oil and gas should be testable. Extreme acrimony among some of the experts in petroleum geology and related fields over the last decades has slowed progress in the debate. We are trying to form a program without acrimony in which, for example, we obtain new samples and measurements and distribute them to different laboratories around the world for testing and analysis to see if people obtain the same answers. We are also developing instruments ten times more sensitive than present instruments to characterize molecules of methane and ascertain their origins. The existence of abiotic oil and especially natural gas could have implications for the global abundance of oil and gas and also where to prospect for it. It is easy to understand why the subject is controversial.

A third school of thought about deep carbon has grown recently. The third school says, yes there was a lot of relatively shallow recycling of dead organic material from the surface into coal, oil, and gas. And it says, yes, there may be a small amount of deep primordial methane outgassing. But they say that most of the deep carbon comes from sediment on the sea floor subducted very deep in the crust. This organic material isn't re-cooked in shallow basins where we normally mine coal and oil, but rather close to the frontier between Earth's crust and mantle, where it reaches very high temperatures and pressures and is transformed into methane. Some papers have been published in major journals in the last few years, showing experimentally that the process can occur. The scale matters a lot, because in a sense the process makes methane a renewable resource, and again would suggest methane in parts of the crust where we might not have explored for it.

Like the Census of Marine Life, the Deep Carbon Observatory requires new field studies, for example to measure much more accurately all the carbon emitted in gases from volcanoes and to acquire samples of pristine rock from deep in Earth's crust and possibly even the mantle. I already had the thrilling experience of hiking into the crater of a volcano in Kamchatka, in the Russian Far East, to measure outgassing.

One reason the abundance of methane matters is that methane is far cleaner than coal and oil. It has less contamination by sulfur, mercury, or even uranium. For those worried about climate change, the same amount of energy from burning methane produces about half as much carbon dioxide as coal and about one-third less than oil. If we do live in a world of methane abundance and the Deep Carbon Observatory could help us recognize it, then we might lessen the worry about global warming by relying, let's say for the next 50 years, on methane while eliminating coal and maybe oil too, and developing non-carbon alternatives.

In the long run, to stop gambling with the climate, we need to go beyond methane, to "decarbonize", a word and concept that my IIASA colleagues Nebojsa Nakicenovic and Arnulf Gruebler and I developed in the late 1980's. "Decarbonization" refers to the declining carbon intensity of hydrocarbon fuels in the sequence from wood (largely carbon) to coal (still heavy in carbon) to oil (moderate in carbon) to natural gas (light in carbon) to the pure hydrogen destined to supply the world energy system in the latter half of this century. The Deep Carbon Observatory could bring my career to a full circle, because I began with greenhouse gases and carbon.

Caveats and Conclusion

Science and technology progress. What about humanity? Together with Marchetti and others, I sometimes look at the human part of the game. I like to say that because the human brain does not change, technology must. Looking at thousands of years of human history we see countless efforts with law and religion to regulate social behavior. Nevertheless, the 20th century was brutal. The treatment of one person by another or one group by another continues very aggressive and violent. In Europe we can speak of the World Wars, but also the Balkans in the 1990s. I have spoken about Vietnam. More than 500,000 people may have died in the conflict between Iraq and Iran in the 1980s. In the first decade of the 21st century observers estimated more than 100,000 child soldiers served in armies in West Africa. So, I hesitate to rely heavily on social innovation.

The basic instincts for territoriality, for social status, the basic fears of one group about another, these remain deep and strong. Even while global population growth may be slowing, we live in a world of explosions and implosions. Populations for example in Pakistan, Yemen, Ethiopia and Mali are still exploding. In some places, including Italy, Japan, and Russia, populations are imploding, and shrinking populations have risks in terms of pensions, social security and how society will support itself. The mix of explosions and implosions creates steep gradients. A gradient favors a lot of migration, and migrations bring a lot of tensions and rivalries.

High rates of migration in the long run may stimulate interesting new cultures and growth but also a lot of anger and resentment. Some people will see their cultures, their identity, diminish or disappear because of low birth rates while other cultures grow. The European Union aims to create some kind of collective umbrella or shelter under which many minorities all treat each other respectfully and constructively.   I hope it works. To some extent the US, Canada, and Australia have made such umbrellas, and maybe during the 19th century Austria-Hungary operated one, too.

But deep instincts are at work. *Homo sapiens* has created perhaps 200 empires. Definitions of empire typically involve concepts such as homage, which translates into payment of taxes and military service.   Marchetti and I recently examined quantitatively 20 empires from the Persian through the Roman, Inca, Mongol, British, and American.

Finally, one can reduce all empire to just three variables, the time the empire took to grow, the midpoint of the growth process, and the area or niche the empire aimed to fill. These form an S- or wave-like curve characteristic of many biological processes, such as the growth of a sunflower or an epidemic.

We found empires grow until a distance is reached from the capital corresponding to 14 days travel with the best means available. We assert that the mechanism that fixes the size of empires comes from the depth of time, the fertility of women, and the need to re-set social hierarchies every lunar cycle. Without a monthly meeting, or the possibility of one, the hierarchy decays, in politics or business.

Testosterone is the driver of empires. Testosteronic individuals tend toward positions of power and drive the society to territorial expansion.   At this point the expansion stops, and testosteronic aggression turns inside for the share of territory and power. Basically, sex hormones run the show and make empires.

With present technology, the next empire may be a true world empire.   Maybe it will provide shelter for everyone. But maybe there will be lots of rebellions and civil wars. With 7 to 10 billion people, there will be lots of testosteronic individuals aspiring to top the hierarchy.

And individual humans may after all change.   A billion people watched the London Olympics, and there was a lot of discussion, what about prosthetic devices. If we look around, we see that there are more and more ways to enhance human performance. I'm wearing eyeglasses, people have hearing aids, people have surgery to have an artificial knee or hip. There are many surgical and physical enhancements that people now have, and increasingly people also have chemical or pharmaceutical enhancements. There are drugs like the famous Ritalin that may help children to concentrate, and drugs like Adderall that may help memory.

We know about the bicycle racers. The drugs work, you pump harder, jump higher, swim faster, hit harder. I think that if one told some of our scientific colleagues that a drug would help them win the Nobel Prize, they would take it.   If a student is competing against 10,000 other students for a place at the best university, the temptation may be irresistible. For an individual, or for parents, or employers, the pressure to use performance enhancement will be very great. There are casual kinds like coffee or just education, but I think that the cognitive potential in hardware, in drugs, in software is growing and the 21st century may see the evolution of super-humans.

And of course people want beauty too. They don't want only intellectual or Olympic performance or health, they want also youth and beauty. In Hollywood, many actresses have surgery on their chest or nose to be more beautiful. Brazil has a big industry in cosmetic surgery. I expect there will be a proliferation of these technologies, people will want to live 100 years or 120 years and they want to be beautiful and perform well. I'm not saying it's good or bad, but I think for the new century this whole collection of new technologies having to do with performance enhancement will be one of the great questions of ethics for individuals and for science itself, because science and engineering will be the source of all of these different powers and how we will use those powers is the great question.

So, the 10 billion people in 2050 or 2100 might be quite different from today. We might look back on today and say: "Those people were so slow, their memories were so bad!" In the world of 2014 we may be amazed by the Internet or worried about climate change. Going ahead, what may surprise us may not be about cellphones or forests. Maybe the surprises in the new century will be about human performance and other areas we are not thinking about much.

In fact, looking back over 40 years about the human environment, overall I'm hopeful. In many areas the worst is probably over, the worst behavior of humanity towards the environment is over. If we do the right things, in 2050 or 2070 we will look upon the industrial revolution as a dirty but necessary transition from a clumsy economy, which put a lot of things in the wrong places, to one that can successfully deal with large human populations, in some ways more decoupled from nature, but allowing the rest of nature to grow more freely.

If we look at energy systems, we can continue to decarbonize, to move to a hydrogen economy. If we look at food, we can have very high yields with precision agriculture and with very little environmental fall out. We can use water much more efficiently, we can use materials more efficiently and reduce waste, we can travel and transport goods more efficiently with magnetically levitated trains.

Collectively dematerialization and decarbonization can allow for the terrestrial and also the marine environment to re-grow, to reverse the destruction. By the end of the 21st century there could be a great restoration of nature. Moreover, there are enormous opportunities for careers and for great and heroic achievements, because even though we may have passed the worst points, the actual achievements of making the hydrogen economy work, making precision agriculture work, fostering ecological restoration, these are all great trophies to be won. And fortunes to be made from the companies that make the successful fuel cells and successful magnetic levitated trains: these will be huge enterprises which will create enormous new wealth.

Also, the amount of undiscovered nature is still huge, whether it is at a molecular level or the organism level. The majority of life is still unknown, so people choosing to study the human environment, whether from the point of view of engineering or science, still have beautiful, inspiring work to do.

To conclude on a personal note, I am amazed at my own good fortune. I am a product of the Turkish invasion of Europe, the Battle of the Isonzo, the 1918 flu pandemic. Yet I was born into a classic family unit in the capital of the world in a time of opportunity and given plenty of food and fuel. As for my parents and grandparents, America has been a huge blessing for me. My work in science and technology make me believe in progress. But my own good fortune makes me also wonder about providence.

Photo captions (English)

1 - As part of the Census of Marine Life, during a 30-day "Hidden Ocean" expedition in the summer of 2005 on the US Coast Guard research icebreaker *Healy*, 24 scientists from the US, Canada, Russia, and China explored for life under Arctic ice and found unexpectedly high numbers and varieties of large Arctic jellies, squid, cod, and other animals. Because of the presence of polar bears, scientists working on the ice floes required protection by Coast Guard officers with high-power rifles. Although team members saw several polar bears, fortunately no attacks occurred and no shots were fired. Images of some of the species collected during the expedition are at http://news.coml.org/medres/iceocean/iceocean.htm

2 – Census of Marine Life researchers working from the US Coast Guard ice breaker Healy on a Census of Marine Life expedition in the Arctic Ocean, north of Alaska.

3 – Census of Marine Life researchers sampling Arctic marine biodiversity from an ice floe in the Beaufort Sea, north of Alaska.

4 – Jesse with chinstrap penguins on a Census of Marine Life expedition in Antarctica.

5 – Jesse visiting with tortoises in the Galapagos Islands. Photo: Song Sun.

6 - The scientific leadership of the Census of Marine LIfe meeting on the RMS *Queen Mary* in Long Beach, California, 2009. Jesse had sailed across the Atlantic on the *Queen Mary* as a child in 1955.

7 - In 2007 French marine biologist Philippe Bouchet and colleagues discovered a new species of lobster off the coast of Luzon in the Philippines at a depth of around 250 meters. They named the species *Dinochelus ausubeli* (Ausubel's mighty claw lobster) in honor of Jesse's part in the Census of Marine Life. Photo: Tin-Yam Chan.

8- Jesse and a French colleague prepare to dive to film life on a reef by moonlight in New Caledonia for the film *Oceans*, created by Jacques Perrin and Galatee films.

9- At the Elysees Palace in Paris, Jesse attended the ceremony conducted by French president Nicolas Sarkozy elevating Jacques Perrin to the Legion of Honor. Perrin was honored for his contributions to cinema, both as an actor (*Nuovo Cinema Paradiso*) and producer (*Oceans, Il Popolo Migratore, Microcosmos* and other environmental films).

10 - A group of experts met in July 2006 at the Woods Hole Oceanographic Institution to conceive the Encyclopedia of Life. In the back row from the left: Brewster Kahle (Internet Archive, San Francisco), John McCarter (Field Museum, Chicago), Mark Costello (Ocean Biogeographical Information System, New Zealand), James Edwards (Global Biodiversity Information Facility, Denmark), Jesse Ausubel; front row: John Hurley (MacArthur Foundation, Chicago), David

Patterson (Marine Biological Laboratory, Woods Hole), Fred Grassle (Census of Marine Life, Rutgers University), Andrew Polaszek (International Commission on Zoological Nomenclature, London), Cristian Samper (Smithsonian Institution, Washington DC).

11 - Founded in 1545, the Orto Botanico di Padova is the world's oldest academic botanical garden still in its original location. Jesse attended a meeting about advances in the sciences of biodiversity in Europe in the beautiful and historic garden, which contains numerous medicinal and even toxic plants.

12 - Jesse and other members of a 2011 expedition of the Deep Carbon Observatory to measure the gases coming from the craters of volcanoes in Kamchatka in the far east of Russia stand in front of Vilyuchinsky volcano after concluding their work.

13 - Young Russian scientists in the laboratory of Vladimir Kutcherov at Gubkin State University of Oil and Gas in Moscow share a sample with Jesse of hydrocarbons synthesized at very high temperatures and pressures similar to Earth's upper mantle as part of the quest of the Deep Carbon Observatory to learn possible origins of petroleum and natural gas.

14- In 2012 St. Andrews University (Scotland) honored Jesse with a doctorate for his contributions to environmental science and management. Here he is pictured in regalia with St. Andrews professor Ian Boyd, expert on the effects of sound on marine life, his mother Anne Ausubel, and family friend Margaret Bearn (on the left).

Dialoghi – Science

Sidney Altman - La rivoluzione dell'RNA
F. Tito Areechi - Coerenza, complessita, creativita
Michael F Atiyah - Siamo tutti matematici
Jesse H. Ausubel – La liberazione dell'ambiente
Francisco J. Ayala - Le ragioni dell'evoluzione
Jacob D. Bekenstein - Buchi neri comunicazione energia
Edoardo Boncinelli - A caccia di geni
Luciano Cagljoti - La scienza tradita
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Luigi Luca Cavalli Sforza - II caso e la necessita
Alan Cromer - Visioni della scienza
Paul Davies - Un solo universo o infiniti universi?
Carl Djerassi - Dalla pillola alla penna
Freeman Dyson - L'importanza di essere imprevedibile
Irenaeus Eibl-Eibesfeldt- Dall'animale all'uomo
Antonio Garda-Bellido - Vocazione e ricerca
S. James Gates, Jr. - L' arte della fisica
Michael S. Gazzaniga - L'interprete
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Umberto Guidoni - II giro del mondo in 80 minuti
Margherita Hack - Una vita tra le stelle
Hermann Haken - Nel senso della sinergetica
Roald Hoffmann - Come pensa un chimico?
Massimo Inguscio - Fisica atomica allo zero assoluto
Giorgio Israel - Scienza e storia: la convivenza difficile
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Harold Kroto - Molecole su misura
Anthony J. Leggett - II mistero della superfluidita
Vladilen S. Letokhov - Dalla Siberia alla scienza del laser
Jean-Marc Levy-Leblond - Scienza e cultura
Alfonso Maria Liquori - Etica ed estetica della scienza
Luigi Lugiato – Divertirsi con la ricerca
Benoit Mandelbrot - Nel mondo dei frattali
Desmond Morris - Linguaggio muto
Igor D. N*ovikov* - II ritmo del tempo
George A. Olah - La ricerca di una vita
Francesco Paresce - Tra razzi e telescopi
Giorgio Parisi - La chiave, la luce e l'ubriaco
David Peat- I sentieri del caso
Arno Penzias - L'origine dell'Universo
Martin L.Perl - Tante domande, qualche risposta
Max Perutz - Le molecole dei viventi
Luciano Pietronero - Complessita e altre storie
I!ya Prigogine - Il future e gia determinato?
Martin Rees - La lucciola e il riflettore
Carlo Rovelli - Che cos'e il tempo? Che cos'e il spazio?
Dennis William Sciama - Questa bizzarro universo
Warren Siegel - Particelle, stringhe e altro
Stephen Smale - Matematica sulla spiaggia
Oraizio Svelto - Il fascino sottile dcl laser
lmre Toth - Matematica ed emozioni
Frank Wilczek - La musica del vuoto
Richard N. Zare - Molecole e vita
Semir Zeki - Con gli occhi del cervello

Back Cover

The liberation of the environment is the challenge of the third millennium. Will humanity succeed to restore the freedom to regenerate itself to the environment in which we live?

After the liberation of humanity from the environment – the great conquest of the Industrial Revolution – the moment has arrived for the liberation of the environment from humanity.

No drastic choices or impossible renunciations: to allow Nature to repair itself from our damage, it will be enough to leave space and time for it to follow its course. Permit the forests to regrow, the fish to reproduce, the cities to enjoy an uncontaminated atmosphere.

No radical change, no alarm. Only a more rational and responsible model of interaction with the planet.

From precision agriculture to means of transport by magnetic levitation, from hydrogen cars to reconceived fisheries, here is how and where to intervene.

Jesse H. Ausubel, director of the Program for the Human Environment at The Rockefeller University, has directed numerous research programs in biodiversity and ecology. He has worked for the US National Academy of Sciences and the International Institute for Applied Systems Analysis and participated in organizing the first United Nations World Climate Conference. Among his most relevant contributions are the Encyclopedia of Life, the Census of Marine Life, and DNA Barcoding.

13.30 Euros

1 - Nell'ambito del Censimento della Vita Marina, durante la spedizione "Hidden Ocean", durata 30 giorni nell'estate del 2005 sulla lancia della guardia costiera Americana Healy, 24 scienziati provenienti da Stati Uniti, Canada, Russia e Cina hanno esplorato al di sotto del ghiaccio artico alla ricerca di vita e hanno inaspettatamente trovato un elevato numero e varietà di meduse artiche, calamari, merluzzi e altri animali. Per via della presenza di orsi polari, gli scienziati che lavoravano sui banchi di ghiaccio hanno avuto bisogno della protezione della guardia costiera dotata di fucili ad alta tensione. Pur avvistando numerosi orsi polari, fortunatamente non ci sono stati attacchi e non è stato necessario sparare. Le immagini di alcune delle specie raccolte sono disponibili al link http://news.coml.org/medres/iceocean/iceocean.htm.

2 - Al lavoro sulla rompighiaccio della Guardia Costiera Americana Healy durante una spedizione del Censimento della Vita Marina nell'Oceano Artico, a nord dell'Alaska.

3 - Raccolta di campioni di biodiversità marina dell'Artico da un banco di giaccio nel Mare di Beaufort, a nord dell'Alaska.

4 - Con i pinguini della famiglia dei **pigoscelidi antartici** nel corso di una speidzione del Censimento della Vita Marina nell'Antartico.

5 - Una visita alla tartarughe delle Isole Galapagos.

6 - La direzione scientifica del Censimento della Vita Marina riunita sul piroscafo Queen Mary a Long Beach, in California, nel 2009.

7 - Nel 2007 il biologo marino francese Philippe Bouchet e i suoi colleghi hanno scoperto una nuova specie di aragosta a largo della costa di Luzon nelle Filippine ad una profondità di circa 250 metri e l'hanno battezzata *Dinochelus ausubeli* (ovvero aragosta gigante di Ausubel) in onore del ruolo svolto da Jesse Ausubel nel Censimento della Vita Marina.

8 - Jesse Ausubel e un collega francese si preparano ad un immersione notturna per riprendere la vita marina su una scogliera in Nuova Caledonia per il film *Océans*, realizzato da Jacques Perrin e prodotti da Galatee films.

9 - Al Palazzo dell'Eliseo a Parigi, Jesse Ausubel ha partecipato alla cerimonia nel corso della quale il Presidente francese Nicolas Sarkozy ha attribuito a Jacques Perrin la Legion d'Onore. Perrin ha ricevuto l'onorificenza per i suoi contributi al cinema, sia come attore (*Nuovo cinema Paradiso*) che come produttore (*Océans*, *Il Popolo Migratore*, *Microcosmos* ed altri film ambientalisti).

10 - Il gruppo di esperti che si è riunito nel luglio del 2006 all'Istituto Oceanografico di Woods Hole per ideare l'Enciclopedia della Vita. In seconda fila da sinistra: Brewster Kahle (Internet Archive, San Francisco), John McCarter (Field Museum, Chicago), Mark Costello (Ocean Biogeographical Information System, New Zealand), James Edwards (Global Biodiversity Information Facility, Denmark), Jesse Ausubel. In prima fila: John Hurley (MacArthur Foundation, Chicago), David Patterson (Marine Biological Laboratory, Woods Hole), Fred Grassle (Census of Marine Life, Rutgers University), Andrew Polaszek (International Commission on Zoological Nomenclature, London), Cristian Samper (Smithsonian Institution, Washington DC).

11 - Fondato nel 1545, l'Orto Botanico di Padova è il più antico giardino botanico accademico del mondo ancora situato nel luogo originario. In questo bellissimo giardino storico, che accoglie numerose piante medicinali e anche tossiche, Jesse Ausubel ha partecipato ad un meeting sui progressi delle scienze della biodiversità in Europa.

12 - Jesse Ausubel e altri membri di una spedizione del 2011, nell'ambito dell'Osservatorio del Carbonio Profondo, per la misurazione dei gas provenienti dai crateri dei vulcani della Kamchatka nell'estremo oriente russo, alla conclusione del lavoro.

13 - Giovani scienziati russi nel laboratorio di Vladimir Kutcherov all'Università Statale Gubkin per il Petrolio e il Gas di Mosca condividono con Jesse Ausubel un campione di idrocarburi sintetizzati a temperature e pressioni molto elevate, simili a quelle del mantello superiore della Terra, nell'ambito della ricerca dell'Osservatorio del Carbonio Profondo sulle origini del petrolio e del gas naturale.

14 - Nel 2012 Jesse Ausubel ha ricevuto un dottorato onorario dall'Università di St. Andrews in Scozia per i suoi contributi alle scienze ambientali. Nella foto è ritratto in tenuta accademico insieme al professor Ian Boyd, esperto degli effetti del suono sulla vita marina, sua madre Anne Ausubel, e un'amica di famiglia, Margaret Bearn (a sinistra).