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Tuberculosis in Children

Introduction:

While tuberculosis is caused by a bacterium and AIDS by a virus, both diseases attack the immune system, both diseases are relatively difficult to contract, and both tend to kill adults in the prime of life. TB has declined in the U.S. since the early 1950s except for a time in the 1980s when the AIDS outbreak, increased immigration, and poor public health policy combined to allow TB to increase.

Although we have a cure, there is more tuberculosis disease on the planet now than at any time in history. People with access to good medical care tend to survive TB. Because the poor cannot usually afford TB therapy, which is cheap and effective, our best hope for controlling the disease is the development of a cheap and effective vaccine.

We spoke with Dr. Jeffrey Starke, a pediatrican at Baylor Medical College about the history of TB and the prospects of controlling it.

ER: Dr. Starke, how long has TB been with us?

JS: We know tuberculosis first occurred in mankind at least as far back as 2500 B.C. because evidence of TB has been found in mummies and other preserved human remains. The reason it's been around a long time is that it is almost a perfect parasite for human beings because people get infected with it and don't even know it. The germ has not only adapted to live inside our immune system, but it's adapted to use our immune system to preserve and propagate itself.

ER: Like an early version of AIDS.

JS: That's the perfect analogy: AIDS is just like TB except it happens to be caused by a virus. I consider TB to be an object lesson for people who want to control HIV in the world, because we have everything for TB that the HIV people claim that they want: we have curative therapy for TB, we can treat infection and prevent it from turning into disease, and we have a vaccine. Yet despite the fact that we have those things, we now have more tuberculosis on the planet than any time in the history of mankind.

ER: How do you catch TB?

JS: TB is tricky, it's very different from other infectious diseases. The only way you can catch TB is by breathing the air of someone who is exhaling tuberculosis bacilli, and it doesn't take very many germs to get you infected, just ten or so is probably enough. So the germs are wafting in the air and you breathe those germs down into your lungs. In some people the germs probably get eliminated right away, but in others the germs have adapted so that they can enter some of your immune cells and start dividing, and the cells can't do anything about it. As the germs start to grow, they kill the cell, and then they're taken up by other cells and grow. For the vast majority of people fortunately, the immune system gets turned on and is able to contain the infection. This all occurs without people even knowing that they have TB. It's at a subclinical level.

ER: Is this in the lung?

JS: It almost always occurs in the lung, yes. And so for the vast majority of people, the growth of the TB germs will be arrested. Now, unfortunately the germs are probably not killed. They're still there, but they develop a

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symbiosis where they live in a dormant state. So they continue their life, the human being continues its life, and that's the classic definition of parasite.

Most of those people are destined not to develop tuberculosis disease. They will live their whole lives and die of something else and never develop tuberculosis. But some people, and probably genetics and immunity and luck, human living conditions, all kinds of things have something to do with this, their immune system at some point in their life will get knocked down by something as dramatic as cancer or something as innocuous as a viral infection, the restraints on the TB get released, and it starts to grow again and turns into disease.

ER: If you are infected can you give it to other people?

JS: No. The only people who are infectious are people with active disease. So a person walking around with a positive skin test is at risk for developing TB in the future. Normal healthy adults have a 5-10 percent lifetime risk of developing TB once infected.

ER: What about HIV?

JS: If you're infected with TB first and then you get an HIV infection, your risk of developing TB is not 5 to 10 percent for your lifetime, it's 5 to 10 percent per year. And if you are seriously immuno-compromised with HIV first and then you get infected with TB, you may have as much as a 40 to 50 percent chance of developing tuberculosis over the next couple of years.

ER: That's because HIV knocks out your immune system?

JS: That's right. So that initial event where the immune system puts the organism in check never kicks in, and the organism continues to grow and the person becomes ill.

ER: Do kids respond differently to TB?

JS: Yes. Children are in some ways closer to adults with HIV in the sense that children who get infected, especially little infants, have a much higher chance of developing tuberculosis disease because their immune systems are not yet developed and not able always to keep the organism in check. So TB in children is a huge problem throughout the world.

ER: How big a public health problem is TB?

JS: It's estimated now that there are between 8 and 10 million new cases of tuberculosis every year in the world; 3 to 5 million deaths due to tuberculosis, and one-third of the world's population (2 billion people) are infected with the TB germ. So if we estimate that 5 to 10 percent of those people are going to get TB, that means 1 to 2 hundred million people in the world already are destined to develop tuberculosis, even if nobody else caught it ever again. Of course the health care cost of this is multiple tens of billions of dollars every year.

ER: Does TB increase as the human population grows?

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JS: It's different from other infectious diseases. The rise and fall occurs over hundreds of years, and much of this reflects the biology of tuberculosis. TB is slow growing, it's fairly hard to transmit, it's not a very contagious disease, nothing like measles or chicken pox. That's why you usually have to be around someone for a while in order to catch TB from them.

TB for instance in North America started to decline long before drugs became available. It peaked in the

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early 1900s, it was the leading cause of death in the United States around the turn of the last century, and then started to go down long before the 1940s and 50s when drugs became available.

Why did it go down? Probably several reasons: number one was cleaning up of living conditions, reduced poverty, improved shelter, improved diets undoubtedly had something to do with it. But the real answer probably is genetics; that is, that the TB organism essentially selected out those human beings who are more resistant to it because they survived and propagated it, and it killed off those human beings who were more susceptible to it.

And so right now in those areas of the world with such high TB rates the bug is figuring out which of the human hosts are genetically susceptible and which are genetically resistant. That process is going on now in India, Southeast Asia, Thailand, Africa.

ER: I thought that antibiotics were the turning point in our fight against TB.

JS: Well, that's what most people think. There's no question that it is a curable disease, so the effective use of antimicrobial agents have had an impact, but arguably not the major impact on the control of TB in our society. I am not arguing against them or arguing that people shouldn't be treated, but it does show how dynamic and important these other forces are.

There have been many studies about the effect of warfare on TB. The most famous ones were in Europe after World War II: incredible increases of rates of TB in the Netherlands and other places. There's no question that TB thrives on human misery and it thrives in political upheavals. I wonder what the rates of TB are going to be in Kosovo for the next couple of years. I'll bet you they're going to be pretty high.

ER: There are millions of infected people walking around now. That must not be due to multi-drug resistant tuberculosis.

JS: Well, it's a part of it. One of the lists I'm making for this talk I'm preparing is why I don't think TB is going to improve much. What I have on my list is mostly what we've been talking about: intersection with HIV, continued poverty and poor medical care, political upheaval, immigration and migration, and then the development of drug resistance. Obviously these issues all tend to be intermingled.

The way I see this, the development of TB resistance is a conspiracy.

There are between 8 and 10 million new cases of TB every year in the world; 3 to 5 million deaths; and 2 billion people are infected with the germ.

It's a conspiracy among the organism, the patient, the doctor, and the health care system or the government. What I mean by that is the nature of the TB germ is such that if the patient does the wrong thing, the doctor does the wrong thing, or the health care system does the wrong thing, it leads to the rise of drug resistance, not just in the population, but in that individual specific patient. As a matter of fact, we use TB as a teaching example of how drug resistance develops and impacts people.

ER: What is drug resistance?

JS: Drug resistance simply means that the drug is no longer effective in killing the germ. Germs have developed all kinds of mechanisms to adapt and survive. If anybody doubts that evolution exists, all they have to look at is TB bacteria, because you can replicate on a culture plate in a day what it takes millions of years to replicate in the human population in terms of genetics.

ER: You mean drug resistance is an evolutionary progression for TB germs?

JS: Exactly. The mutations that occur are uncommon, but when you have billions of germs, a few will occur that confer drug resistance. The reason we treat TB with multiple drugs is to make sure that if those resistant mutations occur, they get wiped out right away. But if the person has the wrong drugs or doesn't take the drugs properly, or if the government of the Philippines doesn't provide the proper drugs, as an example, then it invariably leads to the rise of drug resistance.

When I teach the medical students in residence here about drug resistance, my question always is, What's the cause of antibiotic resistance? The answer is, Antibiotics and how we use them. Drug resistance in TB is a manmade problem pure and simple.

ER: It's having a noncompliant patient or an ineffective...

JS: Right. Noncompliant patient, poorly educated or poorly functioning physician, or a government that either

claims it can't afford or won't provide proper medications.

ER: Is the course of disease different in kids other than the fact that they're more susceptible?

JS: Very different. Remember we said that you get the infection and it stays dormant for a period of years or decades and then something causes the germ to wake up and cause mischief? That's the usual pattern in adults. In children it's different.

Children when they get TB, tend to get it directly as a complication of that initial infection. They never contain the initial infection and then the infection just keeps getting worse and then starts causing mischief, either in the lungs or spreads to other parts of the body and causes mischief.

ER: What's the prognosis of TB?

JS: Of infection or disease?

ER: Of disease.

JS: Before we had any drugs for TB approximately 65 percent of the patients died and died fairly quickly, meaning within a few years. About 20 percent of the population was essentially cured; that is, they got over the disease and went on and lived what appeared to be a normal life. And then about 15 percent developed what was called chronic disease, and they were probably the people who were most responsible for spreading tuberculosis throughout a population.

When multi-drug resistant tuberculosis first arose in the United States in the 1980s and the early 90s, the cure rates at first were not too much different than the rates I just gave you, which indicates that the drugs weren't doing much.

Now that we've gotten smarter with the drugs, the prognosis of multi-drug resistant TB in people infected with HIV is still not very good, but the cure rate among people who are otherwise normal immunologically now is in most places between about 65 and 85 percent.

ER: So in the developed world people with access to good health care survive TB, and those without health care don't.

JS: It sounds like HIV doesn't it? One of the important lessons here is that control of diseases like TB or AIDS is not just a matter of medicine and science but very much a matter of politics, human nature; and those will ultimately be the limiting factors in the control of TB just as they will be the limiting factors in the control of HIV. There are very strong parallels: both of them live in the body for a long time before they start to cause disease. And like HIV, TB tends to strike down adults in their prime. There's been a lot of talk about orphans created by HIV. The truth is, there probably are far more orphans created by tuberculosis than there are by HIV.

TB thrives on human misery and it thrives in political upheavals. The rates of TB in Kosovo for the next couple of years are going to be pretty high.

ER: If drug resistance is a conspiracy, how do you propose to break it up?

JS: If that conspiracy analogy is true, then we have to ask, What do we do to make the patients do the right thing? What do we do to make the doctors to do the right thing? And what do we do to make governments do the right thing?

What we do to make patients to the right thing is called directly observed therapy, or DOT. Directly observed therapy means the following: we know the patients with chronic diseases of all kinds at least 30-40 percent of the time are noncompliant with what the physician asks them to do, they don't take the medications properly. What happens with TB if you don't take the drugs properly, not only might you relapse but you might develop drug resistance, and then you might pass it on to another person.

Elegant studies in many places have shown that under DOT the relapse rate goes down dramatically and the rate of development of drug resistance falls right off of the table, it just about disappears. So DOT works, and it has now been standard therapy in most parts of the United States for the better part of the last ten years and the World Health Organization is trying to make it become the standard for the worldwide care of TB.

Addressing the physician is largely a matter of education. What information does a doctor need to know? In an area of the world where there's a lot of TB, that's actually pretty simple because there's no question doctors need to learn about it because they're going to be using that knowledge all the time. But as TB case rates diminish in the United

States, many of us are becoming increasingly concerned about how much time medical schools are going to devote to TB in their curricula? What does the doctor really need to know?

The third issue is health care systems. In the developing world that mostly means provision of medical services and provision of drugs. But now in the United States it means managed care and Medicaid and local public health departments. Where are the resources going to come from? Where is the expertise going to come from? Is managed care, which deals entirely in the cost effectiveness of managing individuals, going to care at all about the public health aspects of TB? That's our challenge right now: to do public health in the era of managed care. I think anybody who says we know how to do it is either lying or fooling themselves.

TB is going to be one of the great experiments. We'll find out whether we figure it out or not. Managed care represents tremendous opportunities too: the ability to standardize treatment, do education, disease reporting. There are many potentially positive aspects of managed care, if we're clever about it; but managed care is as it's practiced is often terrible. A recent issue of the Journal of the American Medical Association has an article about investor HMOs versus not-for-profit HMOs, and the bottom line is, in every indication they looked at, the quality of care was much lower in investor HMOs than it was in not-for-profit HMOs. So the idea of managed care is not necessarily a bad thing, but we could argue that perhaps profit in medical care is a bad thing.

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ER: Is TB increasing in the United States?

JS: From 1953 when we first had accurate numbers, to the early 1980s, we had a 5 to 6 percent decline in the number of TB cases every year, and it was around 22,000 in the early 1980s. During the resurgence of TB that occurred from the mid-1980s to the mid-1990s, we got up to as high as almost 27,000 cases. It was a huge reversal of trends, and over that ten-year period we had on the order of 100,000 more TB cases than we would have had if the previous decline had continued.

For the last five years we have reestablished the decline at almost the same rate that it previously had been, so we're down to about a 18,000 cases a year in the United States. If you ask me how many infected people there are, that is, how many people who are carrying the germ and at risk for disease, no one knows. There are no data. It is estimated to be between 10 and 20 million people in the U.S.

ER: Why did the outburst of TB occur in the 1980s?

JS: Four reasons. Number one, the rise of HIV. Number two is immigration. Number three is what is called congregate settings: the increase of TB in jails, prisons, nursing homes, homeless shelters, some hospitals, places where at-risk people congregated and had uncontrolled spread. The fourth one, which is a little harder to document, is basically the diminution in effectiveness of public health.

As a pediatric TB doctor, that's particularly acute to me because while overall TB case numbers rose about 20 percent during the resurgence, in children it actually rose 40 percent. The entity that prevents childhood TB is the local health department. The way they do that is if Uncle Eddie develops TB, the health department does a contact investigation where they look at all the people who spent a lot of time with Uncle Eddie to find out if any of them had infection or disease.

ER: Like tracking a sexually transmitted disease.

JS: Exactly. Except instead of sharing secretions, we're sharing the air. And so his favorite nephew Johnny comes in because he spends a lot of time with him and we do a skin test and it's positive, we do an x-ray and it's abnormal. Boom, Johnny has tubercu-

losis. When we find TB early, the cure rate is 100 percent and he'll do very well.

But if health departments don't do those investigations at all, or if they delay them, Johnny may get very sick before we get to him, and he's more likely to get disease and more likely to have severe disease. That is precisely what happened in big cities in the United States in the 1980s. We were unprepared and health departments were doing a lousy job of contact investigation. This was in an era where the government funding for TB was zero. So TB control, which we know works, basically fell apart.

Many of us are concerned because we've had five years now of decline of TB case rates, and there is again talk now of cutting back of tuberculosis funds and reinventing history.

ER: A skin test will show if you're infected even if you're not infectious. Is that correct?

JS: Correct. That's exactly right. If you're carrying the organism, for the most part, there are some exceptions.

ER: How hard would it be to put skin patches on every kid in school?

JS: The only tool that we have to tell if a person is carrying the TB germ is the tuberculin skin test; and it is a lousy test. The problem is, if you apply it to people who are at low risk of having TB infection, you'll get a substantial number of positive results, but they'll be false positives. So mass skin testing is a really bad idea.

However, the selective testing of people who are at risk for TB infection is a very good idea. So the key is that we discriminate, that we test people who have risk factors and don't test people who don't have risk factors. The problem is that many of the medical and other factors that determine your likelihood of having infection have social and political overtones. So the question for us as a society is, How discriminatory are we willing to be in our approach in order to pick out and kill off a disease that inherently discriminates? It's popular to say anybody can get TB. Well, that's true, but not everybody does get TB. Poor people get it, minorities get it, homeless get it, down-and-out people for the most part.

Like TB, the only thing that's going to control HIV in the developing world is a vaccine because they'll never be able to afford the therapy, even if it's curative therapy. Why do we know that? Because they can't afford TB therapy, which is cheap and curative.

Most of the emphasis on TB control in the past appropriately has been finding people who have active tuberculosis and treating them to cure. But now the next step's going to be going after that 10 to 20 million infected people and treating them to prevent them from getting disease. A very different problem; very different approach and utilization of resources. And I'm going to tell you, I don't think we really know how to do it.

ER: I think that would be an appropriate place to put some research money.

JS: Well, one would think, wouldn't they? Research money for TB, which was zero about ten years ago has improved, the federal government now puts about 35-40 million dollars into it.

Clearly with international travel and migration it is very much in our interest to try to control TB. What's going to control TB ultimately? In my opinion, only one thing, an effective vaccine. We have the vaccine called BCG. It's used in most areas of the world, but it's just not that effective. It has some effect, but nowhere near enough to actually control the disease.

If I were the czar of the world for TB, I would put every penny of available research money into developing a new and effective vaccine, because that's the only hope, in my opinion, for controlling this disease. Just like with HIV. The only thing that's going to control HIV in the developing world is a vaccine because they'll never be able to afford the therapy, even if it's curative therapy. Why do we know that? Because they can't afford TB therapy, which is cheap and curative.

Additional Reading:

Diagnosis of Tuberculosis in Children: Increased Need for Better Methods. EA Kahn, JR Starke 1995 *Emerging Infectious Diseases* 4:115-123

Will Greenhouse Gases Make Forests Grow Faster?

Introduction:

Increased carbon dioxide in the air is a result of our modern, high energy way of life. It is also the main reason global average temperatures are increasing. A little known side effect of increased atmospheric carbon dioxide is that it can increase the growth of many plants, at least transiently. Apologists for the energy industry have seized on this to argue that increased carbon dioxide will benefit humanity by warming temperatures, and by increasing production from farms and forests. One envisions the entire biological world made over to conform to our way of life: industrialized, privatized, and finally made virtual, existing only on the Internet.

Nonetheless, the fact remains that young trees put on wood at a faster rate if they are exposed to carbon dioxide enriched air. The debate about the effects of increased carbon dioxide is being taken out of the hands of propagandists by scientists who are now conducting careful, long term studies of the effects of elevated carbon dioxide on plants and on entire ecosystems.

We spoke with Evan DeLucia of the University of Illinois about his study of the effects of carbon dioxide on forest growth[1].

ER: Professor DeLucia, what is your background?

ED: I received my Ph.D. from Duke University in ecology, and for the last twelve years I've been a professor. I'm currently an Associate Professor at the University of Illinois in the Department of Plant Biology. My research focus is on forest ecology and the physiology of trees, particularly as it relates to global climate change.

ER: When did we realize that carbon dioxide is increasing in the atmosphere?

ED: Beginning in the nineteen fifties and sixties, scientists generally recognized that human activities were increasing the concentration of carbon dioxide in the atmosphere quite dramatically. Carbon dioxide is a result of burning fuels in automobiles, industrial processes, and electrical power plants.

Widespread deforestation, particularly in the tropics, also contributes to carbon dioxide in the atmosphere in two ways: one, trees are cut down and burned, and that releases carbon dioxide into the atmosphere. The other way is because trees take up carbon dioxide from the atmosphere during photosynthesis, and when you cut them down they no longer do that. Deforestation and industrialization have both increased greatly and contributed to dramatic increases of carbon dioxide in the atmosphere.

ER: How much carbon dioxide is in the air?

ED: Before the industrial revolution in the late 1800s, it was at about 280 parts per million and it had been below this level for over 100,000 years. When I was a graduate student it was about 340 or 350 parts per million, and now it's about 360 parts per million, and it's expected to go to 560 by the year 2050.

ER: What is the connection between carbon dioxide and plant or tree growth?

ED: Photosynthesis of course is done by plants. Plants use light energy to convert carbon dioxide into sugars and carbohydrates, and that's then available for animals to eat. So net primary production is the foundation of the food web. When we measure the net photosynthesis of a landscape, for instance, Connecticut or the Midwest, we estimate net primary production, which is basically the summation of all the carbon taken up by plants by photosynthesis minus that amount of carbon lost by plant respiration. Primary production is basically the only way that energy is made available to other organisms.

About half of the net primary production in the world occurs in forests, and so the carbon dioxide in the atmosphere and the function of forests are tightly related through photosynthesis and respiration. It has been thought that if carbon dioxide in the atmosphere increases it might cause forest trees to grow a bit faster,

It has been thought that if carbon dioxide in the atmosphere increases, it might cause forest trees to grow a bit faster, and that in turn may help slow the increase of carbon dioxide in the atmosphere.

and that in turn may help slow the rate of increase of carbon dioxide into the atmosphere.

ER: Is there any evidence for this idea?

ED: There's abundant evidence that in seedlings and saplings, in potted plants in growth chambers, that if you increase carbon dioxide, plants grow faster. As a matter of fact, horticulturists have been using this to make bigger hothouse tomatoes for quite a long time. But we really had no idea what we were going to see when we increased the carbon dioxide in a natural setting. So the experiment that we're doing now uses technology called FACE, which is an acronym for free air carbon dioxide emission.

We set up plots in the Duke forest, each about thirty meters in diameter, with pipes going up vertically through the forest canopy all the way up through the top of the trees and out. These pipes have little holes up and down their length, and through some sophisticated computer control algorithms created by scientists at Brookhaven National Laboratory, carbon dioxide is emitted from the upwind pipes and it flows through the forest canopy. In doing this we can precisely control the carbon dioxide concentration in the forest canopy. We have three control plots that just get the normal air at 360 parts per million carbon dioxide, and three paired experimental plots that get the normal 360 parts per million plus an additional 200 parts per million that we add to the atmosphere.

ER: That's quite an increase.

ED: We're giving them basically what we expect to see in the year 2050. The estimates of the rate of increase of carbon dioxide in the atmosphere are pretty robust because it's easy to predict how much fossil fuel is consumed by people, and there's great political and defense concerns about understanding fossil fuel consumption. So that number's a pretty good number.

We put this FACE system in without disturbing the forest so we're doing an experimental manipulation of an intact forest. The plots are big enough that we have all of the biological interactions: competition between plants, cycling of nutrients from foliage falling onto the forest floor, insects eating plant material, so all of the biological interactions that we would expect are taking place. Moreover, this forest is growing in a natural soil.

We can precisely control the carbon dioxide concentration in the forest canopy on our experimental plots.

ER: What did you expect to find?

ED: We really didn't know what to expect when we turned the gas on. We collected a year of data on tree growth of all the dominant trees, the pine trees and all of the understory trees and all of the herbaceous plants in the plot before the gas was turned on. Then in August of 1996, we flipped a switch and threw these trees into the year 2050, and then we continued to make our measurements at regular intervals up to now.

At two years into the experiment, we were quite startled to see a substantial growth stimulation. We've seen a dramatic stimulation in the diameter growth rate of trees. And from that we're able to calculate the increase in net primary production for the entire forest, and we're seeing roughly a 25 percent stimulation of net primary production over the first two years.

ER: What are the implications of this result?

ED: We did a back of the envelope calculation, and if you assume that all of the forests in the world behave like our forest, this 25 percent stimulation, if it applied globally to all forests, would consume half of the carbon dioxide emitted by human activities into the atmosphere into the year 2050. So if you make that assumption, it's quite a good carbon dioxide scrubber.

Now, of course, there's great interest in whether forests will take care of the carbon dioxide problem. It's a glass half full, half empty kind of situation. If you take our data and accept our assumptions of the problem, there's good reason to believe that our numbers represent the maximum response you might expect from a forest. At this upper end the best you could expect would be half of the problem solved by forest growth.

ER: Why is it the upper end?

ED: There are a number of reasons for that. In the first place, our experiment has been done in a fifteen-year-old loblolly pine plantation. This is a young, rapidly growing stand of trees; you might expect it to be very responsive to changes in resource availability. This is the reason loblolly is such a good forestry tree, it's such a timber

producer, it's got such rapid growth rates. So we're in a young forest that's in rapid growth, and so we would expect this type of forest to be responsive.

ER: Why is the young forest growing more rapidly? Aren't mature trees putting on wood at the same rate?

ED: No. The growth rate of trees slows dramatically with time. When they're young, they're growing rapidly. When the canopy closes they begin to self shade and compete with one another, their stems get big compared to the foliage, so they now have to support more respiratory tissue with a fairly constant amount of photosynthetic tissue. The production of forests decreases after canopy closure. So in another few years we'd expect the growth rate of our forest productivity to start to decrease.

ER: Are you going to keep going with these experiments?

ED: We hope to go ten years, for a couple of different reasons. One, to see if this forest does slow down and the treatment abates with time. And two, we essentially have a natural experiment every year. The first two years of the experiment we've been in a rather severe drought, so we're basically looking at a carbon dioxide by water availability interaction. It will be interesting to see how this carbon dioxide response changes as we have moist years and hotter years and colder years.

Another reason we think this may be a maximum response is that when we started the experiment we flipped a switch and we basically gave the forest what we call a square wave. We didn't ramp up carbon dioxide slowly, as is happening in nature, we gave them the year 2050. So the trees have not had an opportunity to acclimate to this high carbon dioxide environment.

What we think might happen, and there's good evidence for this from seedling and sapling studies, is that as trees begin to grow faster, they begin to deplete soil nitrogen and phosphorus more rapidly and ultimately the availability of soil nutrients is going to cap the growth response. That's a second reason that we're expecting to see this abate with time.

ER: Is there any data to suggest the response will decline?

ED: There are no experiments to test the hypothesis I've just proposed to you. There have been some mathematical models that predict this and there is one study that supports our expectation. An Italian group has studied some oak trees growing around a natural carbon dioxide source, a spring of carbon dioxide that is outgassing from the Earth. So they have a natural experiment where these trees have grown next to this carbon dioxide for generations, and they've cored those trees and measured their growth response over time by looking at their tree rings. And in fact, they see a rapid stimulation because of this carbon dioxide when the trees are young, and it abates with time.

So this is what we think is going to happen. But because of the political implications of this work, we've been very cautious in our statements. We think our trees are showing the maximum response you might find.

And, of course in terms of a global energy policy consideration, we're not planting more forest. The land area covered by forest, regardless of how it responds, is decreasing steadily in almost all parts of the globe.

ER: Is there some feed back mechanism where the plant enzymes that fix carbon dioxide might decrease or be less active if carbon dioxide concentration goes up?

ED: Yes, and there are a number of people looking at this. In the scientific parlance it's called down regulation. C3 plants, which almost all trees are, use an enzyme called Rubisco to fix carbon dioxide from the air. Rubisco is not saturated at current carbon dioxide concentrations, so if the carbon dioxide goes up, it can fix more carbon dioxide. But as Rubisco works faster, the whole carbohydrate content of the plant increases, and the plant, by mechanisms we don't completely understand, begins to sense that it's facing an imbalance and that it now needs to reinvest in other functions, perhaps to acquire more nitrogen and more phosphorus, to bring it back into balance with this new high carbohydrate state.

There is mounting evidence that what plants do to achieve this new balance is they not only reduce the activity, but they begin decreasing the amount of Rubisco and reinvesting in other functions. Now, the first part of that statement we have good evidence for: there's a lot of evidence that Rubisco contents are decreased. As far as I know, no one's yet determined where that nitrogen is put.

> At two years into the experiment we were quite startled to see a substantial growth stimulation.

ER: Can we extrapolate your results to trees in different parts of the world?

ED: We don't have that information. This is the first experiment of its kind, and the climate conditions, the soil conditions, the types of organisms involved, of course, are very different in other environments, particularly as you go down to the tropics. You can see some similarity between the evergreen forests in our temperate areas and the boreal forests, but when you get into the tropics it's a completely different set of organisms, and we don't have information on that.

But this experiment that's now been going three years has helped us refine the technology and also refine the types of questions that we can answer with this technology. Some scientists from Canada, in collaboration with the Smithsonian Institution and the Department of Energy are now planning to put this same kind of FACE technology into a tropical forest in Panama. There's great interest in seeing how these forests might respond.

We have limited capacity to extrapolate, but hopefully our results are exciting enough that that will help us begin to garner the resources we need to study these other impressive ecosystems.

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Jobs versus the Environment?

Introduction:

The popular perception is that environmental regulations cost jobs or damage the economy. Eban Goodstein, a professor of economics, examined twenty year's worth of economic data and research to see if the facts support this idea. In his recent book he examines the two "worst cases" of environmental protection impacts on the economy, layoffs of coal miners in the East and of loggers in the West[1]. In both cases the number of layoffs were on the order of 1 to 2 thousand per year in an expanding economy, an economy where 2 million people are laid off every year.

Rather than creating a drag on the economy environmental regulations, which are often labor and construction intensive, create about as many new jobs as they eliminate. We spoke with Professor Goodstein about some aspects of the economics and politics of environmental regulations.

ER: Professor Goodstein, what is your background?

EG: I am an Associate Professor of Economics at Lewis and Clark College; I'm also a Research Associate at the Economic Policy Institute in Washington, D.C. I've got a B.A. from Williams College in Geology and a Ph.D. from the University of Michigan in Economics.

ER: What is your book about?

EG: The book has two parts: the first part is a review of what economists agree upon about environmental regulations and jobs, and then in the second part there's some new research. Let me address the research consensus first.

The popular perception when you talk about environmental regulations is of jobs versus the environment, or tradeoffs. In the popular culture it's gotten to the point that during the Clean Air Act debates in 1990, the *Wall Street Journal* conducted a poll where they asked people if they thought they might lose their job because of environmental regulations. An amazing 33 percent of the public thought that they were somewhat likely or very likely to lose their own job as a consequence of environmental regulations.

ER: Sounds like the beginning of an urban myth.

EG: I agree, and in the book I take the myth apart. The first point to make is that at the economy-wide level there is simply no tradeoff between jobs and the environment. Economy-wide unemployment rates are determined primarily by business cycle forces, and environmental regulation has not prevented the achievement of full employment in the late 90s. In fact, the Federal Reserve has just raised interest rates because they think the

economy's going too fast, in spite of the fact that we're spending much more money on environmental protection than we did thirty or even ten years ago.

Environmental regulations don't prevent full employment; they don't deepen recessions. If anything, environmental regulations may actually boost employment during recessions a little bit because of the extra spending that's added into the economy.

At the national level the response to environmental regulations is a gradual shifting in the types of jobs. It becomes a jobs versus jobs situation. One might think environmental regulation just creates jobs for pencil-pushing bureaucrats in regulatory agencies, but environmental spending supports more than its share of jobs in blue-collar sectors of the economy, and in particular, construction and manufacturing.

Construction and manufacturing constitute about 20 percent of the overall employment in the economy, but 30 percent of the jobs in those categories that are supported by environmental spending. Environmental regulatory spending is construction intensive: building sewage treatment facilities and cleaning up hazardous waste sites; that's where a disproportionate number of the jobs show up.

That should be the end of myth number one: at the economy-wide level there is no tradeoff between environment and jobs. So maybe at the economy-wide level there's no tradeoff, but what about at the local level? What are the impacts? How many jobs are we talking about? There's been a lot of survey work done on this, and survey after survey shows that nationwide somewhere between 1,000 and 3,000 workers are laid off every year because their plants can't comply with environmental regulations. About 2 million people are laid off every year in the U.S. in total, so on average about one-tenth of one percent of all layoffs are due to environmental regulation.

So there is no economy-wide tradeoff, there are not many people getting laid off, but isn't new investment going overseas to escape onerous environmental regulation? This is called the pollution haven hypothesis.

Economists have been looking at this hypothesis for thirty years, and there's little evidence to support it. Ask anybody, Does corporate America flee the United States to escape environmental regulations? And whether they're Republicans or Democrats, they'll say, Yes, of course they are. But when you ask them to name one case, they can't.

> At the economy-wide level there is simply no tradeoff between jobs and the environment.

ER: Smith Corona.

EG: Was that environmental regulations?

ER: No, they just moved for cheaper labor.

EG: Yes, that's the reason they're moving. I'm not saying that plants aren't moving overseas, but you can't find very many cases of firms that leave because of environmental regulations. There are a few cases like wood furniture manufacturers in the Los Angeles Basin. So there are anecdotes out there, but there is no evidence whatsoever that this is a large-scale phenomenon or that environmental regulations drive industry overseas in any measurable quantity.

That's why my book is being written: in spite of the fact that economists have looked at these arguments and we agree, there is a widespread perception by the public that all three of those tradeoffs exist.

I'm not saying that environmental regulations are costless; but the way that the costs show up is in higher prices for goods and services. Those price increases aren't significant enough to shut down many industries or even lead to many layoffs, but they do eat into corporate profits. So corporations fight regulations, but they can't really say that they're opposing a regulation because it's going to raise prices, because nobody really cares about that. So whenever a new regulation is proposed, they crank out a study that shows it's going to be a job killer. My favorite is a study on the proposed Clean Air Act that was done by the Business Roundtable in 1990. Bob Hahn and a co-author did it. Hahn used to be on President Bush's Council of Economic Advisors, but he was working for the US Business Roundtable at the time. They predicted that at a minimum 200,000 jobs would be quickly lost, with plants closing in dozens of states, perhaps one million or even two million jobs at stake.

Then you go back and look at the record, and over an 8-year period since that law was enacted, less than 8,000 workers in total were laid off as a consequence of the Clean Air Act amendment; almost all of them were coal miners in the East. Here in the Pacific Northwest with the spotted owl we had figures of 100,000 jobs likely

to be lost. And in my book I estimate what I think the job losses were. You've got to be careful here, because what was lost was really job slots; by that I mean, some of the workers have quit or retired anyway, so if there are, say 1000 fewer job slots, that doesn't mean there were 1000 layoffs.

In the timber worker case, employment peaked in 1988 at the peak of the business cycle; then came the recession in 1989 and the industry just got killed, there were about 20,000 layoffs in Oregon and Washington in the timber industry over a two year period.

Then came Judge Dwyer's injunction in 1990 and there were no more sales of timber from federal land, but there was still a big backlog of timber that could be cut on non federal and federal lands. So you don't really get the spotted owl restrictions biting until 1993 or 94. Meanwhile there had been tens of thousands of layoffs due to the recession. So the main consequence of the spotted owl protection was that there wasn't a rebound in the industry in the mid-90s. It wasn't that there were lots of additional layoffs, maybe a couple of thousand over three or four years, but primarily it was a situation where the industry didn't recover. I calculate that there were between 6,000 and 7,500 fewer jobs in the late 1990s than there would have been if there were no spotted owl protection.

ER: Does that include northern California?

EG: No. That doesn't include northern California, so you could add on maybe another 1,000. So less than 10,000 I think is a very conservative estimate for the Northwest. And again, most of those aren't people laid off, because those people were already laid off from the late 80s recession. It's just that they or other people didn't get those jobs back when the industry would otherwise have been recovering.

It's a boom and bust industry. Many of the mills in the Northwest were pretty much geared up just to handle old growth, and those mill jobs were definitely on their way out sooner or later.

ER: But they could retool for smaller timber.

EG: Yes. To an extent, some of them have been doing that. But the industry has been disinvesting from the Northwest for the last twenty years. A lot of job loss in the Northwest has been due to technological productivity improvements which were dramatic during the 1980s. But many mills were just abandoned and the industry was investing much more heavily in the Southeast, in particular, of the United States.

Environmental regulations don't prevent full employment; they don't deepen recessions. If anything environmental regulations may actually boost employment during recessions a little bit because of the extra spending that's added into the economy.

Oregon and Washington had tremendous job growth and very low unemployment rates over the last seven or eight years since we came out of the last recession. In some new research, I looked both at the impacts in the coal counties in the East from the Clean Air Act layoffs, and also spotted owl protection. Part of the reason that this jobs/environment myth settled in was that there were these two high profile cases in the early 1990s: the coal miners in the East, the timber workers in the West. Both cases were worst-case scenarios, so this is as bad as it's ever going to get from a jobs/environment conflict. In each case, fewer than 10,000 workers were affected, spread out over multi-state regions over periods of several years.

I don't want to minimize the impact on those workers, especially for the coal miners where they have very high structural unemployment rates and nothing pays like coal mining in the coal country. Those workers really got nailed, but this is just not news. In an economy where two million people were getting laid off every year, you're talking 1,000 or 2,000 jobs on an annual basis. It just is amazing how this perception of the jobs/environment tradeoff is spread.

One reason for the local fear of layoffs is that if you lose these so-called primary jobs in timber or coal, that there is going to be a ripple effect, the so-called indirect job losses. In my book I look at the county level to see to what extent that's true. Is there any correlation between layoffs in coal mining and timber-related employment and job growth in the rest of the county? It's just not there. You look for those secondary job effects, and you can't find them in large numbers.

In part that's because this idea there is a base to the economy, timber or coal, and the rest of the economy is a parasite that feeds off of it — it's called a base model of economic development and it's pretty much outmoded. These counties are either much more resilient and developed, in which case the job losses in those industries have an impact, but it doesn't make the counties crumble or the towns crumble. Or else they really don't have any secondary industry to begin with, and so the miners and the timber workers are spending their money outside their immediate communities anyway.

ER: Why is the base theory wrong?

EG: Two reasons. One is that there are many income flows in and out of a community. You can either characterize the rural economy as being fairly well developed, in which case it has a lot of linkages with the outside, and there are small businesses who do sales outside of the region and there is income coming in in the form of Social Security or veterans payments and other income flows. That characterizes most rural economies. So if there's a layoff in one sector, people have a variety of other sources of income and the loss just doesn't have that big an impact. The other alternative is that the economy is undeveloped. Right? Those jobs really are dependent on that spending.

ER: What else is new in your book?

EG: The main new ground in the book looks at the employment impacts of addressing climate change and global warming. Again, industry is cranking out studies that are predicting, if we were to meet the Kyoto targets for reduction of greenhouse gas emissions, job losses will be on the order of 2 to 4 million jobs.

The main point of my book is that we've been at this decision point now many times over the last twenty-five to thirty years. In the beginning we didn't really know what the employment impacts of regulation were going to be and it was a legitimate debate. But we've seen these kinds of predictions again and again, and they just are not borne out.

So I offer an estimate that I think if we were to meet the Kyoto targets we would likely see job losses on the order of a few thousand per year, just as we've seen with other types of environmental regulation, and those would be concentrated in the coal industry. So we have a responsibility to take care of those workers. And I have some discussion of the failures of the job training programs and what probably should be done about them in terms of assistance.

ER: Are there cases where regulations could be good for the economy?

EG: I talk a little bit about jobs/environment synergies too. There's a chapter that outlines seven theoretical ways in which environmental protection might lead to faster than average job growth.

The main point is that just as environmental regulations don't create cyclical unemployment, they also can't cure it. So that nationwide, you shouldn't really think about environmental protection leading to faster than average job growth.

Can you use environmental regulations as an economic development strategy in regions that have high structural unemployment? And the answer there is there are a half a dozen ways in which that can help, one of which is the Tom Power (University of Montana economist), amenity-based growth idea.

That is, if you've got footloose workers and businesses, then one of the things that's going to attract them to an area is quality of life, and much of that has to do with good forests and clean water. You could make an argument that the growth in the Northwest, which has been pretty robust over this business cycle, and also the inland Northwest, is due to that amenity-based growth.

But there are other ways. You can have an export promotion strategy based on environmental products, either by exporting clean technology like fuel-cell vehicles or solar panels, or more locally, you can do industrial ecology and waste-based manufacturing, trying to reuse resources. So then

It's easy for environmentalism to become a scapegoat in an economic environment where there's not much of a safety net for most people, and the job training that most people have been able to get when they are laid off is not very good.

you do a local inventory of what you're throwing away, and you think about what you could make out of that to export. For example, I'm on the board of the Center for Watershed and Community Health, which has been trying to set up a futon manufacturing plant in Bend, Oregon, that's going to reuse old bedding materials.

You can also use environmental regulations to promote a sustainable use of natural capital. For example, promoting the health of Willapa Bay, that by restoring the health of the Bay they can create jobs in the oyster fisheries. By restoring the health of the natural environment, you can harvest those resources in a sustainable way and use that as your job base. That's the export promotion strategy.

Then there's import substitution, which is the Rocky Mountain Institute approach where you plug the energy and water leaks out of a community; by getting more efficient you reduce spending on wasted water and energy, and then you have more money to spend locally on development efforts.

My conclusion in that chapter is that environmental regulations are not a magic bullet, but there are reasons to believe that in addition to regulations being good for the environment, you can also create some jobs locally if you are looking to do it. Basically green development should be a piece of any economic development strategy.

ER: That approach might provide about as many jobs as regulations cost.

EG: At the national level that's exactly what happens. But that can be true even at the plant level. Economists Linda Bui and Eli Berman did a careful study of the impact of environmental regulation on California refineries, which are more heavily regulated than refineries in Louisiana. They tracked employment at different locations and they found that the more heavily regulated plants actually added a few more workers than the ones who were less heavily regulated because they had to install and maintain the equipment. So regulation directly creates about as many jobs in the compliance sectors, as are lost in other sectors. You're really talking about a shift in jobs.

But the jobs/environment synergy is more about how can you use clean up, not necessarily regulation but clean up activities and environmentally sound production technologies and techniques as a way to promote faster than average growth.

Whenever a new regulation is proposed, industry cranks out a study that show's it's going to be a job killer.

In Al Gore's book *Earth in the Balance*, he talks about environmental protection laying the foundation for a new wave of innovation: if you're at the cutting edge of producing solar panels and fuel-cell vehicles, you're going to capture those export markets and it's going to promote faster than average growth.

ER: That has been criticized as wishful thinking.

ED: Here would be the historical analogy: the U.S. government basically created Boeing, which is now the world leader in commercial airplane technology. The U.S. government also created the Internet. And of course not just the Internet, but the U.S. now is on the leading edge of the whole computer world. So there are ways in which those kinds of getting out ahead really matters. And it's just as true for environmental technology as it is for any other technology.

You could make the case though, that because environmental concerns are at the forefront in many developed nations, and if you want to export to the German market for example, and they've got remanufacturing requirements, that you know how to do that. There's a race in the auto industry right now to produce a fuel-cell vehicle by 2004 because they know that that's where the industry's headed.

One of the reasons of the jobs/environment tradeoff is an issue is because industry cranks out these studies predicting these huge job losses, and journalists eat it up. But the other reason is uniquely an issue in America. You don't see this jobs/environment discussion nearly so heated in Europe, although it's there, but there's no widespread opposition in Europe, for example, to the very idea of global warming. But for workers, losing your job in the U.S. is catastrophic because there's not much in the way of good adjustment assistance. There's no universal health care system. People's health care is tied to their jobs. Unemployment benefits run out after six months. We're in an era of rising economic insecurity, so recognizing the economic insecurity that American workers face is important in thinking about the mechanics of this debate.

It's easy for environmentalism to become a scapegoat in an environment where there's not much of a safety net for most people, and the job training that most people have been able to get when they are laid off is not very

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good. One of the most important things that could be done in the context of the global warming debate is for environmentalists and workers to come together and say, "The last thing we should do is create yet another program that doesn't work very well for the few thousand workers who were laid off in this case. We need to think about overhauling the entire worker adjustment and retraining programs in ways that are going to serve people more effectively. There's common ground there that should be explored.

Environmentalists and workers are the two groups that the book tries to bridge. Part of the way I do that is to point out to environmentalists that the decline of labor unions has meant the decline of progressive legislators in the U.S. Congress. To me it was astounding that there has been no leadership in the U.S. Senate on the global warming issue. In past environmental debates there have always been the Hatfields and the Muskies, the Churches and McGoverns who are now gone, and in large measure that's due to the decline of unions. So that coalition of environmentally concerned people, workers unions, and minorities that traditionally elected progressive Democrats has been less and less able to do that, and it was those Senators who in the past took the lead on environmental issues. So environmentalists have a stake in seeing a stronger labor movement.

NEXT MONTH

HUMAN IMPACTS ON THE OCEANS AND HOW TO REDUCE THEM:

Sylvia Earle

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